DOE/RL-2010-99
Draft A

Remedial Investigation/ Feasibility Study for the 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units

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

U.S. DEPARTMENT OF ENERGY | Richland Operations Office

P.O. Box 550
Richland, Washington 99352

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Executive Summary

Introduction

This remedial investigation/feasibility study (RI/FS) document supports remedy selection for the 300-FF-1 and 300-FF-2 Source Operable Units (OUs) and the 300-FF-5 Groundwater OU under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA)[1]. The RI/FS summarizes the results of investigations and remedial actions that been conducted and provides an evaluation of a range of remedial alternatives that are being considered for addressing contaminated waste sites and groundwater within these OUs. These OUs are located in the 300 Area of the Hanford Site, which is the southernmost of six geographic areas that border the Columbia River (Figure ES-1). The combined geographic areas along the Columbia River are referred to as the River Corridor and include groundwater OUs, source OUs, and facilities that comprise the 100 and 300 Areas National Priority List (NPL) sites (400 CFR 300, Appendix B[2]).

A total of 552 sites have been identified within the 300 Area. An evaluation was performed to assess which of these sites should be carried forward for cleanup decisions. This evaluation determined that 275 sites do not contain contamination at concentrations that exceed risk-based levels of concern and as a result, were being removed from further consideration for cleanup actions. Of the remaining 277 sites, 122 sites are identified for no further action based on investigations and remedial actions performed to date. The remaining 155 waste sites are individually evaluated in this RI/FS for a range of remedial actions.

A range of cleanup technologies and remedial alternatives were also evaluated to address localized groundwater contamination from uranium and tritium within the 300-FF-5 OU. Contaminant-specific groundwater cleanup recommendations are identified that are linked with the waste site remedial alternatives.

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[1] *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, 42 USC 9601, et.seq., Pub. L. 107-377, December 31, 2002. Available at: http://epw.senate.gov/cercla.pdf.

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

This RI/FS supports a CERCLA Proposed Plan that summarizes the remedial action alternatives considered and recommends a Preferred Alternative for implementation. Ultimately, a Record of Decision (ROD), and ROD amendments, will be issued that addresses the cleanup of contaminated materials within these OUs to protect human health and the environment (HHE).

Hanford Site and 300 Area Background

The Hanford Site, managed by U.S. Department of Energy (DOE), encompasses approximately 1,517 km^2 (586 mi^2) in the Columbia Basin of south-central Washington State. In 1942, the Hanford Site was selected as the site for building nuclear reactors to produce plutonium for nuclear weapons. The Site was chosen because of its remoteness, the availability of water from the Columbia River, and access to electricity from hydropower plants. The Hanford Site's plutonium production mission continued until the early 1990s.

The 300 Area, which is located in the southeastern portion of the Hanford Site, as shown in Figure ES-2, includes distinct subregions: the 300 Area Industrial Complex (major liquid waste disposal sites, burial grounds, and facilities); the 400 Area; and waste sites within the 600 Area (including the 618-11 Burial Ground and the 618-10/316-4 Burial Ground).

The 300 Area Industrial Complex (Figure ES-3) includes the fuel fabrication buildings, raw material storage, waste storage, finished product storage, technical support, service support, and research and development (R&D) related to fuel fabrication and other Hanford Site processes. It includes the buildings, facilities, and process units where the majority of uranium fuel production and R&D activities took place.

Liquid wastes consisting of sanitary wastes and various radiochemical and radio-metallurgical process wastes were discharged via the Process Sewer System (300-15) to open ponds and trenches during most of the 300 Area's operational history. The process sewer system consists of an extensive network of underground piping where liquid wastes were conveyed to the North and South Process Ponds (316-1 and 316-2) between 1943 and 1975. Both ponds received upwards of 1.5 to 11.4 million L/day (400,000 to 3 million gal/day) of liquids from the fuel fabrication facilities until they were phased out of service in 1974 and 1975. The 300 Area Process Trenches (316-5) replaced the ponds in 1975 and were used for disposal until 1994.

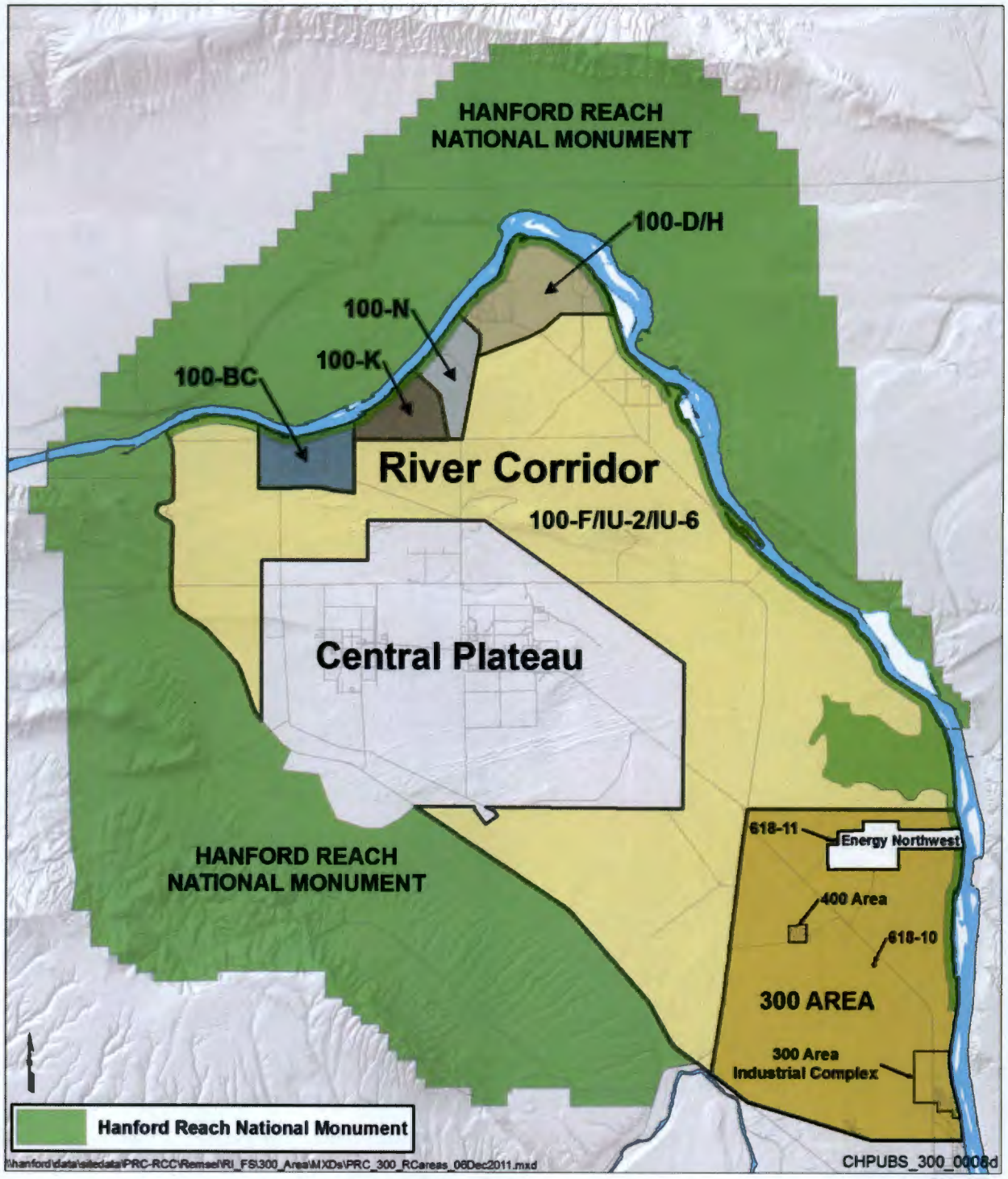

Figure ES-1. River Corridor Areas

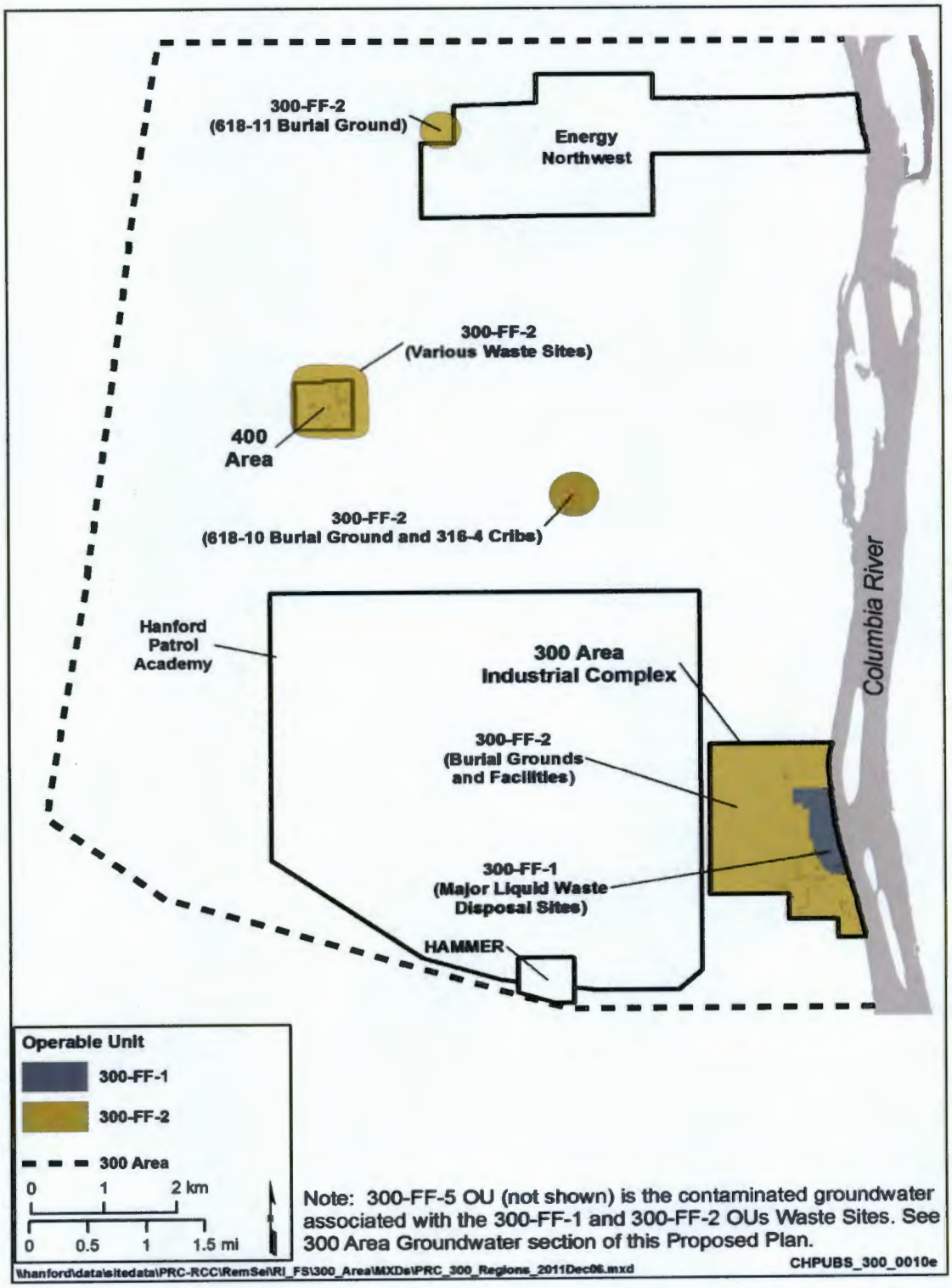

Figure ES-2. 300 Area Boundaries

Figure ES-3. 300 Area Industrial Complex (June 1976)

A complex series of waste streams were disposed to these facilities, including process waste from nuclear fuel fabrication (the primary waste stream), radioactive liquid waste, sewage, laboratory waste, and coal power plant waste. The waste from nuclear fuel fabrication included basic sodium aluminate solutions and acidic copper/uranyl nitrate solutions. Primary chemical contaminants disposed to North and South Process Ponds included uranium (33,565 to 58,967 kg [74,000 to 130,000 lb), copper (241,311 kg [532,000 lb]), fluoride (117,026 kg [258,000 lb]), aluminum (113,398 kg [250,000 lb]), nitrate (2,060,670 kg [4,543,000 lb]), and large volumes of nitric acid and base (NaOH).

Other liquid waste handling facilities include the Sanitary Sewer System (300-276), 340 Complex (340 Complex), 300 Area Retention Process Sewer (300-214), 300 Area Radioactive Liquid Waste System (300 RLWS), 307 Process Trenches (316-3), the 307 Retention Basins (307 RB), Tank Farm (311-TF), Waste Acid Treatment System (WATS) (300-224), and 316-4 Crib.

Solid wastes initially were disposed in burial grounds and shallow landfills between 1943 through the 1950s. In later years, highly radioactive wastes, including wastes with transuranic constituents were disposed in 600 Area Burial Grounds. The primary burial grounds are: 300-7, 300-9, 300-10, 618-1, 618-2, 618-3, 618-4, 618-5, 618-7, 618-8, 618-9, 618-10, 618-11, 618-12, and 618-13.

The 400 Area contains the Fast Flux Test Facility (FFTF) Reactor and its support facilities. The FFTF is a sodium-cooled research reactor. Because the design, construction, and operation of the FFTF differed from that of the Hanford Site production reactors, the type and extent of contamination associated with FFTF also differed. All interfacing equipment and systems are sealed in an inert atmosphere to prevent adverse reactions with the liquid sodium. As a result, the FFTF is radiologically clean. The FFTF reactor is not within the scope of this RI/FS and is addressed under a separate regulatory process.

The 618-10 and 618-11 Burial Grounds received solid waste from operations in the 300 Area Industrial Complex. The 618-10 Burial Ground, which operated between 1954 and 1963, consists of 12 trenches and 94 vertical pipe units (VPUs). Each VPU consists of five 210 L (55 gal) drums with tops and bottoms removed that are stacked vertically, tack welded together, and placed on a concrete footing with the bottom left open to the soil column. The VPUs were used to dispose of containers holding moderate- to high-activity solid wastes. Wastes include radiologically contaminated laboratory instruments, bottles, boxes, filters, aluminum cuttings, irradiated fuel element samples, metallurgical samples, electrical equipment, lighting fixtures, barrels, laboratory equipment and hoods, and low- and high-activity liquid waste sealed in containers. The site is expected to contain hazardous wastes, radiological wastes, and mixed wastes (including waste with TRU constituents). The volume of waste with TRU constituents in the 618-10 Burial Ground is estimated to be 417 m^3 (14,888 ft^3).

The 618-11 Burial Ground, which operated between 1962 and 1967, consists of 3 slope-sided trenches, 50 VPUs, and 3 to 5 large caissons. VPUs and caissons were used for disposal of high dose rate waste and materials. The caissons are constructed of 2.4 m (8 ft) diameter by 3.1 m (10 ft) tall, corrugated metal cylinders that are buried vertically with their tops about 4.6 m (15 ft) below grade. A 0.9 m (3 ft) diameter angled chute extends from grade to the top of the caisson through a concrete slab lid.

As the Hanford Site production reactors were being shut down, fuel fabrication activities in the 300 Area decreased and R&D activities increased. The newer buildings in the 300 Area primarily housed laboratory operations and large-scale test facilities. R&D activities focused on peaceful uses of plutonium, reactor fuels development, liquid metal technology, FFTF support, gas cooled reactor development, and life science research. Industrial activities continue today in the 300 Area that are associated with ongoing R&D, electrical power generation (Energy Northwest), training activities (Hazardous Materials Management and Emergency Response [HAMMER]), and security (Hanford Patrol Academy).

Early Cleanup Decisions

In July 1989, the U.S. Environmental Protection Agency (EPA) placed four areas of the Hanford Site (the 100, 200, 300, and 1100 Areas) on its NPL (40 CFR 300, Appendix B). The NPL (40 CFR 300, Appendix B) represents the nation's highest ranked hazardous waste sites prioritized based on their known or potential threat to release hazardous substances, pollutants, or contaminants to the environment and guides EPA in determining waste sites that warrant further investigation. Coincident with NPL (40 CFR 300, Appendix B) listing, the Hanford Site mission was redefined from plutonium production to environmental cleanup. In the same year, EPA, DOE, and the Washington State Department of Ecology (Ecology) (known as the Tri-Parties) developed a strategy to document the decisions needed to complete cleanup on the Hanford Site into the *Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989a[3]), known as the Tri-Party Agreement.

In the early 1990s, the Tri-Parties decided that sufficient information was known to begin Hanford Site cleanup. A strategy was developed (the *Hanford Past Practice Strategy*[4]) that focused decisions and actions on waste sites and groundwater contamination that may pose a near term impact to public health and the environment. Protection of the Columbia River by taking action in the River Corridor was a central objective of the strategy. Uranium contamination in the 300 Area was identified as problematic and became the focus of early decisions and actions.

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[3] Ecology, EPA, and DOE, 1989a, *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=81.

[4] DOE/RL-91-40, 1991, Hanford Past-Practice Strategy, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D196113090.

For investigation and cleanup purposes, the 300 Area was divided into the 300-FF-1 and 300-FF-2 source OUs and the 300-FF-5 groundwater OU (Figure ES-2). The 300-FF-1 OU contains contaminant sources associated with facilities and waste sites mainly represented by the former North Process Pond (316-1), South Process Pond (316-2), and 300 Area Process Trenches (316-5), where large volumes of liquid waste containing uranium were discharged. The 300-FF-2 OU contains contaminant source areas associated with facilities and waste sites within the 300 Area Industrial Complex, the 400 Area, the 618-10 Burial Ground Subregion, and the 618-11 Burial Ground Subregion. Contaminant releases from these waste sites resulted in several groundwater contaminant plumes that lie within the 300-FF-5 groundwater OU.

Remedial Investigations (RIs) and Limited Field Investigations (LFIs) were initiated in the early 1990s for the 300-FF-1, 300-FF-2, and 300-FF-5 OUs. These investigations provided information on the nature and extent of contaminants present in vadose zone soil and groundwater and the threat that the contaminants posed to HHE. A comprehensive summary of 300 Area previous investigations and their findings are included in this RI/FS.

The findings from these investigations resulted in the selection of actions to remediate source and groundwater contamination within the 300-FF-1, 300-FF-2, and 300-FF-5 OUs under the following ROD and interim RODs and three explanations of significant difference (ESD) documents:

- *Record of Decision for the 300-FF-1 and 300-FF-5 Operable Units, Hanford Site, Benton County, Washington*[5] (300-FF-1 and 300-FF-5 ROD) describes remediation activities for 300-FF-1 OU waste sites and interim remedial actions for 300-FF-5 OU groundwater.

[5] EPA/ROD/R10-96/143, 1996, *Record of Decision for the 300*-FF-1 and 300-FF-5 Operable Units, Hanford Site, Benton County, Washington, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. Available at: http://www.epa.gov/superfund/sites/rods/fulltext/r1096143.pdf.

- *Interim Remedial Action Record of Decision for the 300-FF-2 Operable Unit, Hanford Site, Benton County, Washington*[6] (300-FF-2 Interim ROD) describes interim remediation activities for 300-FF-2 OU waste sites.

- *USDOE Hanford 300 Area, 300-FF-1 Operable Unit, Hanford Site, Benton County, Washington Explanation of Significant Difference (ESD)*[7] (300-FF-1 ESD) addresses *Resource Conservation and Recovery Act of 1976*[8] hazardous waste that is required to meet the land disposal restriction (LDR) criteria.

- *Explanation of Significant Difference for the 300-FF-5 Record of Decision*[9] (300-FF-5 ESD) expands the scope for 300-FF-5 to all groundwater that underlies the 300 Area waste sites and burial grounds.

- *Explanation of Significant Differences for the 300-FF-2 Operable Unit Record of Decision*[10] (300-FF-2 ESD) changes the soil cleanup level for uranium from 350 to 267 pCi/g.

Remedial Action Implementation

The Tri-Party agencies conducted two removal actions in 1991 to mitigate the threat to HHE from contaminant migration in the 300 Area: removal of soil from the 300 Area Process Trenches in the 300-FF-1 OU (EPA, 1991, *Action Memorandum: 316-5 Process Trenches, U.S. Department of Energy (DOE) Hanford Site, Richland, Washington*[11]); and removal and disposal of drums containing uranium contaminated hexone from the 618-9 Burial Ground in the 300-FF-2 OU (DOE, 1991, *618-9 Burial Ground Expedited*

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[6] EPA/ROD/R10-01/119, 2001, *Interim Remedial Action Record of Decision for the 300*-FF-2 Operable Unit, Hanford Site, Benton County, Washington, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. Available at: http://www.epa.gov/superfund/sites/rods/fulltext/r1001119.pdf.

[7] EPA/ESD/R10-00/505, 2000, USDOE Hanford *300 Area*, 300-FF-1 Operable Unit, Hanford Site, Benton County, Washington Explanation of Significant Difference (ESD), U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. Available at: http://www.epa.gov/superfund/sites/rods/fulltext/e1000505.pdf.

[8] Resource Conservation and Recovery Act of 1976, 42 USC 6901, et seq. Available at: http://epw.senate.gov/rcra.pdf.

[9] EPA/ESD/R10-00/524, 2000, *Explanation of Significant Difference for the 300*-FF-5 Record of Decision, U.S. Environmental Protection Agency, Region 10, Washington State Department of Ecology, and U.S. Department of Energy, Seattle, Washington. Available at: http://www.epa.gov/superfund/sites/rods/fulltext/e1000524.pdf.

[10] EPA, Ecology, and DOE, 2004, *Explanation of Significant Differences for the 300-FF-2 Operable Unit Record of Decision*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. Available at: http://www5.hanford.gov/pdw/fsd/AR/FSD0001/FSD0015/D5048583/D5048583_23291_21.pdf

[11] EPA, 1991, *Action Memorandum: 316*-5 Process Trenches, U.S. Department of Energy (DOE) Hanford Site, Richland, Washington, U.S. Environmental Protection Agency, Richland, Washington. Available at: http://www5.hanford.gov/arpir/index.cfm?content=findpage&AKey=D196068241.

Response Action[12]). As a result of these expedited response actions, the 300 Area Process Trenches were partially remediated, and all waste was removed from the 618-9 Burial Ground.

In 1996, as part of the final action ROD for the 300-FF-1 OU, remedies were selected for 15 waste sites. The 15 waste sites included liquid waste disposal sites (e.g., South Process Pond [316-1], North Process Pond [316-2], and 300 Area Process Trenches [316-5]) and other solid waste disposal sites (e.g., 618-4 Burial Ground and 628-4 Landfill). Following implementation of these remedial actions, the Tri-Party agencies determined that remediation was complete for these 15 waste sites.

In 1996, the remedy selected in the 300-FF-1 and 300-FF-5 ROD (EPA/ROD/R10-96/143) for interim actions in the 300-FF-5 groundwater OU was monitored natural attenuation (MNA) with institutional controls to prevent human exposure to groundwater. The 300-FF-1 and 300-FF-5 ROD (EPA/ROD/R10-96/143) required continued groundwater monitoring to verify modeled predictions of contamination attenuation and to evaluate the need for active remedial measures. Institutional controls were required to prevent groundwater use while contaminant plumes were still present above drinking water standards (DWSs). The 300-FF-1 and 300-FF-5 ROD (EPA/ROD/R10-96/143) assumes that the groundwater aquifer is a potential future source of drinking water and will be restored to DWSs in a reasonable time frame. The remedial action objectives (RAOs) defined in the 300-FF-1 and 300-FF-5 ROD (EPA/ROD/R10-96/143) were to protect human and ecological receptors from exposure to contaminants in the groundwater and to protect the Columbia River such that contaminants in the groundwater do not result in an impact to the Columbia River that could exceed the Washington State Surface Water Quality Standards.

In 2001, as part of the interim ROD for waste sites in the 300-FF-2 OU, interim remedial actions were identified for 56 known wastes sites. The interim ROD also provided a regulatory framework for a "plug-in" approach to allow newly discovered sites to be remediated under the 300-FF-2 OU interim ROD, pending approval by the Tri-Party agencies.

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[12] DOE, 1991, 618-9 Burial Ground Expedited Response Action, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www5.hanford.gov/arpir/index.cfm?content=findpage&AKey=E0012793.

CERCLA Five-Year Reviews

The CERCLA process requires that the status of remedial actions be reviewed at least every five years to determine whether the selected remedy(ies) at a site remain protective of HHE. In 2001, the first five-year review of the 1996 300-FF-1 and 300-FF-5 ROD (EPA/ROD/R10-96/143) concluded that the remedy selection decisions for the 300 Area were still appropriate. However, the review included an action item to add more requirements for monitoring along the river shoreline and to assess the effectiveness of the natural attenuation remedy. The natural attenuation remedy assessment required by the five-year review was provided in PNNL-15127, *Contaminants of Potential Concern in the 300-FF-5 Operable Unit: Expanded Annual Groundwater Report for Fiscal Year 2004.*[13]

In 2006, *The Second CERCLA Five-Year Review Report for the Hanford Site* (DOE/RL-2006-20[14]) of the 1996 ROD for the 300-FF-1 and 300-FF-5 OUs and the 2001 ROD for the 300-FF-2 OU concluded that the final remediation actions for the 300-FF-1 OU waste sites met all of the RAOs; the interim remedial actions selected for the 300-FF-2 OU waste sites were still appropriate; and remediation of the uranium plume in the 300 Area groundwater through natural attenuation had not achieved the remedial action objectives in the 10-year time frame envisioned in the ROD. The issue identified in the five-year review stated:

> *Predicted attenuation of uranium contaminant concentrations in the groundwater under the 300 Area has not occurred. DOE is currently performing additional characterization and treatability testing in the evaluation of more aggressive remedial alternatives.*

To address this issue concerning uranium contamination, the review included an action to complete the focused feasibility study for the 300-FF-5 OU to provide better characterization of the uranium contamination; develop a conceptual model; validate

[13] PNNL-15127, 2005, *Contaminants of Potential Concern in the 300*-FF-5 Operable Unit: Expanded Annual Groundwater Report for Fiscal Year 2004, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D7748359.

[14] DOE/RL-2006-20, 2006, *The Second CERCLA Five*-Year Review Report for the Hanford Site, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=DA04570094.

ecological consequences; and evaluate treatment alternatives. The action also required concurrent testing of polyphosphate injection into the aquifer to immobilize the uranium and reduce the concentration of dissolved uranium. The characterization, evaluation, and testing required by the second five-year review action item are documented in several reports with the results provided in this RI/FS report.

Because remediation of uranium in deep subsurface soils using polyphosphate injection is a relatively new remedial process at the Hanford Site, DOE undertook laboratory-scale and field-scale pilot testing to evaluate the technology. The evaluation and screening of potential uranium treatment alternatives found that methods to immobilize uranium in the vadose zone and/or aquifer offer the potential for reducing the continued input of mobile uranium to the groundwater plume (PNNL-16761, *Evaluation and Screening of Remedial Technologies for Uranium at the 300-FF-5 Operable Unit, Hanford Site*[15]; DOE/RL-2008-36, Remediation Strategy for Uranium in Groundwater at the Hanford Site 300 Area, 300-FF-5 Operable Unit[16]). The concept is to change the dissolved uranium to a form that is more permanently stored within the sediment, with a resulting drop in concentrations of dissolved uranium. For the 300 Area uranium plume, one approach is sequestration of uranium as insoluble phosphate phases in the unconfined aquifer. A project to study the ability of phosphate phases to precipitate and adsorb dissolved uranium was performed. The project tested both the direct formation of the uranium mineral autunite [$Ca(UO_2)_2(PO_4)_2 \cdot nH_2O$] by the introduction of a polyphosphate mixture and the formation of the mineral apatite (various forms of calcium phosphate) in the aquifer as a continuing source of phosphate for long-term treatment of uranium.

After a series of successful bench scale tests, a field treatability test was conducted in June 2007 in a well at the 300 Area (PNNL-16008, *Site Characterization Plan: Uranium Stabilization through Polyphosphate Injection*[17]). The objective of the treatability test was to evaluate the efficacy of using polyphosphate injections to treat uranium

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[15] PNNL-16761, 2007, *Evaluation and Screening of Remedial Technologies for Uranium at the 300*-FF-5 Operable Unit, Hanford Site, Washington, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-16761.pdf.

[16] DOE/RL-2008-36, 2008, Remediation Strategy for Uranium in Groundwater at the Hanford Site *300 Area*, 300-FF-5 Operable Unit, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www2.hanford.gov/arpir/?content=findpage&AKey=0810240397.

[17] PNNL-16008, *Site Characterization Plan: Uranium Stabilization through Polyphosphate Injection*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-16008.pdf.

contaminated groundwater in situ. A test site consisting of an injection well and 15 monitoring wells was installed in the 300 Area at the south end of the former 300 Area Process Trenches, which had previously received uranium-bearing effluents. The results indicated that while the direct formation of the uranium mineral autunite was successful, the outcome of the apatite formation part of the test was limited. A complete description of the aquifer injection test and its results is presented in PNNL-18529, *300 Area Uranium Stabilization through Polyphosphate Injection: Final Report.*[18]

Two separate overarching issues impact the efficacy of apatite remediation for uranium sequestration within the 300 Area: the formation and emplacement of apatite via polyphosphate technology, and the efficacy of apatite for sequestering uranium under the present geochemical and hydrodynamic conditions (PNNL-17480, *Challenges Associated with Apatite Remediation of Uranium in the 300 Area Aquifer*[19]). The first challenge, dealing with the emplacement, was largely due to the very high groundwater velocities in this part of the 300 Area, which could reach 18 m/d (59 ft/d). This issue could be overcome by modifying the timing and application process to correspond with periods of low groundwater velocity. The second issue is more fundamental. The role of apatite was to adsorb dissolved uranium from groundwater. The uranium was expected to subsequently react with the phosphate in the apatite to form insoluble mineral phases, such as autunite. However, because of the elevated alkalinity of the groundwater, apatite does not adsorb the uranium to a sufficient degree to make it an effective treatment for reducing concentrations in groundwater.

Because it appears that apatite has limited effectiveness to work as a continuing supply of phosphate in the aquifer, the remaining alternative is to treat the uranium source in the vadose zone and the periodically rewetted zone (PRZ), the lowermost portion of the vadose zone that becomes saturated with the river stage rises and locally elevates the water table. The most straightforward approach is to infiltrate solutions containing phosphate from the ground surface. As these solutions contact the uranium in the vadose zone and the PRZ, they should react to form insoluble autunite minerals, thus limiting further leaching of the uranium to the aquifer. As of September 2011, preliminary

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[18] PNNL-18529, 2009, *300 Area* Uranium Stabilization Through Polyphosphate Injection: Final Report, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-18529.pdf.

[19] PNNL-17480, 2008, Challenges Associated with Apatite Remediation of Uranium in the *300 Area* Aquifer, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17480.pdf.

infiltration tests at the 300 Area have not indicated high infiltration rates, although only a very small area has been tested. If direct surface infiltration is not successful, then treating the lower portion of the vadose zone and PRZ using injection wells will be developed to augment surface infiltration. An evaluation of the approaches to augment surface infiltration with injection wells to target the PRZ and upper aquifer has been completed (PNNL-19461, *Evaluation of Reagent Emplacement Techniques for Phosphate-based Treatment of the Uranium Contamination Source in the 300 Area: White Paper*[20]).

300 Area Remedial Investigation/Feasibility Study

An RI/FS work plan[21] was developed for the 300 Area to identify additional data needed to make an integrated, comprehensive final action decision for contaminated soil and groundwater. The work plan uses information collected since the beginning of construction, including operational history, process knowledge, waste generation, waste handling, waste disposal, remedial investigations, treatability testing, and knowledge gained through ongoing implementation of interim actions. The 300 Area RI/FS Work Plan (DOE/RL-2009-30) identified data gaps, data needs, and uncertainties, and designed a field program to address these data needs and uncertainties by collecting information to support remediation decisions.

This 300 Area RI/FS report describes the data that were gathered (Chapter 2) and analyzes identified contaminants and their interaction with the environment (Chapters 3 through 5), summarizes pertinent information related to human health and environmental risk (Chapters 6 and 7), and identifies and evaluates remedial alternatives to provide protection (Chapters 8 through 10). The conceptual site model (CSM) is an ongoing, refined collection and interpretation of data that supports the entire RI/FS investigative and decision process.

Conceptual Site Model

The 300 Area CSM describes the features, events, and processes that resulted in environmental contamination, the fate and transport of contaminants in soil and

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[20] PNNL-19461, 2010, *Evaluation of Reagent Emplacement Techniques for Phosphate*-based Treatment of the Uranium Contamination Source in the *300 Area*: White Paper, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19461.pdf.

[21] DOE/RL-2009-30, 2009, *300 Area* Decision Unit Remedial Investigation/Feasibility Study Work Plan, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www2.hanford.gov/arpir/?content=findpage&AKey=0910271278.

groundwater, and the risks posed by the contaminants via exposure pathways at the site. The contamination observed currently in the subsurface has resulted from activities that occurred in the past; especially during the peak nuclear fuels and plutonium production years of the 1950s and 1960s. High volume waste effluents resulting from fabrication of nuclear fuel assemblies were sent to ponds and trenches for infiltration into the soil column. Effluents were typically acidic, which promoted movement through environmental pathways, and contained significant quantities of uranium and other metals, such as copper. Volatile organic compounds (VOCs), such as trichloroethene (TCE), were used extensively and included in the effluent mix.

Other chemicals and radionuclides resulting from fuels processing research were also disposed to ponds and trenches, but in lesser volumes. Solid wastes from 300 Area activities were buried at locations within the 300 Area, or sent to outlying burial grounds when radiation levels of the waste were too high for densely occupied areas.

The preponderance of contamination in liquid effluent sent to ponds and trenches is no longer present in the 300 Area, having moved through the vadose zone and aquifer and discharged into the Columbia River. Contaminants retained on sediment at the disposal facilities, or at solid waste burial grounds, are currently being removed by removal, treatment, and disposal (RTD) remedial actions. Contamination currently observed in the soils and groundwater beneath the 300 Area is residual amounts that persist for a variety of reasons. Attenuation of these contaminants, to greater and lesser degrees dependent on contaminant properties, continues to occur by natural processes along environmental pathways away from the source locations. Contamination that has entered the groundwater pathway ultimately discharges to the Columbia River via upwelling through the riverbed sediment and occasionally through riverbank springs. Groundwater contamination today is residual and will attenuate more slowly than when higher levels were present during operations.

Discharge of liquid waste during operations formed groundwater mounds beneath the disposal waste sites. Mobile contaminants, including volatile organic solvents such as tetrachloroethene (PCE), migrated with the flow of liquid, while less mobile contaminants such as uranium migrated at slower rates. The mounds dissipated after discharge ceased, with a portion of the contaminants dispersed inland.

Contaminants can remain in the vadose zone following active liquid waste discharge as dissolved fractions within pore water or sorbed to soil unless sufficient moisture is available for transport. This residual contamination remains as secondary sources that potentially retain sufficient levels of contaminants to provide continuing sources of contamination entering soil, surface water, groundwater, or air. Only secondary sources are currently found in the 300 Area.

Uranium is present as a secondary source in the lower vadose zone. The form uranium takes in solution is influenced by alkalinity which, in turn, affects uranium mobility. Uranium tends to sorb to aquifer matrix mineral surfaces and be less mobile when alkalinity in the aquifer is lowered. Columbia River water is low in alkalinity. At high river levels, river water infiltrates inland from the shore into the aquifer to some distance dependent on aquifer properties. Portions of the lower vadose zone become periodically rewetted (the PRZ) by a mix of groundwater and river water that is lower in alkalinity than pure groundwater. As a result, uranium in this zone of mixed river water/ groundwater is sorbed to a large degree on the matrix mineral surfaces. The combination of uranium sorption and dilution results in diminished uranium concentrations in the river water/groundwater mixing zone during high river levels.

Further inland from the river water/groundwater mixing zone, the river stage creates an interruption of the natural groundwater gradient towards the river, causing groundwater levels to rise into the PRZ. In these inland areas, the relatively high-alkalinity groundwater comes in contact with uranium in the PRZ (in the form of both entrained vadose zone water and sorbed forms). Under these conditions, the uranium takes the form of a negative ion carbonate complex, which has less tendency to sorb. The overall effect is that in the inland areas, uranium concentrations rise in groundwater as the water table rises during high river stages. The effects of high and low river stage on uranium mobility are illustrated in Figure ES-4.

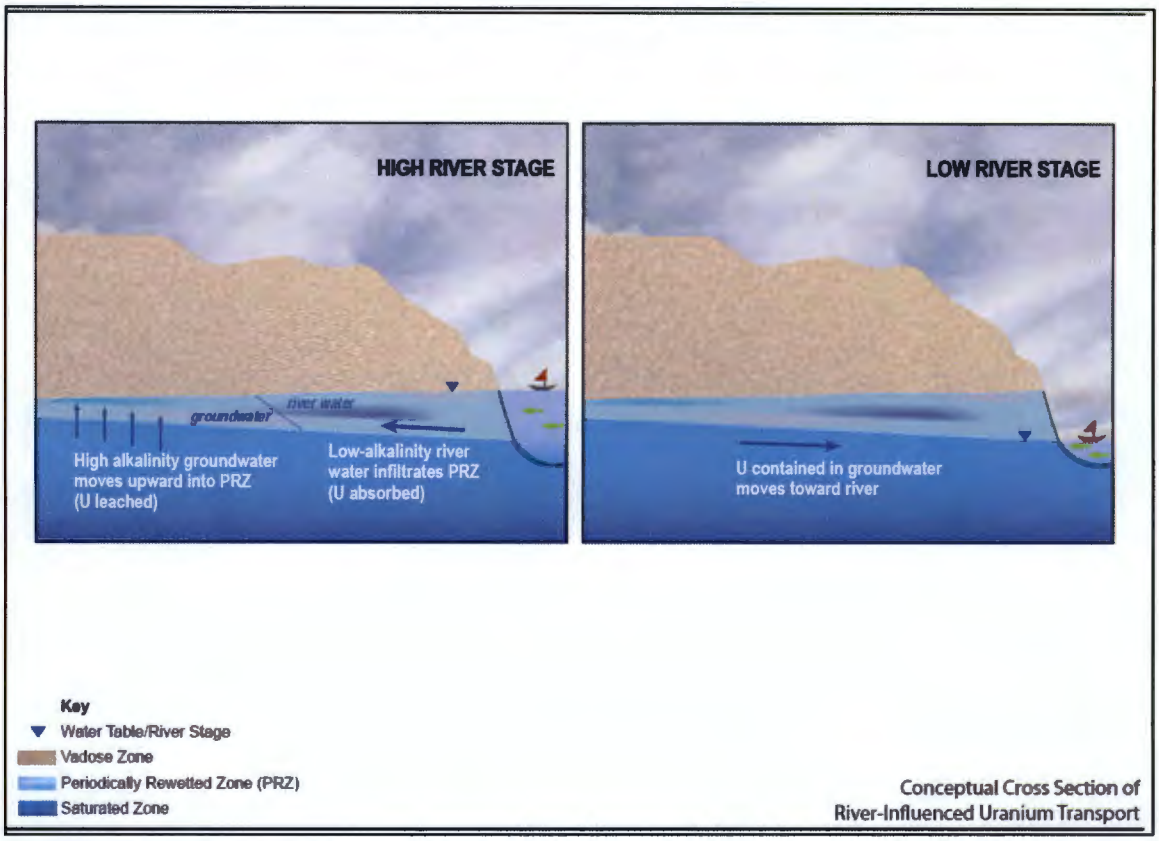

Figure ES-4. Combined Effects of River Stage on Uranium Mobility

A groundwater flow and contaminant transport model was developed for the Hanford Site 300 Area to simulate future uranium migration and to assist with development of remedial action alternatives. The model simulated the fate and transport of uranium within the vadose zone, PRZ, and unconfined aquifer associated with the 300 Area FF-5 OU. The predictions based on the calibrated models indicate a long-term declining trend in the dissolved uranium concentrations with episodic rises and falls in concentrations seasonally as the water table rises and falls with river stage fluctuations. The mean annual dissolved uranium concentration for the monitoring wells is predicted to take less than 30 years from now to drop below the groundwater action level of 30 μg/L, while the 95th percentile upper confidence limit (UCL-95 on the mean) annual dissolved concentration is predicted to take approximately 35 years. The 90th percentile dissolved concentration is predicted to take approximately 38 years. These estimates are based on the assumption of current hydrologic and chemical conditions remaining unchanged. The time frame is based on the 90th percentile or UCL-95 concentration (whichever is longest) for the well with the highest uranium concentration to achieve the DWS.

Tritium is present in the groundwater beneath and down-gradient of the 618-11 Burial Ground. A previously published model simulating tritium concentrations in groundwater at the 618-11 Burial Ground predicts that a combination of natural decay and dispersion during transport will result in acceptable tritium concentrations by 2031.

Other contaminants that have been detected above state or federal standards in the 300 Area include gross alpha, TCE, cis-1,2-dichloroethylene (cis-1,2-DCE), chromium, and nitrate.

- Gross alpha in groundwater is primarily associated with the uranium contamination.

- TCE occurs in in the 300 Area Industrial Complex and is primarily confined to a low permeability unit that does not yield sufficient water to be used as a source for drinking water. Elevated TCE contamination has been identified in a fine-grained interval of Ringold Formation sediment that has a very low permeability. Given the low permeability of this unit, no additional monitoring wells have been installed in this sediment and its likelihood of future consideration as a water supply aquifer is very low.

- Cis-1,2-DCE is present in one well near the 300 Trench (well 399-1-16B). The likely source of the observed cis-1,2-DCE is degradation of the TCE historically used in the reactor fuel fabrication process and expected to have been regularly released with the uranium-bearing process waste water.

- Chromium has been identified above the DWS in two wells near the 618-7 Burial Ground. It appears that the source for the elevated chromium is related to the remedial action of the 618-7 Burial Ground associated with excavation activities such as dust control water application. It is also possible that the elevated chromium concentrations are associated with the corrosion of the stainless-steel well screen.

- Nitrate concentrations exceed the DWS at the southern portion of the 300 Area where groundwater has been impacted by agricultural and industrial activities not associated with the Hanford Site. The relatively higher concentrations in the southern portion currently reflect the migration of nitrate-contaminated groundwater into the 300 Area from sources to the southwest. Gradually increasing concentrations are also observed

in wells and at shoreline sites as the nitrate-laden groundwater migrates into the 300 Area. Nitrate also migrates into the 300 Area from the northwest as part of the site-wide plume that originates in the 200 East Area. The nitrate concentrations from the 200 Area are below the DWS (45,000 mg/L) when that water arrives in the northwest portion of the 300 Area (25 to mg/L).

During the development of the 300 Area RI/FS Work Plan (DOE/RL-2009-30), an initial list of contaminants of potential concern (COPCs) is identified to guide data collection as well as the evaluation and analysis in the RI/FS report. In the RI/FS process, the results of the risk assessment and fate and transport evaluations are used to identify final vadose zone and groundwater COPCs. Table ES- 1 lists the initial COPCs and highlights the final COPCs that have been identified in the human health and ecological risk assessment evaluations as well as the fate and transport evaluations for the vadose zone and groundwater.

The DOE Public Safety and Resource Protection Program monitors the radiological and chemical characteristics of the Columbia River adjacent to the 300 Area and downstream to the city of Richland water intake structure. Contaminants introduced at the 300 Area via groundwater discharge have no discernible impact on the river water quality away from the immediate vicinity of the 300 Area shoreline. Monitoring at a cross-river transect just upstream from the Richland intake structure, and at the structure itself, reveals no Hanford Site contaminants at levels reaching relevant standards. City of Richland monitoring of intake river water confirms that Hanford Site contaminants, along with contaminants carried by the river from multiple other sources, are not entering the water supply at levels of concern.

Table ES-1. Vadose Zone and Groundwater COPCs

Radionuclides	Metals	Volatile Organics
Americium-241	Aluminum**	1,1,1-Trichloroethane
	Antimony	
Carbon-14	Arsenic	1,2-Dichloroethene (total)
Cesium-137	Barium	2-Butanone
Cobalt-60	Beryllium	4-Methyl-2-pentanone
Europium-152	Bismuth	Benzene
Europium-154	**Boron**	Carbon tetrachloride**
Europium-155	Cadmium	Chloroform**
Iodine-129	Chromium, total	**Cis-1,2-Dichloroethene***
Nickel-63	**Chromium, Hexavalent***	Ethyl acetate
Plutonium-238	Cobalt	Ethylene glycol
Plutonium-239/240	**Copper**	Hexachlorobutadiene
Technetium-99	Iron**	Hexachloroethane
	Lead**	
Strontium-90	Lithium	Nitrobenzene
Tritium*	Manganese	Tetrachloroethene
Uranium-233/234	**Mercury**	Toluene
Uranium-235	**Nickel****	**Trichloroethene***
Uranium-238	**Selenium**	Vinyl chloride
	Silver**	
Inorganic Anions	Strontium	**Semivolatile Organics**
Cyanide	Thallium	Bis(2-ethylhexyl)phthalate
Fluoride	Tin	Benzo(a)anthracene
Nitrate (i.e., **Nitrate**)*	**Uranium***	Butylbenzylphthalate
Nitrite (as Nitrogen)	Vanadium	Chrysene
Sulfate**	Zinc	Phenanthrene
PCB Aroclors	**Organics**	Tributyl phosphate
Aroclor 1016	**Total Petroleum Hydrocarbons (diesel range, motor oil)**	Aldrin
Aroclor 1221	Normal paraffin hydrocarbons	
Aroclor 1232		
Aroclor 1242		
Aroclor 1248		
Aroclor 1254		
Aroclor 1260		

Table ES-1. Vadose Zone and Groundwater COPCs

Source: From Table 8-3 in Chapter 8.

Note: **Bold** indicates the final COPCs based upon human health and ecological risk evaluation.

* Indicates a groundwater contaminant.

** Indicate contaminants that have been detected in groundwater and will be added to the site-wide monitoring program.

COPC = contaminant of potential concern

PCB = polychlorinated biphenyl

Current and Projected Land and Groundwater Use

Several Hanford Site special purpose industrial areas or facilities in the 300 Area are not included in this RI/FS report. These include: the Hanford Patrol Training Academy (including the firing range), FFTF reactor and associated facilities, Energy Northwest (including Bonneville Power Administration facilities), and the HAMMER Training Facility.

In addition, R&D activities within the 300 Area Industrial Complex are ongoing and projected to continue within defined facilities through at least 2027. Given the large amount of current and planned future industrial land use in this area, the reasonably anticipated future land use for the 300 Area is industrial. The industrial future land use is also supported by previous decisions.

Under "Requirement to Develop Future Use Plans for Environmental Management Programs" (50 USC 2582[22]), DOE holds express statutory authority to establish future land use for the Hanford Site. DOE involved Tribal Nations and stakeholders during the Environmental Impact Statement (EIS) process, under the *National Environmental Policy Act of 1969*[23] (NEPA) and the "State Environmental Policy" (RCW 43.21C[24]), to evaluate future land use alternatives. This process was conducted in coordination with nine cooperating government agencies and resulted in the *Final Hanford Comprehensive*

[22] 50 USC 2582, "Requirement to Develop Future Use Plans for Environmental Management Programs," *United States Code*. Available at: http://law.onecle.com/uscode/50/2582.html.

[23] National Environmental Policy Act of 1969, 42 USC 4321, et seq. Available at: http://www.fhwa.dot.gov/environment/nepatxt.htm.

[24] RCW 43.21C, "State Environmental Policy," *Revised Code of Washington*, Olympia, Washington. Available at: http://apps.leg.wa.gov/RCW/default.aspx?cite=43.21C.

Land Use Plan Environmental Impact Statement (DOE/EIS-0222-F[25]) and Record of Decision (ROD) (64 FR 61615, "Record of Decision for Hanford Comprehensive Land-Use Plan Environmental Impact Statement"[26]).

The 1999 Hanford Comprehensive Land Use Plan (CLUP) Environmental Impact Statement (EIS) ROD (DOE/EIS-0222-F) and ROD Amendment (73 FR 55824, "Amended Record of Decision for the Hanford Comprehensive Land Use Plan Environmental Impact Statement"[27]) designated future land use as predominately industrial with several isolated areas designated as conservation (mining) for the non-processing areas. Figure ES-5 presents the land use for the 300 Area.

Preservation of cultural and historic properties under the *National Historic Preservation Act of 1966*[28] and other laws, and land use considerations, such as consistency with the Hanford CLUP (DOE/EIS-0222-F), are considered in remedial action decisions under the Tri-Party Agreement (Ecology, et al., 1989a). Tribal treaty reserved fishing rights are also recognized on rivers within the ceded lands, including the Columbia River, which flows through the Hanford Site. The Tribal Nations have participated in DOE's land use planning process, and DOE considered Tribal Nation concerns in that process.

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[25] DOE/EIS-0222-F, 1999, *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*, U.S. Department of Energy, Washington, D.C. Available at:
http://www5.hanford.gov/arpir/?content=findpage&AKey=D199158842.
http://www5.hanford.gov/arpir/?content=findpage&AKey=D199158843.
http://www5.hanford.gov/arpir/?content=findpage&AKey=D199158844.
http://www5.hanford.gov/arpir/?content=findpage&AKey=D199158845.
http://www5.hanford.gov/arpir/?content=findpage&AKey=D199158846.
http://www5.hanford.gov/arpir/?content=findpage&AKey=D199158847.

[26] 64 FR 61615, "Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS)," *Federal Register*, Vol. 64, No. 218, pp. 61615-61625, November 12, 1999. http://www.gpo.gov/fdsys/pkg/FR-1999-11-12/pdf/99-29325.pdf.

[27] 73 FR 55824, "Amended Record of Decision for the Hanford Comprehensive Land-Use Plan Environmental Impact Statement," *Federal Register*, Vol. 73, No. 188, pp. 55824-55826, September 26, 2008. Available at: http://www.gpo.gov/fdsys/pkg/FR-2008-09-26/pdf/E8-22676.pdf.

[28] *National Historic Preservation Act of 1966*, Pub. L. 89-665, as amended, 16 USC 470, et seq. Available at: http://www.achp.gov/docs/nhpa%202008-final.pdf.

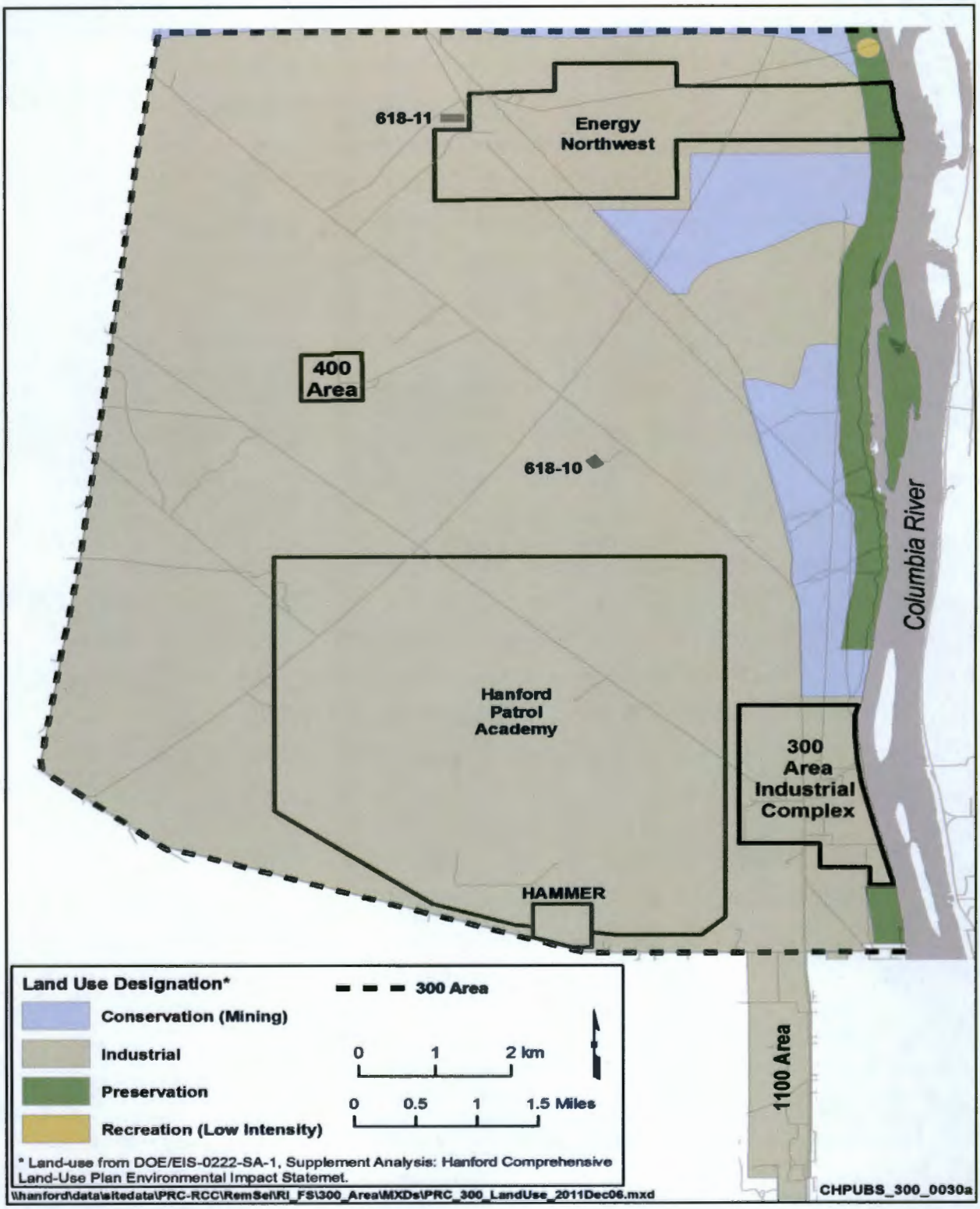

Figure ES-5. Land Use in the 300 Area

A Presidential Proclamation in 2000 (65 FR 37253, "Establishment of the Hanford Reach National Monument"[29]) established the Hanford Reach National Monument (HRNM) within the boundaries of the Hanford Site (Figure ES-1). The Proclamation (65 FR 37253) generally mandated more restrictive land uses within the HRNM boundaries than those DOE adopted in the Hanford CLUP (DOE/EIS-0222-F). The HRNM mandate is to preserve the natural and cultural resources for which the HRNM was established. The U.S. Fish and Wildlife Service has developed a comprehensive conservation plan (*Hanford Reach National Monument: Final Comprehensive Conservation Plan and Environmental Impact Statement Adams, Benton, Grant and Franklin Counties, Washington*[30]) for management of the HRNM.

Regarding groundwater, the National Contingency Plan (NCP) (40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan"[31]) establishes an expectation to "return useable ground waters to their beneficial uses wherever practicable, within a time frame that is reasonable given the particular circumstances of the site" (40 CFR 300.430[a][1][iii][F]). EPA generally defers to state definitions of groundwater classification provided under EPA-endorsed Comprehensive State Groundwater Protection Programs (EPA/540/G-88/003, *Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites*[32]). Under EPA's groundwater classification program, 300 Area groundwater would be designated Class IIA/B, groundwater that is a current and future source of drinking water.

Risk Evaluation

The RI/FS integrates past and ongoing human health and ecological risk assessment (ERA) evaluations to support development of remedial alternatives for waste sites and contaminated groundwater in the 300 Area. The River Corridor Baseline Risk

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[29] 65 FR 37253, "Establishment of the Hanford Reach National Monument," *Federal Register*, Vol. 65, No. 114, pp. 37253-37257, June 13, 2000. Available at: http://www.gpo.gov/fdsys/pkg/FR-2000-06-13/pdf/00-15111.pdf.

[30] USFWS, 2008, Hanford Reach National Monument: Final Comprehensive Conservation Plan and Environmental Impact Statement Adams, Benton, Grant and Franklin Counties, Washington, U.S. Fish and Wildlife Service, Burbank, Washington. Available at: http://astro.berkeley.edu/~kalas/ethics/documents/environment/final-ccp-no-maps.pdf.

[31] 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," *Code of Federal Regulations*. Available at: http://www.gpo.gov/fdsys/pkg/CFR-2010-title40-vol27/xml/CFR-2010-title40-vol27-part300.xml.

[32] EPA/540/G-88/003, 1988, *Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites*, Interim Final, OSWER Directive 9283.1-2, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://www.epa.gov/superfund/policy/remedy/pdfs/540g-88003-s.pdf.

Assessment (RCBRA)[33] addresses the CERCLA regulatory requirement that a baseline risk assessment be performed to evaluate current and potential future risks posed by hazardous substance releases. The RCBRA human health risk assessment (HHRA) and the companion ERA evaluated ecological and human health risk from residual contamination at previously remediated waste sites.

Based on the current industrial land use and existing institutional controls, there are currently no complete exposure pathways in the 300 Area for risk to human populations. Nevertheless, for purposes of assessing potential risks in the absence of remediation and controls, hypothetical land use and human exposure scenarios were evaluated in the 300 Area RI/FS supplemental risk evaluation. The industrial, resident HRNM worker, and casual recreational user exposure scenarios reflect exposure assumptions and exposure pathways that are consistent with reasonably anticipated future land use. The residential exposure scenario represents a conservative case that is used for comparison against the other scenarios while also providing the basis for remedial action decision making.

Assumptions for the residential scenario and the industrial scenario provide the basis for the RAOs that define the extent to which waste sites require cleanup to protect HHE. Preliminary remediation goals (PRGs) are the numeric values that represent the RAOs. In addition to the residential scenario and industrial scenario, PRG values were developed for the resident HRNM worker and the casual user exposure scenarios. Additionally, these numeric values were used as risk-based screening levels (RBSLs) in the supplemental soil risk evaluation.

The soil and groundwater risk evaluations provided in Chapter 6 and the ERA provided in Chapter 7 are intended to supplement the RCBRA, and were prepared to address differences in scope and purpose. Integration of the RCBRA, the supplemental soil and groundwater risk evaluations, and the ERA will support the development of the 300 Area ROD(s).

The supplemental soil risk evaluation used data from previously remediated waste sites. The principal contaminants identified as COPCs in vadose zone soil are radionuclides and polychlorinated biphenyl (PCB) Aroclors. Radionuclides included cesium-137,

[33] DOE/RL-2007-21, 2008, *Risk Assessment Report for the 100 Area and 300 Area Component of the River Corridor Baseline Risk Assessment*, Draft B, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

strontium-90, uranium-233/234, uranium-235, and uranium-238. The cumulative risk from radionuclides in the top 4.6 m (15 ft) of soil are no greater than 2×10^{-4} for the residential scenario. Cancer risks associated with the resident HRNM worker scenario are similar to the residential scenario. Cancer risks for a casual recreational user scenario are approximately two orders of magnitude lower than the residential scenarios.

Four waste sites (316-1, 316-2, 316-5, and 618-3) report an exceedance of 1×10^{-4} based on the residential scenario. The 316-1, 316-2, and 316-5 waste sites were remediated under the 300-FF-1 ROD using the cleanup levels for industrial land use. The 618-3 waste site was remediated under the 300-FF-2 ROD and also based on industrial land use. The land use for the 316-1, 316-2, 316-5, and 618-3 waste sites is designated as industrial and the associated risks are less than 1×10^{-4} for this scenario. The industrial exposure scenario represents the reasonably anticipated future land use and no further action is warranted.

For the residential scenario, the noncancer hazard indices for noncarcinogens were less than EPA's and WAC 173-340-708[34] target hazard index (HI) of 1. The noncancer hazard indices for noncarcinogens were less than EPA's target HI of 1 for the resident HRNM worker and casual user scenarios.

Residents are unlikely to be exposed to contaminants in soil located at depths greater than 4.6 m (15 ft) below ground surface (bgs) through the direct contact exposure pathway. However, soil concentrations from deep zone soils were compared to residential RBSLs in order to account for residual concentrations in the environment from waste disposal practices. This evaluation provides information to risk managers to assess the need for enhanced controls to prevent contact with this media. The FS evaluated two waste sites because concentrations of one or more radioisotopes in the deep zone are greater than the residential RBSL. The FS concluded institutional controls (ICs) are needed to prevent uncontrolled drilling or excavation into the deep zone.

The RCBRA assessed human health risks for the avid angler, casual user, and Tribal use scenarios from exposure to COPCs in upland and riparian surface soils, river water and sediment, and fish tissue. The results from the 300 Area for the casual user and avid angler scenarios showed that lifetime cancer risks generally were near or below target

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

thresholds and were below the noncancer HI for direct exposures to soil, sediment, and surface water. The analysis from the casual user and avid angler scenarios concluded there are no COPCs in riparian soils, near shore sediments, and surface water that warrant further evaluation in the FS.

The nonresident Tribal scenario risks from riparian soils were above the target cancer threshold and noncancer hazard index. Fish ingestion cancer risks exceeded thresholds for the Tribal scenarios. However, this RI/FS report concludes that it is unlikely that sources or transport pathways exist from Hanford Site soils or groundwater that would have resulted in transport of those contaminants (PCBs, mercury, or chlorinated pesticides) that have accumulated into fish tissue. The Tribal scenarios assist interested parties in providing input on remedial alternatives, and are not used for development of PRGs as part of alternatives analyses in the FS.

The groundwater contaminants are uranium, gross alpha, tritium, cis-1,2-DCE, chromium, TCE, and nitrate based on comparing concentrations in groundwater with federal and state DWSs, federal and state surface water standards for protection of human health and aquatic organisms, and state groundwater cleanup levels. Gross alpha is associated with uranium and is not specifically carried forward as a groundwater COC because achieving the uranium cleanup standards will result in the gross alpha standard being achieved.

TCE is observed in two wells (399-3-21 and 399-4-14) located south of the former South Process Pond. Cis-1,2-DCE is observed in a single well (399-1-16B) that is located near the former North Process Pond. The origin for cis-1,2-DCE is likely degradation of TCE disposed to the former 300 Area Process Trenches and/or North Process Pond. Chromium is observed in two wells (399-8-5A and 399-8-1), which are located to the east of the former 618-7 Burial Ground.

Elevated nitrate concentrations are identified at the southern portion of the 300 Area where groundwater has been impacted by agricultural and industrial activities not associated with the Hanford Site. Tritium and nitrate are present in the groundwater beneath and downgradient of the 618-11 Burial Ground. The origin for nitrate observed in the vicinity of the 618-11 Burial Ground is enigmatic. Waste acids, such as nitric acid, are not known to have been placed in the burial ground. One explanation is that the

nitrate is part of a plume resulting from waste disposal that occurred in 200 East Area sites upgradient of the burial ground that has been transported to its present location.

The supplemental ecological risk evaluation included soil contaminant concentrations at 38 interim closed and no action waste sites in the 300 Area Source OUs. Soil concentrations were compared to background and to PRGs protective of plants, invertebrates, and wildlife. Analytes with concentrations greater than background and PRGs were retained as contaminants of ecological concern (COECs). Eighteen waste sites were retained for additional consideration based on exposure point concentration (EPC) exceedances of 17 COECs including seven metals (boron, copper, mercury, nickel, selenium, silver, and total uranium), one pesticide (aldrin), and seven polychlorinated biphenyl Aroclors (Aroclor 1016, Aroclor 1221, Aroclor 1232, Aroclor 1242, Aroclor 1248, Aroclor 1254, and Aroclor 1260) and total petroleum hydrocarbons-motor oil.

The results of the supplemental ecological risk evaluation were considered in the context of other factors (such as spatial coverage, data, chemical specifics, receptors at risk, confidence in PRGs, etc.) to determine which COECs should be brought forward to the FS. Based on an assessment of endpoints, representative receptors, and complete exposure pathways that correspond to the COECs, the supplemental ecological risk evaluation concluded that no waste sites should be carried forward into the FS for evaluation of remedial alternatives.

The ecological risk assessment presented in the RI/FS Report also evaluates potential impacts to aquatic life from exposure to uranium and TCE originating in groundwater. Uranium and TCE can be transported from groundwater to the Columbia River via upwelling through the riverbed, and to a lesser extent, via riverbank springs that appear during periods of low river stage. Porewater samples (also known as groundwater upwelling samples) were collected and analyzed to determine if uranium and TCE are present at concentrations that could impact aquatic life.

There are no Washington State ambient water quality criteria/standards for uranium or TCE; therefore, concentrations of uranium and TCE were compared to published benchmarks developed for protection of aquatic plants and aquatic invertebrates for comparison purposes. Concentrations of uranium in some pore water samples are greater than available aquatic plant- and invertebrate based water benchmarks; however, uranium

was not detected in the Columbia River. TCE was not detected in pore-water samples and it was not detected in the Columbia River. Based on the results of this evaluation, the amount of uranium and TCE in groundwater is small and impacts to aquatic life in the Columbia River are not measureable.

Feasibility Study

RAOs present statements of protectiveness for HHE from risks identified in the baseline risk assessment. The RAOs describe what the remedial actions are expected to accomplish to meet the applicable or relevant and appropriate requirements (ARARs) and protect HHE. For the 300 Area, the anticipated future land use has been identified as industrial. However, both the unrestricted land use criteria based upon the future residential scenario and the industrial land use criteria were used for the preparation of the following RAOs:

- **RAO 1.** Prevent unacceptable risk to human health from ingestion of and incidental exposure to groundwater containing contaminant concentrations above federal and state standards and risk-based thresholds.
- **RAO 2.** Prevent unacceptable risk to human health and ecological exposure to surface water containing contaminant concentrations above federal and state standards and risk-based thresholds.
- **RAO 3.** Prevent unacceptable risk from contaminants migrating and/or leaching through soil that will result in groundwater concentrations that exceed state and federal standards and risk-based thresholds for protection of surface water and groundwater.
- **RAO 4.** Prevent unacceptable risk to human health from exposure to the upper 4.6 m (15 ft) of soil and to structures and debris contaminated with nonradiological constituents at concentrations above the unrestricted land use exposure scenario for areas outside the 300 Area Industrial Complex and waste site 618-11 (adjacent to Energy Northwest).
- **RAO 5.** Prevent unacceptable risk to human health from exposure to the upper 4.6 m (15 ft) of soil and to structures and debris contaminated with radiological constituents at concentrations above a dose rate limit that causes an excess lifetime cancer risk threshold of 10-6 to 10-4 above background for the unrestricted land use exposure

scenario for areas outside the 300 Area Industrial Complex and waste site 618-11 (adjacent to Energy Northwest).

- **RAO 6.** Prevent unacceptable risk to human health from exposure to the upper 4.6 m (15 ft) of soil and to structures and debris contaminated with nonradiological constituents at concentrations above the industrial land use exposure scenario for the 300 Area Industrial Complex and waste site 618-11 (adjacent to Energy Northwest).

- **RAO 7.** Prevent unacceptable risk to human health from exposure to the upper 4.6 m (15 ft) of soil and to structures and debris contaminated with radiological constituents at concentrations above a dose rate limit that causes an excess lifetime cancer risk threshold of 10-6 to 10-4 above background for the industrial land use exposure scenario for the 300 Area Industrial Complex and waste site 618-11 (adjacent to Energy Northwest).

- **RAO 8.** Prevent unacceptable risk to ecological receptors from exposure to the upper 4.6 m (15 ft) of soil and to structures and debris contaminated with nonradiological constituents above the soil contaminant levels and radiological constituents above a dose rate limit of 0.1 rad/day for terrestrial wildlife populations.

PRGs have been developed as numeric representations of the RAOs to define the allowable concentrations of COCs in environmental media under specified exposure conditions and to allow the calculation of area and volume estimates for remedial actions. PRGs are used to assess the effectiveness of the selected remedial alternatives to meet the RAOs. PRGs provide the basis for identifying cleanup levels in the ROD. PRGs for unrestricted land use and industrial land use for the vadose zone and PRGs for groundwater are presented in Chapter 8.

The following sections provide a summary of the waste sites and groundwater comparisons to the PRGs.

Waste Sites Comparison to PRGS. This RI/FS report addresses all the waste sites in the 300 Area that have been identified for the 300-FF-1 and 300-FF-2 OUs. A total of 552 potential waste sites were identified in the 300 Area. Of these potential waste sites, 275 sites were not accepted as waste sites during the waste site evaluation process because they do not have contaminants that exceed risk-based levels. These sites have been removed from further consideration for cleanup actions. Of the 277 remaining sites,

122 are identified for no further action based on investigations and remedial actions taken to date. The remaining 155 waste sites have been evaluated for remedial actions as follows:

- Six waste sites that have been previously remediated warrant additional remedial actions because they exceed groundwater protection PRGs for total uranium isotopes. These waste sites are located in an area of uranium groundwater contamination and will be addressed as part of the groundwater remedy.

- Forty-three waste sites are currently being remediated under the 300-FF-2 interim ROD (EPA/ROD/R10 01/119), or are anticipated to be remediated by the time this final action ROD is signed. These waste sites are included in this RI/FS report and will achieve the proposed PRGs. DOE assumes that the ongoing interim actions will meet the PRGs so that no further action (or costs) will be required.

- Sixty-six waste sites will not have interim remedial actions completed before this final action ROD is signed. These wastes sites are evaluated for remedial alternatives in this RI/FS report.

- Forty waste sites, identified as Consolidated Sites, lie within the remediation footprint of other sites. The costs for remediation of these waste sites are already included in the costs for remediation of the other waste sites.

Groundwater Comparison to PRGs. A risk management approach was applied in developing COCs to be addressed by remedial action alternatives for the groundwater plumes. The COCs for groundwater at the 300 Area are described below.

- Uranium in groundwater that exceeds DWSs occurs in the 300 Area Industrial Complex and covers an area of about 0.5 km^2 (0.2 mi^2). Cleanup of the groundwater plume and protection of the Columbia River will be accomplished through remediation of the source of uranium contamination that resides in the vadose zone and PRZ. Groundwater monitoring will be included to assess progress toward achieving cleanup goals. The waste sites that exceed the groundwater protection PRGs are located within the uranium groundwater plume. These waste sites have undergone previous remediation, but based on confirmation sampling, the residual uranium concentrations remain above the proposed PRGs for groundwater protection.

Based on process knowledge of historical waste disposal, soil concentration data, and uranium concentrations in the groundwater, it appears that the majority of the vadose zone contamination is associated with waste sites 316-1, 316-2, 316-3, and 316-5. Waste site 316-1 did not exceed the proposed soil PRGs for groundwater protection, but is included for remediation because of the waste disposal history and nearby contaminated groundwater.

Remediation of the contaminated groundwater using typical pump-and-treat technology was screened out during the FS mainly because only about 1 percent of the total uranium resides in the groundwater that would be affected by this remediation technique. Implementation of pump-and-treat technology will not reduce the time to achieve cleanup. Since the vast majority of the uranium contamination resides in the vadose zone and PRZ, an effective remediation approach will target those zones to reduce the amount of mobile uranium that is available to enter the groundwater. In situ mining of uranium (flush the uranium from the vadose zone and PRZ) with pump-and-treat capture in the groundwater was not carried into the remedial alternatives. Industry experience demonstrates it is problematic to restore the aquifer after extraction. Sequestration of uranium through biological manipulation of the vadose zone, PRZ, and aquifer was also not carried forward into the remedial alternatives because it is not possible to maintain long-term anoxic conditions required to keep uranium sequestered with this technology.

- Tritium in groundwater that exceeds the DWS occurs beneath the 618-11 Burial Ground. A groundwater transport model was constructed using monitoring well chemical and hydraulic data, along with dispersion estimates and tritium decay and used to predict future tritium concentrations in the area. Several scenarios were run with this model, and it was concluded that the maximum tritium concentration will decline to below the DWS by 2031. Thus, the model predicts that a combination of natural radiological decay and dispersion during transport will achieve the PRG within a reasonable time frame.

The approach taken for the remaining groundwater COPCs that will be carried forward for monitoring is discussed below:

- Most gross alpha is associated with uranium; therefore, it will not be carried forward as a groundwater COC and will not be included in the monitoring program.

- Nitrate concentrations in 300 Area Industrial Complex groundwater have exceeded the 45 mg/L DWS at the southern portion of the 300 Area where groundwater has been impacted by agricultural and industrial activities not associated with the Hanford Site. Therefore, nitrate will not be carried forward as a groundwater COC in the 300 Area Industrial Complex. Nitrate in the 600 Area Subregion (618-11 Burial Ground) is in part associated with waste disposal at the 200 East Area sites which is part of a dilute site-wide groundwater plume in the northern portion of the 300 Area. Due to its likely association, at least in part, with the site-wide contamination, nitrate at the 618-11 Burial Ground will not be carried forward as a groundwater COC.

- Recent analytical results for TCE at several wells at the southern portion of the 300 Area show increases in concentrations, some of which now exceed the DWS of 5 μg/L (wells 399-3-21 and 399-4-14). Other VOCs do not show similar increases, and the TCE increases do not appear correlated with trends for other waste constituent indicators. Offsite groundwater from the southwest migrates into the southern portion of the 300 Area, and TCE contamination that is potentially associated with offsite sources (e.g., the AREVA facility and DOE's former Horn Rapids Landfill) is present in that groundwater. Due to the potential association with offsite sources, TCE will not be carried forward as a COC.

- Cis-1,2-DCE concentrations continue to exceed the DWS at only one well (399-1-16B) located near the former North Process Pond. Well 399-1-16B is screened in Ringold Formation gravelly sediment in the lower portion of the unconfined aquifer. Since the areas of exceedance are localized, cis-1,2-DCE will not be carried forward as a COC.

- Chromium recently appeared as part of the plume associated with remedial action at the 618-7 Burial Ground, which was completed in late 2008. At well 399-8-5A, which is adjacent to the eastern fence line of the former burial ground, concentrations measured as total chromium in filtered and unfiltered samples during late 2008 and 2009 had a high value of 105 μg/L in July 2009. Concentrations have since declined to near the hexavalent chromium ambient water quality criteria of 10 μg/L. The source for the chromium is unknown but is suspected to be related to release of material from the burial ground during remedial action excavation activities, dust

control water application, or corrosion of the stainless-steel well screen in well 399-8-5A, which may have occurred because of the elevated chloride level. Other constituents showing a concurrent increase at this well include calcium, chloride, gross alpha, gross beta, nitrate, and sodium. Since the areas of chromium exceedance are localized and likely associated with completed remediation activities at the 618-7 Burial Ground, chromium will not be carried forward as a COC.

Remedial Alternatives. The FS identified and screened technologies to determine suitability in remediating the identified sources and contaminant plumes for development of remediation alternatives. Factors considered in the evaluation included the state of technology development, site conditions, waste characteristics, nature and extent of contamination, and presence of constituents that could limit the effectiveness of the technology. A qualitative comparison of the implementability, effectiveness, and cost provided an additional evaluation of the technologies. Five alternatives emerged that include a range of technology groupings that address vadose zone soil and groundwater collectively.

Alternative 1—No Action

The NCP (40 CFR 300) requires consideration of a No Action alternative, which serves as a baseline for evaluating other remediation action alternatives and is retained throughout the FS process. All site remedial activities and interim actions (with the possible exception of backfilling any open excavations that are not safe) will be discontinued in December 2012, including additional monitoring. Conceptual design details and cost estimates are not prepared for Alternative 1.

Based upon a two-dimensional model of the uranium concentration in the area with the highest residual uranium mass in the vadose zone and PRZ, it is estimated to take approximately 38 years[36] for the uranium concentrations in the groundwater to decrease below the DWS without additional source control measures. This analysis was performed using three wells that have the highest uranium concentrations and are located downgradient from the waste sites with the highest uranium source mass.

[36] The time frame is based on either the 90th percentile or 95-UCL concentration (whichever is longest) for the well with the highest uranium concentration to achieve the DWS.

Alternative 2—RTD and Groundwater Monitoring

Alternative 2 completes DOE's commitments in the 300-FF-2 interim ROD (EPA/ROD/R10-01/119) for RTD of the waste sites for protection of human health direct exposure and ecological receptors (less than 4.6 m [15 ft] bgs), MNA for tritium, and groundwater monitoring. Under Alternative 2, the time frame for the uranium concentration in the groundwater to decrease below the DWS is the same as the No Action alternative (approximately 38 years). Actions will vary depending on the nature and extent of contamination at each waste site.

Remedial technologies include:

- RTD of shallow vadose zone areas. RTD includes removing contaminated soil and debris with concentrations above cleanup levels from the waste site, treating it as necessary to meet disposal facility requirements, and sending it to the ERDF or another facility approved by EPA. The RTD components of the alternative assume an excavation depth sufficient to meet all RAOs, including protection of groundwater, protection of the Columbia River (except for residual uranium in the deep vadose zone/PRZ which is addressed as a separate component of the groundwater remedy), and the prevention of direct exposure. The RAOs for protection of groundwater and the Columbia River must be met through the entire soil column from the surface to groundwater. The RAO for direct exposure applies only to the upper part of the soil column, which is defined as the top 4.6 m (15 ft) of soil below the surrounding grade or the bottom of an engineered structure (burial ground trench, caisson, or pipe unit), whichever is deeper.

  If residual contamination exceeding cleanup standards in the soil column is found below 4.6 m (15 ft), the extent of remediation may require reevaluation by the Tri-Parties. Any decision to leave contaminants that exceed cleanup standards in place below 4.6 m (15 ft) will be made by the Tri-Parties and will require public comment depending on the nature of the waste.

- RTD of waste sites exceeding surface and groundwater protection criteria for COCs other than uranium.

- RTD of pipelines that are shallower than or at 4.6 m (15 ft) bgs for the protection of human health direct exposure and ecological receptors.

- RTD of the contaminated pipelines (300-15) that transported the majority of the uranium waste to the disposal sites (316-1, 316-2, and 316-5 and 618-1, 618-2, and 618-3).
- MNA for tritium in groundwater.
- Groundwater monitoring uranium, nitrate, TCE, cis-1,2-DCE, and chromium.
- ICs designed to achieve the substantive restrictions needed during the period of remedial actions to achieve cleanup objectives. ICs that are in place to prevent exposure to contamination will remain in place until all waste sites are remediated. ICs will be implemented on the entire River Corridor, and not independently for each waste site or groundwater plume.

Temporary surface caps will be installed over the waste sites that are adjacent to the 300 Area facilities and utilities that will remain in operation through at least 2027 (long-term facilities). In addition, pipelines associated with long-term facilities will be interim void filled, as necessary for groundwater protection. When the long-term facilities are no longer in use and removed, the waste sites and pipelines will be remediated as described above.

Alternative 3—RTD, Uranium Sequestration and Groundwater Monitoring

Alternative 3 uses a combination of RTD (less than 4.6 m [15 ft] bgs) for waste sites, uranium sequestration using phosphate for the waste sites with deep uranium contamination, MNA for tritium in groundwater, and groundwater monitoring. This alternative reduces the time required to restore the uranium-contaminated groundwater to the DWS to approximately 18 years. This shortened time frame assumes a 50 percent reduction in the amount of mobile uranium in the vadose zone due to sequestration. Remedial technologies include:

- RTD of shallow vadose zone areas same as Alternative 2.
- RTD of waste sites exceeding surface and groundwater protection criteria for COCs other than uranium.
- RTD for pipelines shallower than 4.6 m (15 ft) bgs and pipelines that transported the majority of the uranium waste to the disposal sites (i.e., waste sites 316-1, 316-2, 316-3, and 316-5).

- Phased implementation of uranium sequestration using a combination of both surface and deep application techniques for the waste sites with deeper (greater than 4.6 m [15 ft] bgs) uranium contamination. Uranium sequestration in the vadose zone and PRZ will target the waste sites having the largest mass of residual contamination based on waste disposal history, sample data, and groundwater monitoring data. Groundwater monitoring for uranium is also a component of this alternative.

  Uranium sequestration Phase I will determine the ability to reduce the amount of mobile uranium in the vadose zone sediments that could enter the groundwater. If Phase I is not successful in demonstrating the effectiveness of uranium sequestration by evaluating the pre- and post-remediation soil core samples collected in the Phase I area, then the approach to restore the groundwater under Alternative 2 will be implemented. Alternative 2 is appropriate because the groundwater cleanup levels will be achieved in 38 years (a reasonable time frame), there will be minimal impacts to the Columbia River, and the area will be maintained under ICs that restrict groundwater use.

- MNA for tritium in groundwater.

- Groundwater monitoring for nitrate, TCE, cis-1,2-DCE, and chromium.

- ICs designed to achieve the substantive restrictions needed during the period of remedial actions to achieve cleanup objectives. ICs that are in place to prevent exposure to contamination will remain in place until all waste sites are remediated. ICs will be implemented on the entire River Corridor, and not independently for each waste site or groundwater plume.

Temporary surface caps will be installed over the waste sites that are adjacent to the 300 Area facilities and utilities that will remain in operation through at least 2027 (long-term facilities). In addition, pipelines associated with long-term facilities will be interim void filled, as necessary for groundwater protection. When the long-term facilities are no longer in use and removed, the waste sites and pipelines will be remediated as described above.

Alternative 4—RTD, Uranium Sequestration, Focused Deep RTD for Uranium, and Groundwater Monitoring

Alternative 4 uses a combination of RTD (less than 4.6 m [15 ft] bgs) for waste sites, focused deep RTD for areas of higher uranium contamination, sequestration using surface application of phosphate for areas of lower uranium contamination, MNA for tritium in groundwater, and groundwater monitoring. The time frame for the uranium concentration in the groundwater to decrease below the DWS is estimated to be approximately 12 years. This shortened time frame assumes a 100 percent reduction in the uranium mass from the focused deep RTD areas and a 50 percent reduction in the amount of mobile uranium in the vadose zone due to sequestration. Remedial technologies include:

- RTD of shallow vadose zone areas same as Alternative 2.
- RTD of waste sites exceeding surface/groundwater protection criteria for COCs other than uranium.
- RTD for pipelines shallower than 4.6 m (15 ft) bgs and pipelines that transported the majority of the uranium waste to the disposal sites (i.e., waste sites 316-1, 316-2, 316-3, and 316-5).
- Focused deep RTD in areas of higher uranium mass in the vadose zone.
- Uranium sequestration using surface infiltration of phosphate in areas of lower uranium mass and groundwater monitoring for uranium.
- MNA for tritium in groundwater.
- Groundwater monitoring for nitrate, TCE, cis-1,2-DCE, and chromium.
- ICs designed to achieve the substantive restrictions needed during the period of remedial actions to achieve cleanup objectives. ICs that are in place to prevent exposure to contamination will remain in place until all waste sites are remediated. ICs will be implemented on the entire River Corridor, and not independently for each waste site or groundwater plume.

Temporary surface caps will be installed over the waste sites that are adjacent to the 300 Area facilities and utilities that will remain in operation through at least 2027 (long-term facilities). In addition, pipelines associated with long-term facilities will be interim void filled, as necessary for groundwater protection. When the long-term

facilities are no longer in use and removed, the waste sites and pipelines will be remediated as described above.

Alternative 5—RTD, Expanded RTD for Uranium, and Groundwater Monitoring

Alternative 5 uses a combination of RTD (less than 4.6 m [15 ft] bgs) for waste sites, expanded deep RTD for mass removal of uranium contamination, MNA for tritium in groundwater, and groundwater monitoring. The time frame for the uranium concentration in the groundwater to decrease below the DWS is estimated to be approximately 10 years. This shortened time frame to achieve the DWS for uranium assumes a 100 percent reduction in the uranium mass from the expanded deep RTD of the waste sites. Remedial technologies include:

- RTD of shallow vadose zone areas same as Alternative 2.
- Expanded deep RTD of the waste sites with higher uranium mass in the vadose zone (source removal).
- MNA for tritium in groundwater.
- Groundwater monitoring for uranium, nitrate, TCE, cis-1,2-DCE, and chromium.
- ICs designed to achieve the substantive restrictions needed during the period of remedial actions to achieve cleanup objectives. ICs that are in place to prevent exposure to contamination will remain in place until all waste sites are remediated. ICs will be implemented on the entire River Corridor, and not independently for each waste site or groundwater plume.

Temporary surface caps will be installed over the waste sites that are adjacent to the 300 Area facilities and utilities that will remain in operation through at least 2027 (long-term facilities). In addition, pipelines associated with long-term facilities will be interim void filled, as necessary for groundwater protection. When the long-term facilities are no longer in use and removed, the waste sites and pipelines will be remediated as described above.

The alternatives are evaluated using criteria in threshold, balancing, and modifying categories based on the purpose of each category in the remedy selection process. Protection of HHE and compliance with ARARs are threshold criteria that must be met by the selected remedial action. The balancing criteria represent specific categories for

detailed analysis and include long-term effectiveness and permanence; reduction of toxicity, mobility, and volume through treatment; short-term effectiveness; implementability; and cost. The preferred alternative will be the alternative that is protective of HHE, is ARAR-compliant, and provides the best combination of primary balancing attributes.

Community and state acceptance are not addressed in the FS. State and community acceptance are modifying criteria that are formally assessed during preparation of the Proposed Plan and following review of public and stakeholder comments (state and community acceptance) on the Proposed Plan.

Individual evaluations rated the performance of each alternative relative to threshold and balancing criteria. A comparative analysis provided an indicator of performance relative to the other alternatives (Table ES-2). Alternative 1, which did not meet threshold criteria, was not evaluated further against balancing and modifying criteria. Alternatives 2 through 5 meet the threshold and balancing criteria with different tradeoffs. These alternatives provide a robust approach through eliminating sources and treating existing groundwater contamination to prevent exposure. The selected alternative will be implemented for the 300-FF-1 and 300-FF-2 source OUs, and the 300-FF-5 groundwater OU. The available information is sufficient to implement a remedy that will protect HHE and achieve ARARs.

Waste site remediation that is ongoing under interim action RODs will continue until the final ROD is issued, at which time the actions will be evaluated against RAOs established under the final ROD. The information used to verify interim waste site closure for previously remediated waste sites was evaluated further in this RI/FS. The human health and ecological risk evaluations showed RTD has proven effective in meeting interim action RAOs and is sufficient to meet RAOs developed for the RI/FS. Sites that do not meet the cleanup goals will be evaluated depending on the risk drivers that remain and a remedy will be selected from the final ROD. The selected remedial actions will be considered minor modifications to the ROD. These minor modifications to the ROD will be made through an administrative process, such as an NPL (400 CFR 300, Appendix B) fact sheet, with public notification. These waste sites will be added to the appropriate remedial design/remedial action work plan for implementation of the remedial action.

Table ES-2. Comparative Evaluation of Alternatives for 300-FF-1, 300-FF-2, and 300-FF-5 OUs

CERCLA Criteria	Remedial Alternatives				
	1	2	3	4	5
Threshold Criteria					
Protection of human health/environment	No	Yes	Yes	Yes	Yes
Compliance with ARARs	No	Yes	Yes	Yes	Yes
Balancing Criteria					
Long-term effectiveness and permanence	Not Evaluated	○	○	○	◉
Reduction of toxicity, mobility, or volume through treatment	Not Evaluated	●	◉	◉	●
Short-term effectiveness and time to achieve RAOs	Not Evaluated	●	◉	○	○
Implementability	Not Evaluated	◉	◉	◉	○
Estimated Time to Cleanup, yr.		38	18	12	10
NPV Cost (million)					
- Waste Site	$0	$296	$400	$545	$1,155
Treatment*	$0	$5	$13	$11	$3
- Groundwater	$0	$301	$413	$556	$1,158
Total NPV Cost					
Modifying Criteria					
State acceptance	To be determined				
Community acceptance	To be determined				

Notes:

Although the remedial alternatives developed for evaluation do not have specific provisions for sustainable elements, those values can be incorporated during the remedial design phase.

◉ = Expected to perform very well against the criterion with no apparent disadvantage or uncertainty

○ = Expected to perform moderately well against the criterion but with some disadvantages or uncertainty

● = Expected to perform poorly against the criterion and may have disadvantages or uncertainty

The time frame is based on either the 90th percentile or 95-UCL concentration (whichever is longest) for the well with the highest uranium concentration to achieve the DWS.

* Does not include the cost for construction of an additional ERDF Super Cell at $27.1 million each.

Table ES-2. Comparative Evaluation of Alternatives for 300-FF-1, 300-FF-2, and 300-FF-5 OUs

	Remedial Alternatives				
CERCLA Criteria	**1**	**2**	**3**	**4**	**5**
Alternatives					
Alternative 1—No Action					
Alternative 2—RTD and Groundwater Monitoring					
Alternative 3—RTD, Uranium Sequestration, and Groundwater Monitoring					
Alternative 4—RTD, Uranium Sequestration, Focused Deep RTD, and Groundwater Monitoring					
Alternative 5—RTD, Expanded RTD and Groundwater Monitoring					

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Terms

2-D	two-dimensional
3-D	three-dimensional
ACM	asbestos-containing material
AEA	*Atomic Energy Act of 1954*
AMSL	above mean sea level
AR	Administrative Record
ARAR	applicable or relevant and appropriate requirement
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
AUF	area use factor
AWQC	ambient water quality criteria
BAF	bioaccumulation factor
BCG	Biota Concentration Guide
BDL	below detection limit
BEHP	bis(2-ethylhexyl)phthalate
bgs	below ground surface
BRA	baseline risk assessments
CalEPA	California Environmental Protection Agency
CAS	Chemical Abstract Service
CCC	criteria continuous concentration
CCl_4	carbon tetrachloride
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
cis-DCE	cis-dichloroethene
cis-1,2-DCE	cis-1,2-dichloroethene
CLARC	"Cleanup Levels and Risk Calculations"
CLUP	Comprehensive Land-Use Plan
CMC	criteria maximum concentration
COC	contaminant of concern
COEC	chemical of ecological concern

COPC	contaminant of potential concern
COPEC	contaminant of potential ecological concern
CFR	Code of Federal Regulations
Cr(VI)	hexavalent chromium
CRC	Columbia River Component
CSM	conceptual site model
CTE	Central Tendency Estimate
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CV	coefficient of variation
CVP	cleanup verification package
CY	calendar year
D4	deactivation, decommission, decontamination, and demolition
DaVE	Data Viewer and Evaluator
DNAPL	dense non-aqueous phase liquid
DOE	U.S. Department of Energy
DOE-RL	DOE Richland Operations Office
DQA	data quality assessment
DQO	data quality objective
DWS	drinking water standard
EC10	effective concentration affecting 10 percent of a test population
EC20	effective concentration affecting 20 percent of a test population
Eco-SSLs	EPA's Ecological Soil Screening Levels
Ecology	Washington State Department of Ecology
EIS	environmental impact statement
ELCR	excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
EQL	estimated quantitation limit
ERA	expedited response action
ERDF	Environmental Restoration Disposal Facility

ESAL	Environmental Sciences Analytical Laboratory
ESD	Explanation of Significant Difference
ESHWSA	East Side Hazardous Waste Storage Area
ESL	ecological screening level
FEP	feature, event, and process
FFTF	Fast Flux Test Facility
FIR	food intake rate
FS	feasibility study
FMEF	Fuels and Materials Examination Facility
FY	fiscal year
GHG	greenhouse gas
GRA	general response action
GCW	groundwater circulation well
HAMMER	Hazardous Materials Management and Emergency Response
HCP EIS	*Hanford Comprehensive Land-Use Plan Environmental Impact Statement*
HDPE	high-density polyethylene
HEAST	Health Effects Assessment Summary Table
HEIS	Hanford Environmental Information System
HHE	human health and the environment
HHRA	human health risk assessment
HI	hazard index
HMS	Hanford Meteorological Station
HQ	hazard quotient
HRNM	Hanford Reach National Monument
HSP	health and safety plan
HVAC	heating, ventilation, and air conditioning
HWSA	Hazardous Waste Storage Area
IC	institutional control
ICP	inductively coupled plasma
ID	identification

IEUBK	Integrated Exposure Uptake Biokinetic (EPA model)
IFRC	Integrated Field Research Challenge
IRIS	Integrated Risk Information System
ISCO	in situ chemical oxidation
ISGR	in situ gaseous reduction
K_d	distribution coefficient
LDR	land disposal restriction
LFI	Limited Field Investigation
LHWSA	Laydown Hazardous Waste Storage Area
LIDAR	Light Detection and Ranging
LLW	low-level waste
LOAEC	lowest observed adverse effects concentration
LOAEL	lowest observed adverse effects level
LOEC	lowest observed effect concentration
LSLDF	Life Sciences Laboratory Drainfield
MASF	Maintenance and Storage Facility
MATC	maximum acceptable toxicant concentration
MCL	maximum contaminant level
MCLG	maximum contaminant limit goal
MDL	method detection limit
MNA	monitored natural attenuation
MS	mass spectroscopy
MSA	Mission Support Alliance
MTCA	*Model Toxics Control Act*
NA	not applicable
NAVD 1988	North American Vertical Datum of 1988
NCP	National Oil and Hazardous Substances Pollution Contingency Plan or National Contingency Plan
ND	no data
NEPA	*National Environmental Policy Act of 1969*
NESHAP	National Emission Standards for Hazardous Air Pollutants

NJDEP	New Jersey Department of Environmental Protection
NOAEC	no observed adverse effects concentration
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NPV	net present value
O&M	operation and maintenance
OEHHA	Office of Health Hazard Assessment (CalEPA)
OMB	Office of Management and Budget
ORNL	Oak Ridge National Laboratory
OSE	orphan site evaluation
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response (EPA)
OU	operable unit
PA	preliminary assessment
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PEF	particulate emission factor
PNNL	Pacific Northwest National Laboratory
PPE	personal protective equipment
PPSS	Process Pond and Sewer System
PQL	practical quantitation limit
PRG	preliminary remediation goal
PRTR	Plutonium Recycle Test Reactor
PRZ	periodically rewetted zone
PSHWSA	Paint Shop Hazardous Waste Satellite Area
PSRPP	Public Safety and Resource Protection Program
PVC	polyvinyl chloride
QA	quality assurance
QAPjP	quality assurance project plan

QC	quality control
R&D	research and development
RACS	Remediation and Closure Science Project
RAG	remedial action goal
RAO	remedial action objective
RAWP	remedial action work plan
RB	retention basin
RBSL	risk-based screening level
RCBRA	River Corridor Baseline Risk Assessment
RCRA	*Resource Conservation and Recovery Act of 1976*
RD	remedial design
redox	reduction-oxidation
REMChlor	Remediation Evaluation Model for Chlorinated Solvents
RESRAD	RESidual RADiation
RFBP	Retired Filter Backwash Pond
RfD	reference dose
RI	remedial investigation
RLWS	Radioactive Liquid Waste System
RME	reasonable maximum exposure
ROD	Record of Decision
RPO	remedial process optimization
RPS	Retention Process Sewer
RRLWS	Retired Radioactive Liquid Waste Sewer System
RSVP	Remaining Sites Verification Package
RTD	removal, treatment, and disposal
SAP	sampling and analysis plan
SciDAC	Scientific Discovery through Advanced Computing
SDWA	*Safe Drinking Water Act of 1974*
SESP	Surface Environmental Surveillance Project
SI	Site Investigation

SMDP	scientific management decision point
SOF	sum-of-fractions
SSL	soil screening level
SSS	Sanitary Sewer System
STOMP	Subsurface Transport Over Multiple Phases
SVE	soil vapor extraction
SVOC	semi-volatile organic compound
TBC	to be considered
TCE	trichloroethene
TEDF	Treated Effluent Disposal Facility
TF	Tank Farm
TFWAST	Tank Farm Waste Acid Storage Tank
TI	technical impracticability
TMV	toxicity, mobility, or volume
TPA	Tri-Party Agreement
TPH	total petroleum hydrocarbons
Tri-Parties	The U.S. Department of Energy, the U.S. Environmental Protection Agency, and the Washington State Department of Ecology
TRU	transuranic
TRV	toxicity reference value
TSCA	*Toxic Substances Control Act of 1976*
TSD	treatment, storage, and/or disposal
UCL	upper confidence limit
UCL-95	95 percent upper confidence limit
UPR	unplanned release
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VOC	volatile organic compound
VPU	vertical pipe unit
VTS	Vitrification Test Site

WATS	Waste Acid Treatment System
WCH	Washington Closure Hanford
WIDS	Waste Information Data System
XRF	X-ray fluorescence

1 Introduction

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

For the purpose of CERCLA cleanup, four sections of the Hanford Site were placed on the National Priorities List (NPL) as separate areas: 100 Area (Reactor Operations), 200 Area (Irradiated Fuel Reprocessing and Waste Management), 300 Area (Nuclear Fuel Production and Research and Development), and 1100 Area (Equipment and Maintenance). The 400 Area waste sites were consolidated into the 300 Area NPL Site because of their proximity to the 300 Area and because of the few number of waste sites within the 400 Area. Because of the large number of waste sites, unplanned releases (UPRs), and extensive groundwater contamination, the areas were further divided into source and groundwater operable units (OUs) for management of the investigation and remediation. The River Corridor is the area adjacent to the Columbia River (Figure 1-1).

The initial mission of the 300 Area Industrial Complex was the fabrication of uranium fuel elements for the 100 Area reactors. The 300 Area facilities included the fuel fabrication buildings, raw material storage, waste storage, finished product storage, technical support, service support, and research and development (R&D) related to fuel fabrication and other Hanford Site processes. Waste generated from these operations was the major source of contamination in the 300 Area Industrial Complex.

As the Hanford Site production reactors were being shut down, fuel fabrication activities in the 300 Area decreased; at the same time, R&D activities increased. The newer buildings in the 300 Area primarily housed laboratory operations and large-scale test facilities. Over the operational history of the 300 Area, 228 facilities were built to support fuel fabrication and research projects.

This document presents the results of a CERCLA Remedial Investigation/Feasibility Study (RI/FS) undertaken for the 300 Area, which includes the 300-FF-1 and 300-FF-2 Source OUs and 300-FF-5 Groundwater OU (see Figure 1-2). The 300-FF-1 OU includes the large ponds, trenches, and burial ground waste sites. The 300-FF-2 OU contains the remaining waste sites. To avoid confusion within the RI/FS, the larger area that encompasses all the waste sites and groundwater beneath them will be referred to as the "300 Decision Area." The 300-FF-5 OU includes the groundwater impacted by the 300 Decision Area waste sites. The 300 Decision Area is comprised of four separate subregions (the 300 Area Industrial Complex, the 400 Area, 618-11, and 316-4 and 618-10). In addition, within the 300 Decision Area boundary are facilities that are currently active and will continue to be for the foreseeable future. Examples include the Energy Northwest nuclear power plant, Hanford Patrol firing range and the Hazardous Materials Management and Emergency Response (HAMMER) buildings, and facilities that are scheduled to be decontaminated and demolished by other actions, such as the Fast Flux Test Facility (FFTF), which are not included in this RI/FS.Industrial Complex

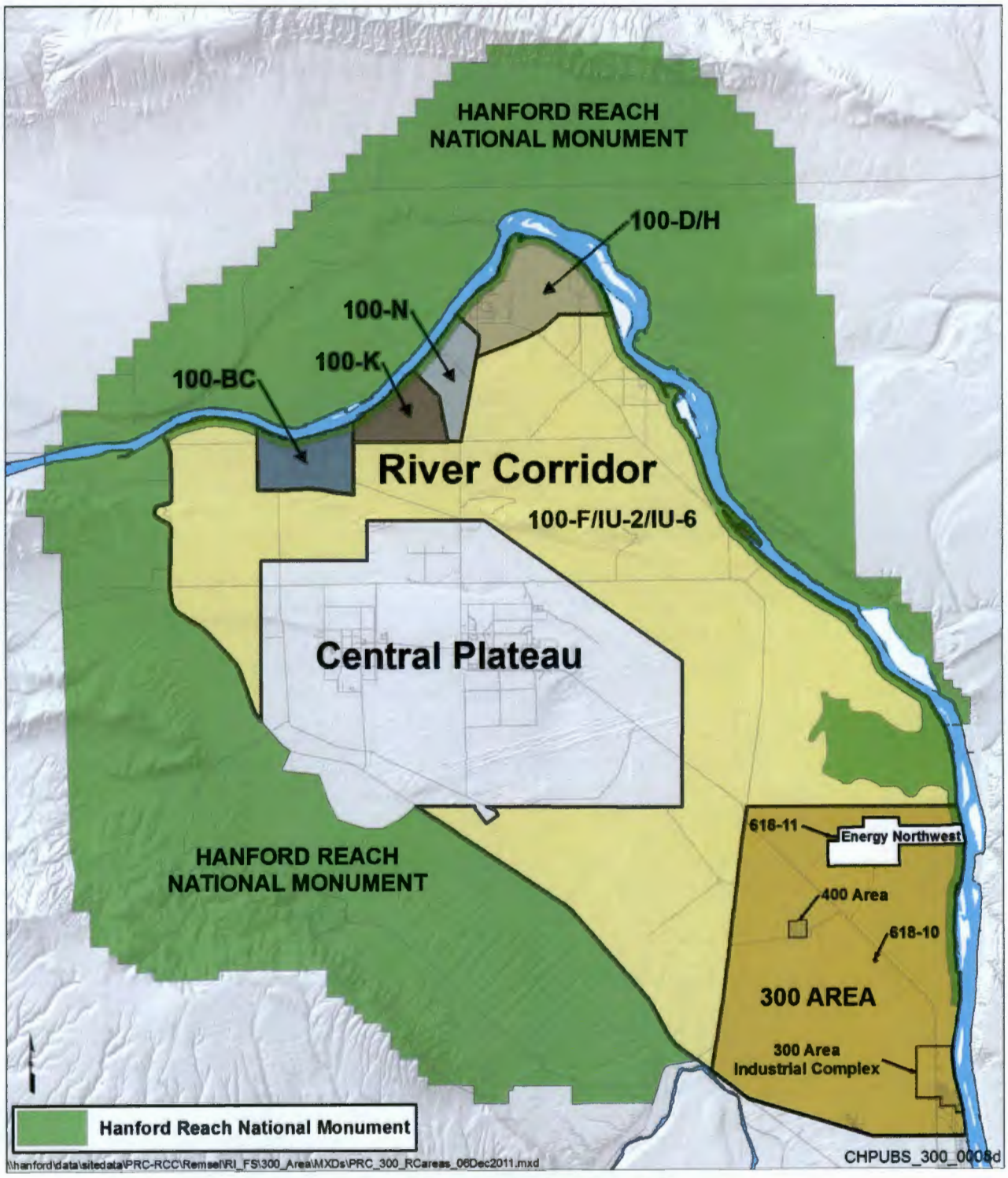


Figure 1-1. River Corridor Area Boundaries

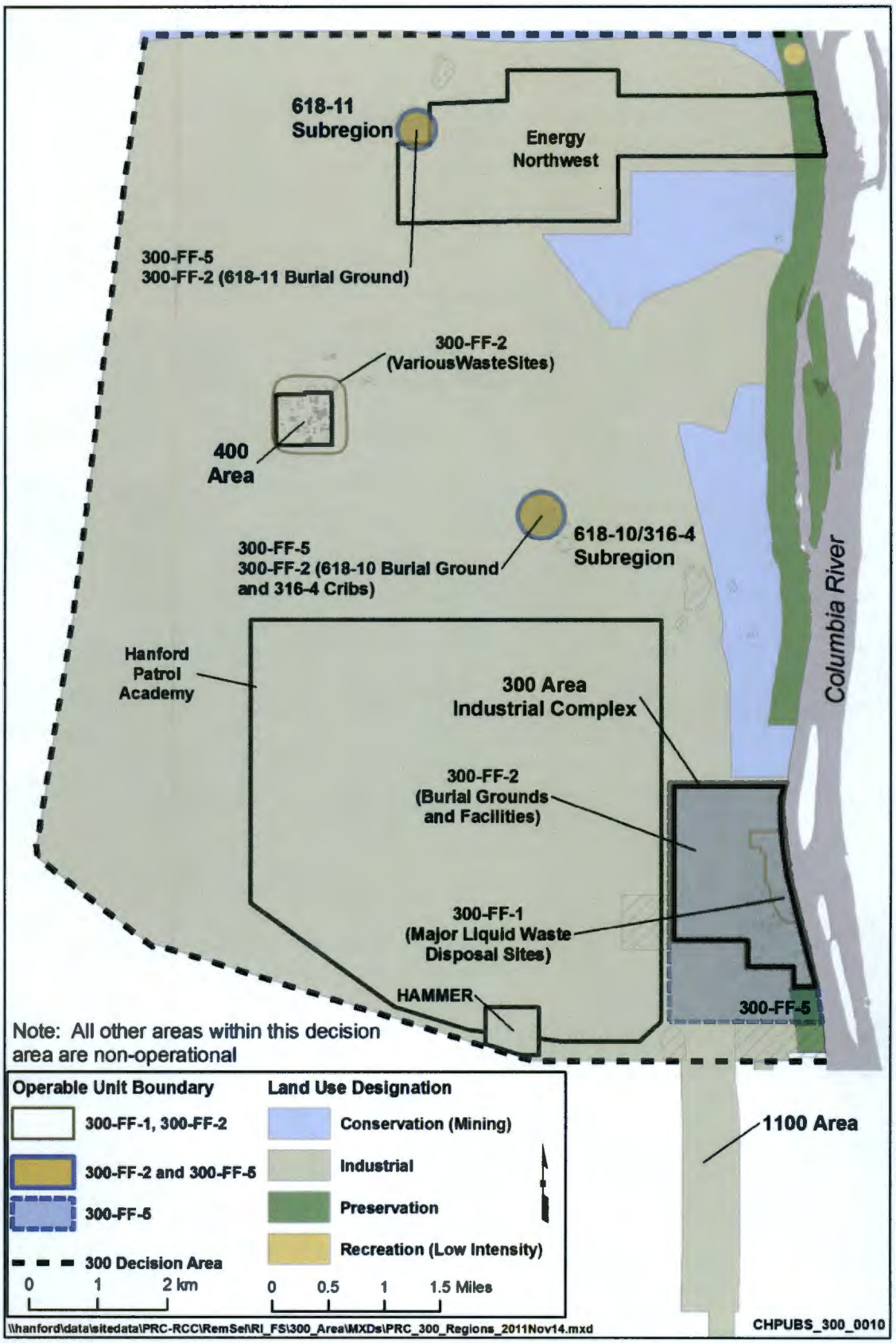


Figure 1-2. Illustration in Plan View Showing 300 Decision Area

The information contained in this RI/FS will support a Proposed Plan that will undergo public participation. The RI/FS supports the final remedial actions for the 300 Decision Area. This RI/FS will result in a single Record of Decision (ROD) that includes: (1) an amendment for residual uranium beneath certain 300-FF-1 OU waste sites posing a threat to groundwater, and (2) a new ROD for the 300-FF-2 and 300-FF-5 OUs. The remedial alternatives presented in Chapters 9 and 10 have been developed for the residual contamination beneath the 300-FF-1 OU waste sites, waste sites in 300-FF-2 OU, and groundwater contamination in 300-FF-5 OU. The ROD will consider the interaction between sources, groundwater, and surface water as a whole system within the 300 Decision Area and will replace existing interim RODs.

In 1991, the Tri-Parties determined there was a need to prioritize the CERCLA investigations and identify early actions to address waste sites and groundwater contamination. The *Hanford Past-Practice Strategy* (hereinafter called the Past-Practice Strategy [DOE/RL-91-40]) describes a bias-for-action approach through optimizing the use of interim actions and maintaining some level of effort for long-term data collection needs documented in interim RODs. This strategy emphasized the need to address waste sites and groundwater contamination that may pose a near-term impact to public health and the environment.

Initial waste site identification for the Hanford Site, including the 300 Decision Area, began when liquid and solid wastes were first disposed into the soil column. As more disposal locations were constructed and operated, documents that tracked location and content were developed. Eventually, these waste sites were assigned a standardized identification (ID) number and included for tracking purposes in a database, the Waste Information Data System (WIDS). As a result of the potential listing on the NPL, a preliminary assessment/site investigation (PA/SI) was conducted. This PA/SI identified the potential waste site by geographic area across the Hanford Site and assigned each waste site a hazard ranking. This combined hazard ranking score resulted in the four areas to be added to the NPL (100, 200, 300, and 1100). Waste sites identified within the geographic areas included the 300 Decision Area and the nearby environs. These waste sites were included in WIDS and formed the basis for the preliminary list of waste sites in the 300 Area NPL. Since the PA/SI, additional efforts have been conducted to ensure that all waste sites posing a threat to human health and the environment (HHE) are addressed through the non-operational area evaluation process, including the orphan site evaluation (OSE) and discovery site processes. These processes help ensure that no waste sites will be missed.

For the 300 Decision Area, the Past-Practice Strategy (DOE/RL-91-40) translated into priority investigations. Limited Field Investigations (LFIs) (*Limited Field Investigation Report for the 300-FF-2 Operable Unit* [DOE/RL-96-42]; *Limited Field Investigation Report for Uranium Contamination in the 300-FF-5 Operable Unit at the 300 Area, Hanford Site, Washington*, hereinafter called the 300-FF-5 LFI [PNNL-16435]) were initiated for the 300-FF-1, 300-FF-2, and 300-FF-5 OUs. These LFIs characterized the nature and extent of contamination in the vadose zone and groundwater. This led to the selection of actions to remediate source and groundwater contamination within the 300-FF-1, 300-FF-2, and 300-FF-5 OUs under the following ROD and interim ROD and three explanations of significant difference (ESD) documents:

- *Record of Decision for the 300-FF-1 and 300-FF-5 Operable Units, Hanford Site, Benton County, Washington* (hereinafter called the 300-FF-1 and 300-FF-5 ROD [EPA/ROD/R10-96/143]) This ROD described remediation activities for 300-FF-1 OU waste sites and interim remedial actions for 300-FF-5 OU groundwater. These final and interim RODs contained cleanup levels for various contaminants based on the existing data and risk information available at the time the decisions were issued.

- *Interim Remedial Action Record of Decision for the 300-FF-2 Operable Unit, Hanford Site, Benton County, Washington* (hereinafter called the 300-FF-2 Interim ROD [EPA/ROD/R10-01/119]). This ROD described interim remediation activities for 300-FF-2 OU waste sites.

- *USDOE Hanford 300 Area, 300-FF-1 Operable Unit, Hanford Site, Benton County, Washington Explanation of Significant Difference (ESD)* [EPA/ESD/R10-00/505]. The ESD was required because lead in a form and quantity that causes the soil to be a RCRA hazardous waste that is required to meet the land disposal restriction (LDR) criteria was discovered in the 628-4 or Landfill 1D waste site.

- *Explanation of Significant Difference for the 300-FF-5 Record of Decision* (EPA/ESD/R10-00/524). The ESD was required to change the scope for the 300-FF-5 from groundwater beneath and in the immediate vicinity of the 300 Area Industrial Complex, including all of the 300-FF-1 waste site and most of the 300-FF-2 waste sites to expand the area to all groundwater that underlies the 300 Area waste sites and burial grounds.

- *Explanation of Significant Difference for the 300-FF-2 Operable Unit Record of Decision* (EPA, Ecology, and DOE, 2004). The ESD was required to change the soil cleanup level for uranium from 350 pCi/g to 267 pCi/g as well as modify the soil cleanup levels for eight outlying waste sites.

DOE is the lead agency at the Hanford Site, per CERCLA, *Superfund Implementation* (Executive Order 12580), and the TPA (Ecology, et al., 1989a). DOE develops implementation strategies and conducts response actions in this lead federal agency role. With implementation of the Past-Practice Strategy (DOE/RL-91-40) and progress with the interim remedial actions, DOE prepared the *Hanford Site Cleanup Completion Framework* (hereinafter called the Cleanup Completion Framework [DOE/RL-2009-10]) to describe the cleanup strategy (Table 1-1).

Table 1-1. Overarching Goals for Hanford Site Cleanup

Goal	Description
1	Protect the Columbia River.
2	Restore groundwater to its beneficial use to protect human health, the environment, and the Columbia River.
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, and support anticipated future land uses.
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, and support anticipated future land uses.
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.
6	Consolidate waste treatment, storage, and disposal operations on the Central Plateau.
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.

Source: DOE/RL-2009-10, *Hanford Site Cleanup Completion Framework.*

One of the principal components of the Cleanup Completion Framework (DOE/RL-2009-10) is the River Corridor, which consists of approximately 570 km^2 (220 mi^2) of the Hanford Site along the Columbia River, and includes a contiguous area that extends from the 100 and the 300 Areas to the Central Plateau boundaries (Figure 1-1). The 100 Area contains nine retired plutonium production reactors, numerous support facilities, solid and liquid waste disposal sites, contaminated groundwater, and uncontaminated areas. The 300 Area Industrial Complex, located north of the city of Richland, contains fuel fabrication facilities, R&D facilities, and their associated solid and liquid waste disposal sites that have contaminated soil and groundwater.

Table 1-1 lists the overarching goals stated in the Cleanup Completion Framework (DOE/RL-2009-10). These goals are the result of consultation with the Tribal Nations and Hanford Natural Resource Trustees and dialogue between the Tri-Parties, stakeholders, and the public. These goals provide a set of principles that guide all aspects of DOE's implementation 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.

The Columbia River, one of the largest rivers in North America, is a critical resource for the people and ecology of the Pacific Northwest. Its waters support a multitude of uses that are vital to the economic and environmental well being of the region. Because of the importance of the Columbia River, cleanup actions must protect the river, as emphasized in Table 1-1.

Remedial actions for waste sites in the River Corridor are expected to restore groundwater to drinking water standards (DWSs) and ensure that the aquatic life in the Columbia River is protected by achieving ambient water quality standards where aquatic biota are exposed at groundwater discharge points to the river. These objectives will be achieved within a reasonable time considering site conditions. In instances where remedial action objectives (RAOs) are not achievable in a reasonable time, or are determined to be technically impracticable, programs will be implemented to prevent further migration of and exposure to contaminated groundwater, and evaluate further risk reduction opportunities as new technologies become available.

Current River Corridor cleanup work is progressing based on existing interim RODs. A primary objective of this work has been to remove potential sources of contamination that are close to the Columbia River to the Central Plateau for final disposal. Interim actions have also been taking place to address groundwater contamination. A part of the Cleanup Completion Framework (DOE/RL-2009-10) is to continue addressing contamination in the River Corridor in order 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.

The River Corridor has been divided into six geographic decision areas to achieve final source and groundwater OU remedy decisions including the 300 Decision Area. These final decisions will provide comprehensive coverage for all areas within the River Corridor and will incorporate interim action cleanup activities into final cleanup decisions. At the conclusion of cleanup actions, the federal government will retain ownership of land in the 300 Decision Area unless land transfers with deed restriction for some portions of the land occurs and will implement long-term stewardship activities to ensure protection of HHE.

Much of the waste site remediation has already been accomplished through the interim remedial actions. All waste sites are reevaluated in this report (see Chapter 4) to confirm whether interim closed-out waste sites have been adequately addressed, or if additional information and/or remediation are needed. Final remedial action decisions for all waste sites will be contained in the RODs.

The RI/FS for the 300 Decision Area was conducted in accordance with the *300 Area Decision Unit Remedial Investigation/Feasibility Study Work Plan* (hereinafter called the 300 Area RI/FS Work Plan [DOE/RL-2009-30]). In addition, the RI/FS was conducted in accordance with the *300 Area Remedial Investigation/Feasibility Study Sampling and Analysis Plan for the 300-FF-1, 300-FF-2 and 300-FF-5 Operable Units* (hereinafter called the 300 Area SAP [DOE/RL-2009-45]). Data and analyses from the previous investigations listed in Section 1.2.3 are also utilized in this report.

This introduction describes the purpose and scope of this RI/FS Report and summarizes background information on the 300 Decision Area, including a site description and history, previous investigation and remediation activities, regulatory basis and history, and current and anticipated future land use. Chapters 1 through 7 contain the RI sections, and Chapters 8 through 10 contain the FS sections, as follows:

- Chapter 1—Purpose and Scope, Background, and History
- Chapter 2—RI Activities and Field Activity Documentation
- Chapter 3—Physical Characteristics of the 300 Area
- Chapter 4—Nature and Extent of Contamination in the 300 Area
- Chapter 5—Contaminant Fate and Transport
- Chapter 6—Human Health Risk Assessment
- Chapter 7—Ecological Risk Assessment
- Chapter 8—RAOs and Identification and Screening of Remediation Technologies
- Chapter 9—Development and Screening of Remedial Action Alternatives
- Chapter 10—Detailed analysis of Remedial Action Alternatives for the 300 Area
- Chapter 11—References

This RI/FS includes extensive data used to perform calculations and assessments. Due to the volume of this information (e.g., laboratory analytical data and risk calculations), summaries of data are provided in this document and appendices, and "clickable" links on electronic media may be used to access more detailed information contained in particular studies, databases, or reports found in the Administrative Record (AR). The following appendices are included:

- Appendix A—300 Area Maps
- Appendix B—Description and Brief History of 300 Area Waste Sites and Facilities
- Appendix C—Geophysical Logs
- Appendix D—Analytical Data
- Appendix E—Nature and Extent Supporting Information
- Appendix F—Fate and Transport Modeling Documentation
- Appendix G—Human Health Risk Assessment Tables and Calculation Briefs
- Appendix H—Ecological Risk Assessment Calculation Brief
- Appendix I—Alternatives for Evaluated Waste Sites
- Appendix J—Technology Screening—Not Retained Technologies
- Appendix K—Cost Estimates
- Appendix L—Non-Operational Areas
- Appendix M—Riparian Area
- Appendix N—Previous Investigations

1.1 Purpose and Scope of Report

This section summarizes the regulatory process driving the investigation and remediation of waste sites and groundwater in the 300 Decision Area. The report does not include detailed discussions of the deactivation, decommission, decontamination, and demolition (D4) of buildings and facilities conducted under CERCLA removal actions. The purpose of this report is to support final remedy selection under CERCLA for the 300-FF-1, 300-FF-2 and 300-FF-5 OUs in the 300 Decision Area. The RI/FS process is outlined in EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (hereinafter called CERCLA RI/FS Guidance [EPA/540/G-89/004]) and DOE's *Remedial Investigation/Feasibility Study (RI/FS) Process, Elements and Techniques* (DOE/EH-94007658). The RI/FS process represents the methodology that the *Superfund Amendments and Reauthorization Act of 1986* program has established for characterizing the nature and extent of risks posed by uncontrolled hazardous waste sites and for evaluating potential remedial options. This approach is a dynamic, flexible process that is tailored to specific circumstances of individual sites; it is not a rigid, step-by-step approach that must be conducted identically at every site.

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

The objectives of an RI/FS are as follows:

- Provide information concerning the physical and environmental setting and site characterization.
- Draw conclusions concerning the types and quantities of contamination present at the site, the potential for contamination to migrate from the site, and the potential for adverse effects to HHE if no action is taken at the site and exposure occurs. This is achieved by evaluating the following:
  - Historical and operational information about the site
  - Contaminants of potential concern (COPCs)
  - Potential migration pathways
  - Potential receptors
  - Exposure (dose)
  - Contaminant toxicity
- Develop and evaluate an appropriate range of remedial action alternatives for the site, based on unacceptable risk to HHE.

A substantial body of information has been developed pertaining to contamination in the 300 Decision Area and potential threats to HHE that may result if exposure to contaminants occurred. The references section (Chapter 11) identifies documents used in this report. Many of these documents are available in the AR, and electronic links have been provided where possible.

EPA is the lead regulatory agency for the 300-FF-1, 300-FF-2, and 300-FF-5 OUs, and has the responsibility for overseeing all remedial actions to ensure they meet applicable requirements. DOE is responsible for performing all remedial actions within the 300 Decision Area. DOE has completed its RI/FS for the 300 Decision Area and is issuing it as a component of CERCLA and the "National Oil and Hazardous Substances Pollution Contingency Plan" (hereinafter called National Contingency Plan or NCP [40 CFR 300]). This report also fulfills DOE's responsibility to assess *National Environmental Policy Act of 1969* (NEPA) values when evaluating CERCLA remedial actions. DOE will issue a

Proposed Plan detailing the proposed remedy for comment by Tribal Nations and the public. EPA and DOE will issue a ROD for the 300 Decision Area, which will include responses to the comments received as well as the final remedies. After the ROD is issued, a remedial design/remedial action work plan (RD/RAWP) will be developed, approved, and implemented. Figure 1-3 summarizes the CERCLA decision process.

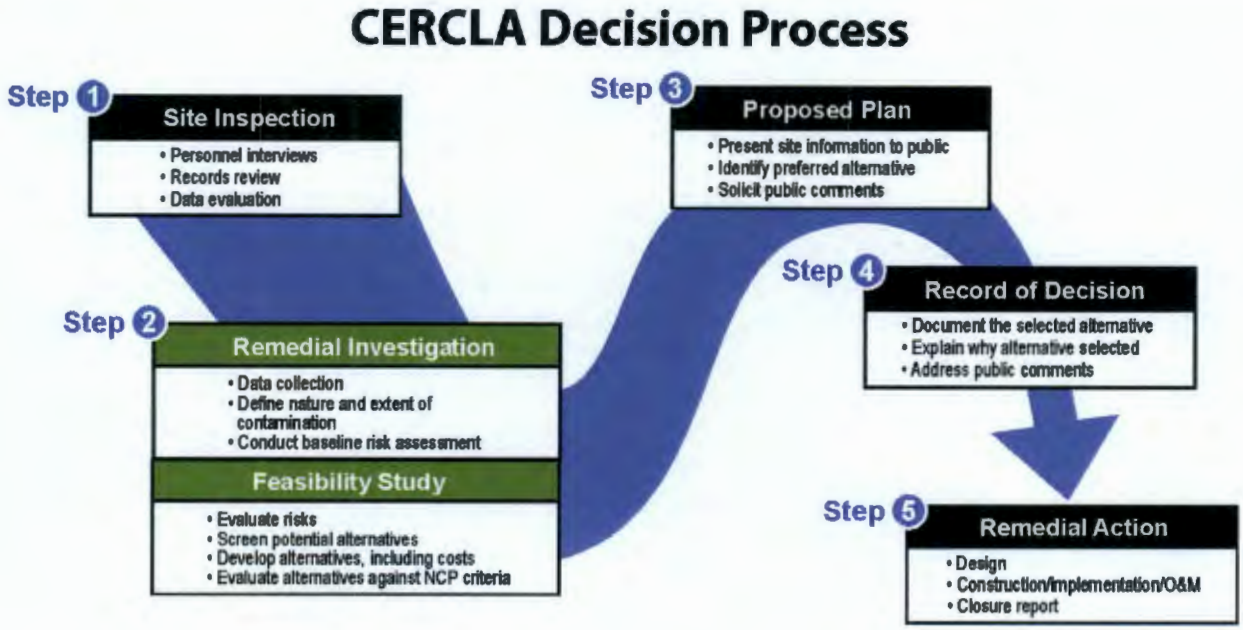
The conceptual site model (CSM) will be used in this RI/FS Report to present what is known about the 300 Decision Area. The *Standard Guide for Developing Conceptual Site Models for Contaminated Sites* (ASTM E1689-95) defines the CSM as "a written or pictorial of an environmental system and the biological, physical, and chemical processes that determine the transport of contaminants from sources through environmental media to environmental receptors within the system." For the 300 Area RI/FS Work Plan (DOE/RL-2009-30), the CSM was used as a base to integrate relevant site information, to determine whether information including data were missing (data gaps), and to identify additional information to be collected. In Chapters 2 through 7 of this report, the CSM is refined with additional information and then used to identify and evaluate potential risk to HHE. Figure 1-4 is a representation of the basic activities associated with a CSM.

For an exposure pathway to be complete, all of the following components must be present:

- "Source" is the location from which a contaminant has entered the physical setting. The primary source of contaminants was releases and effluents related to fuel fabrication operations. Chapter 1 describes the primary sources. A secondary source is created when the contaminants are then mixed in the vadose zone and then the groundwater. Operations that caused contamination within the 300 Area have ceased; therefore, this document focuses on secondary sources of contaminants in the vadose zone and groundwater and potential risk to HHE. Chapter 4 describes these secondary sources.

- "Release Mechanisms" are the potential to release contamination to the environment through resuspension of particulate matter, surface runoff, vadose zone leaching, plant intrusion, animal burrowing, erosion, or groundwater migration. Chapter 5 discusses release mechanisms and relevant 300 Decision Area physical features (introduced in Chapter 3).

- "Transport" is movement of a chemical or physical agent in the environment from a secondary source to an environmental medium, or via a food chain. Contaminants introduced into the environment can flow between different environmental media such as air, vadose zone, groundwater, and surface water due to interconnecting release mechanisms. Chapter 5 discusses transport.



Step 1. Site Inspection—Includes interviewing site personnel regarding the history of the site, reviewing waste disposal records, and evaluating existing data.

Step 2. Remedial Investigation/Feasibility Study—Topics of the combined segments are:

- **Remedial Investigation**—Consists of an environmental study to identify the nature and extent of contamination and a preliminary evaluation of the risk posed to human health and the environment.
- **Feasibility Study**—Includes the details of a remedial alternative evaluation and identifies PRGs.

Step 3. Proposed Plan—Based on previous field investigations and reports that are completed in the first two steps of the CERCLA process, the Proposed Plan summarizes the remedial alternative evaluations and presents the preferred alternative for comments.

Step 4. Record of Decision—Formally documents the cleanup alternative that was selected after DOE and EPA have reviewed and responded to comments on the Proposed Plan.

Step 5. Remedial Action—Consists of the actual cleanup activities being performed. When cleanup is completed, a final report is written that describes the remedial actions implemented, the result of the actions, and the conclusion of the CERCLA process.

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Figure 1-3. The CERCLA Remedial Action Decision Process

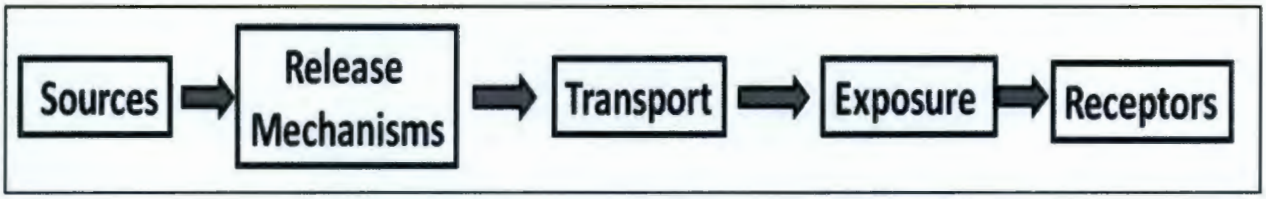

Figure 1-4. Basic Components of Conceptual Site Model

- "Exposure" is the process where a contaminant or physical agent in the environment comes into direct contact with the body, tissues, or exchange boundaries of a receptor organism (e.g., ingestion, inhalation, dermal absorption, or root uptake). Contaminant movement away from a secondary source to a potential receptor is called a pathway. An exposure point is located where a receptor could encounter a contaminant in an environmental medium. Chapters 6 and 7 discuss potential exposure scenarios.

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

In Chapters 8 through 10, the refined CSM helps facilitate the selection of remedial alternatives and evaluate the effectiveness of remedial actions in interrupting the exposure pathways of contaminants to human and environmental receptors. The CSM presented in this report provides the basis for the proposed remedial alternatives presented and screened in Chapter 9, and will facilitate DOE and EPA decision-making (together with public participation) regarding the design and implementation of appropriate long-term remedial actions for the 300 Decision Area.

The identification of data needs in the 300 Area RI/FS Work Plan (DOE/RL-2009-30) led to development of a sampling and analysis plan (SAP) that established characterization activities specific to the 300 Decision Area (300 Area SAP [DOE/RL-2009-45]). The 300 Area SAP (DOE/RL-2009-45) includes a Field Sampling Plan that provides the sampling strategy and techniques used to obtain the supplemental data required for the RI/FS. The 300 Area SAP (DOE/RL-2009-45) also provides a quality assurance project plan (QAPjP) to ensure that data collected meet the appropriate quality assurance (QA) and quality control (QC) requirements. Once the RI activities have filled the CSM data needs, the FS process is used to assemble various combinations of technologies into remedial action alternatives that address the contamination in the various media at the 300 Decision Area (CERCLA RI/FS Guidance [EPA/540/G-89/004]).

1.2 Site Background

The Hanford Site encompasses approximately 1,517 km^2 (586 mi^2) in Benton, Franklin, and Grant Counties, located in south-central Washington State within the semi-arid Pasco Basin of the Columbia Plateau. The Site stretches approximately 50 km (30 mi) north to south and about 40 km (24 mi) east to west, immediately north-northwest of the confluence of the Yakima and Columbia Rivers, the Cities of Kennewick, Pasco, and Richland (the Tri-Cities), and the city of West Richland. The Columbia River flows 80 km (50 mi) through the northern part of the Hanford Site and, turning south, forms part of the Site's eastern boundary. The Yakima River runs near the southern boundary of the Hanford Site, joining the Columbia River at the City of Richland. Rattlesnake Mountain, Yakima Ridge, and Umtanum Ridge form the southwestern and western boundaries of the Site, and Saddle Mountain forms its northern boundary. Two small east-west ridges, Gable Butte and Gable Mountain, punctuate the plateau of the central portion of the Hanford Site. Lands adjoining the Site to the west, north, and east are principally range and agricultural. State Routes 240, 243, and 24 skirt the southwestern and northern portions of the Site.

The Hanford Site area is culturally rich, experiencing a history of multiple occupations. For thousands of years, Native American peoples have inhabited the lands both within and around the Hanford Site (*Tribal Distribution in Washington* [Spier, 1936]; and *Handbook of North American Indians: Volume 12, Plateau* [Walker and Sturtevant, 1998]). Settler presence in the mid-Columbia Plateau began in 1805 with the arrival of the Lewis and Clark Expedition along the Columbia and Snake Rivers. In the late 19th and early 20th centuries, intensive settlement on the Hanford Site established an early settler and farming landscape.

Farmstead communities existed from 1880 to 1943, located primarily in the upland environment adjacent to the Columbia River. The area became one of the premier orchard regions in the state following formation of the Hanford Irrigation and Development Company in 1905. The farming life came to an abrupt halt in 1943 when the U.S. government took possession of the land to produce weapons-grade plutonium as a part of the Manhattan Project. Although orchard lands were prevalent along the river, none existed within the 300 Decision Area.

The Hanford Site is divided into numerically designated areas. These areas served as the location for reactor, chemical separation, and related activities for the production and purification of special nuclear materials and other nuclear activities. The reactors and their ancillary/support facilities were located along the south shore of the Columbia River in the 100 Area because of the need for large quantities of water to dissipate the heat generated during reactor operations. The 200 Area, located about 11 km (7 mi) from the Columbia River, contained all the facilities used to separate, isolate, store, and ship the plutonium.

1.3 Site Description

This section provides a brief overview of the 300 Decision Area, describes the background and history of the 300 Decision Area, and includes information on the processes, activities, and incidents that have the potential to introduce contaminants into the environment. Information in this section was obtained primarily from the following sources:

- *Compilation of Historical Information of 300 Area Facilities and Activities* (hereinafter called the 300 Area Historical Compilation [WHC-MR-0388])
- *Data Compilation Task Report for the Source Investigation of the 300-FF-1 Operable Unit Phase I Remedial Investigation* (PNL-7241)
- *Addendum to Data Compilation Task Report for the Source Investigation of the 300-FF-1 Operable Unit Phase I Remedial Investigations* (hereinafter called the 300-FF-1 Data Compilation Addendum [EMO-1026])
- *300-FF-2 Operable Unit Technical Baseline Report* (hereinafter called the Technical Baseline Report [BHI-00012])
- *History of the Plutonium Production Facilities at the Hanford Site Historic District, 1943-1990* (hereinafter called the Hanford Plutonium Facilities History [DOE/RL-97-1047])
- Other contemporary sources documenting interim remedial actions (e.g., WIDS)

The 300 Decision Area is located in the southeastern portion of the Hanford Site and accounts for about 145.9 km^2 (56.35 mi^2) of the total area. The 300 Decision Area extends from north of Energy Northwest to south of the 300 Area Industrial Complex, and from the west bank of the Columbia River west to Hanford Route 10 (Figure 1-2). The 300 Area Industrial Complex consists of the buildings, facilities, and process units located north of Richland, Washington, where the vast majority of uranium fuel production and R&D activities took place. The 400 Area is located about 8 km (5 mi) northwest of the 300 Area Industrial Complex and about 6 km (4 mi) from the Columbia River. The 400 Area consists of about 55 ha (135 ac) and contains the FFTF Reactor and its support facilities. The 600 Area is tied to the waste management practices conducted in the 300 Area Industrial Complex and includes several burial grounds (e.g., 618-10 and 618-11) as well as other waste disposal sites (e.g., 316-4 Crib) not categorized as being within the 300 Area Industrial Complex or 400 Area, plus the groundwater associated with the waste sites. The non-operational areas, large areas of historically unused land, generally have no waste sites or facilities.

Areas and activities outside the 300 Decision Area boundary (see Figure 1-2) are outside the scope of this document. For example, along the southern border of the 300 Decision Area is the 1100 Area, which contained the central warehousing, vehicle maintenance, and transportation distribution center for the Hanford Site. The 1100 Area waste sites were removed from the NPL in 1996 ("National Oil and Hazardous Substances Pollution Contingency Plan; National Priorities List Update" [61 FR 51019]).

For groundwater in the 1100 Area (i.e., the 1100-EM-1 OU), the selected remedy, as described in *Record of Decision for the USDOE Hanford 1100 Area Final Remedial Action* (EPA/ROD/R10-93/063), included the following actions:

- Capping the Horn Rapids Landfill
- Offsite disposal of soil contaminated with polychlorinated biphenyls (PCBs)
- Offsite incineration of soils contaminated with bis(2-ethylhexyl)phthalate
- Natural attenuation of groundwater that currently exceeds maximum contaminant levels (MCLs) and monitoring for compliance
- Continuation of institutional controls (ICs) for groundwater and land use at the Horn Rapids Landfill
- The technical basis for this ROD is provided in *Draft Remedial Investigation/Feasibility Study for the 1100-EM-1 Operable Unit, Hanford* (DOE/RL-92-67). Implementation of the remedy is described in *Sampling and Analysis Plan Update for Groundwater Monitoring – 1100-EM-1 Operable Unit* (PNNL-12220).

In addition, several Hanford special purpose industrial areas and facilities within the 300 Decision Area boundary are also outside the scope of this document, such as:

- Hanford Patrol Academy, including the firing range
- FFTF reactor and associated facilities
- Energy Northwest including Bonneville Power Administration facilities and related waste sites (600-58, 600-59, 600-60, and 600-62)
- HAMMER Training Facility

Waste sites and associated releases from the 300 Area active facilities are addressed in this RI/FS. Any future releases from these facilities will either be addressed immediately as part of spill response or if needed, be added to the ROD and the RD/RAWP for eventual remediation. Facility decontamination and decommissioning will be accomplished by future removal actions.

For remediation purposes, the 300 Decision Area was divided into two source OUs and one groundwater OU. The 300-FF-1 OU contains source areas associated with facilities and waste sites mainly represented by the former North Process Pond, South Process Pond, and 300 Area Process Trenches. The remediation activities specified in the 300-FF-1 and 300-FF-5 ROD (EPA/ROD/R10-96/143) are complete; however, residual uranium contamination beneath certain 300-FF-1 OU waste sites (i.e., 316-1. 316-2, and 316-5) continues to pose a threat to groundwater. The 300-FF-2 OU contains source areas associated with facilities and waste sites within the 300 Area Industrial Complex, the 400 Area, and the 618-10 Burial Grounds/316-4 Crib and 618-11 Burial Ground subregions. The source OUs address source contamination associated with liquid, solid, and UPR waste sites.

The 300-FF-5 Groundwater OU comprises the groundwater at the 300 Area affected by contaminant releases from the 300 Decision Area source OUs. Although the 200-PO-1 groundwater OU underlies part of the 300 Decision Area, it is not within the scope of this document and will have a separate decision.

1.3.1 Site History

The following subsections present historical information related to 300 Area Industrial Complex operations and processes, the 618-10 Burial Grounds/316-4 Crib Subregion, the 618-11 Burial Ground subregion, and the 400 Area, which focuses on the FFTF and its associated facilities. This information provides understanding of the source element aspect of the CSM.

300 Area Industrial Complex Operation and Process History. Construction of the initial fuel fabrication facilities and associated support facilities within the 300 Area Industrial Complex was completed in 1943 (*Remedial Investigation/Feasibility Study Work Plan for the 300-FF-1 Operable Unit, Hanford Site, Richland, Washington*, hereinafter called the 300-FF-1 OU RI/FS Work Plan [DOE/RL-88-31]). The operational history of the 300 Area, like much of the Hanford Site, evolved and transformed as the Hanford Site mission changed. Figure 1-5 is a photograph taken in 1976 that illustrates the facilities and waste sites, mainly represented by the former North Process Pond (316-1), South Process Pond (316-2), and 300 Area Process Trenches (316-5), where large volumes of liquid waste containing uranium were discharged. The following subsections describe the operational history of the 300 Area during select periods that make up its varied missions:

- Initial fuel manufacturing during World War II (1943 to 1945)
- Cold War buildup and production (1946 to 1987)
- N Reactor buildup and production (1960 to 1989)
- Liquid Effluent Discharge History (1943 to 2010)
- R&D (1943 to 1987)
- Ongoing research by Pacific Northwest National Laboratory (PNNL) and ongoing operations by other Hanford Site contractors (1989 to present)

Appendix B provides additional information for the facilities in the 300 Area and provides a summary of historical operations for each of the key 300 Area Buildings and high volume liquid waste disposal sites.

Initial Fuel Manufacturing during World War II (1943 to 1945). Between 1943 and the end of World War II, over 30 Manhattan Engineering District mission structures were built in the 300 Area. The fuel fabrication process employed at the Hanford Site was for the manufacturing of plutonium for defense purposes (*The Plutonium Production Story at the Hanford Site: Processes and Facilities History*, hereinafter called the Plutonium Production Story [WHC-MR-0521]). Uranium fuel elements for the single-pass reactors were the heart of the plutonium production process. Manufacturing of the fuel elements was the first step in the process, which began in the 300 Area (Hanford Plutonium Facilities History [DOE/RL-97-1047]). Fuel fabrication was conducted primarily in the 313 Metal Fabrication and 314 Press Buildings. Uranium metal arrived as ingots and was cut and lathed into billets in the 314 Building. The billets were cropped, extruded into rods, straightened, and out-gassed in the 314 Building. The rods were then sent to the 313 Building for jacketing or canning (encapsulated in protective cladding). Encapsulation was necessary to conduct heat from the uranium rods to the circulated coolant water in the nuclear reactors in order to avoid overheating. The jackets prevented the release of highly radioactive fission products to the cooling water and prevented uranium metal corrosion by direct contact with water.

Figure 1-5. 300 Area Industrial Complex (June 1976)

Because of issues with the early "whiz-bang" method, thousands of rejected cores had been produced by mid-1944. The Manhattan Engineer District's concern over the adequacy of uranium supplies brought strict policies that mandated the reclamation of all possible uranium scraps at federal atomic sites. For that reason, the rejected fuel rods were washed in nitric acid (later nitric/hydrofluoric acid) and reused. The acid sludges were collected in a dumpster just north of the 314 Building and allowed to evaporate and/or overflow into the surrounding soils (300 Area Historical Compilation [WHC-MR-0388]).

Cold War Build-up and Production (1946 to 1987). International events associated with the intensification of the Cold War during the late 1940s to early 1950s increased allocations to national defense and expansion of America's nuclear weapons program. This translated into a dramatic expansion of facilities at all Atomic Energy Commission sites, including a substantial increase in plutonium production and construction/modification of plutonium production structures at the Hanford Site (Hanford Plutonium Facilities History [DOE/RL-97-1047]). Some of the implemented changes were meant to improve the process, some were meant to increase plutonium production, and others were meant to use the fuel manufacturing materials more economically (Hanford Plutonium Facilities History [DOE/RL-97-1047]). In 1948, the extrusion press in the 314 Building was excessed, and it began receiving rolled uranium rods from an offsite commercial mill. The rolling process seemed to offer metallurgical advantages because the uranium could be processed at lower temperatures, which induced less oxidization and produced smaller and more random grains within the metal (Plutonium Production Story [WHC-MR-0521]).

Because of the significant fuel manufacturing increase during this period, the amount of process effluent also significantly increased. To handle the increase of effluent, several facilities were expanded and new facilities were built. In 1948, a rupture of the South Process Pond's (316-1) northern dike released an estimated 5 to 28 kg (12 to 61 lb) of uranium contained in 54,900,000 L (14.5 million gal) of process waste contaminated effluent to the Columbia River. This release prompted the construction of the North Process Pond (316-2) (300 Area Historical Compilation [WCH-MR-0388]).

After the repair of the South Process Pond (316-1), both ponds received from 1,514,000 to 11,360,000 L/day (400,000 to 3,000,000 gal/day) from the fuel fabrication facilities until 1974 or 1975, when they were taken out of service. Other facilities built to handle the increase included the 307 Disposal Trenches (316-3), 300 Area Process Trenches (316-5), and several other sites throughout the 300 Area Industrial Complex. Appendix B contains information about the Cold War build-up and production period that is more detailed.

N Reactor Buildup and Production (1960 to 1989). The co-extrusion process, or the N Reactor fuel manufacturing process, was developed in the early 1960s to accommodate the fuel needs of the N Reactor, which used slightly enriched uranium fuel. The fuel was a tube-in-tube design consisting of a metallic uranium fuel element surrounded by a thin zircaloy-2 (an alloy of zirconium with nickel, tin, chromium, and iron). The co-extrusion process was developed in the 306 Metal Fabrication Development Laboratory and implemented in the 333 Fuel Fabrication Building (Hanford Plutonium Facilities History [DOE/RL-97-1047]). The 306 Building was built in 1956 with the initial mission to support 313 Building operations and pilot process improvements in the single-pass reactors and operating components. In 1960, an extension was added to the 306 Building to support the co-extrusion fabrication process. In 1972, the 306 Building was split into 306 East and 306 West. The mission of the 306 Building remained focused on fabrication and test development work during its operational history.

From 1965 to 1967, a co-product demonstration campaign in which tritium was produced in the reactor from special lithium aluminate fuel elements took place at N Reactor (Plutonium Production Story [WHC-MR-0521]). The tritium fuel assemblies consisted of an outer, or driver, fuel element manufactured in the 333 Building, and an inner target element made in the 3722 Area Shop. Instead of uranium, the inner target elements contained lithium aluminate, a ceramic material. Lithium aluminate powder was formed into a solid through a sintering[1] process, which used heat and pressure to fuse the material into a pellet. The pellets were then placed into an aluminum can clad in zircaloy-2, which replaced the usual inner tube of the standard fuel assembly. During this same period (1965 to 1967), the 333 Building performed autoclave testing, final etching with nitric-hydrofluoric acid, and inspection of the special lithium aluminate fuel targets made in the 3722 Building. Highly enriched (2.1 percent uranium-235) uranium driver fuel elements for tritium programs also were made in the 333 Building from 1965 to 1970. In 1973, the Waste Acid Treatment System (WATS) began operating to treat uranium bearing waste acids from 333 Building operations.

The N Reactor continued to operate until 1986, when it was placed in stand down (Plutonium Production Story [WHC-MR-0521]). However, the fabrication of standard zircaloy-2 clad, uranium fuel elements for N Reactor, along with standard inspections of such elements before irradiation, continued in the 333 Building until 1987. Between 1987 and 1989, the 333 Building received upgrades and modifications in preparation for fabrication of tritium driver fuel elements for N Reactor, but the shutdown of N Reactor precluded implementation of this program.

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[1] Thermal treatment of a powder or compaction, at a temperature below the melting point of the main constituent, is used to increase its strength by the metallurgical bonding of its particles. Information is available at: https://cdb.iso.org/cdb/termentry!display.action?entry=36018&language=1.

Liquid Effluent Discharge History (1943 to 2010). Over the history of the 300 Area Industrial Complex, liquid wastes consisting of process wastes, sanitary wastes, and various radiochemical and radiometallurgical process waste were generated by fuel fabrication and research laboratories activities. These wastes were disposed of in four sewer systems: the sanitary sewer, the process sewer, an early radioactive liquid waste sewer (which was retired and replaced with a newer radioactive liquid waste sewer), and the Retention Process Sewer (RPS) (*Remedial Investigation/Feasibility Study Work Plan for the 300-FF-2 Operable Unit* [DOE/RL-94-38]).

The original 300 Area Industrial Complex Sanitary Sewer System (300 SSS) built during World War II by the Manhattan Engineering District was designated as the 3903 system (300 Area Historical Compilation [WHC-MR-0388]). It consisted of vitrified clay sanitary sewer pipes, which serviced all existing 300 Area buildings and included one process line from the 313 Building. The system fed into a large septic tank near the northeast edge of the 300 Area Industrial Complex, and connected to a tile field for percolating liquid to the soil. In 1947, a failure in the original system was caused by overuse and plugging, and uranium contamination was found in the sanitary sewer sludge and water. These contaminants entered the system via the hair, shoes, hands, and clothing of workers who used the 300 Area change houses (300 Area Historical Compilation [WHC-MR-0388]). To increase capacity in 1947, a new tile field, overflow ditch, and connecting ditch were excavated 61 m (200 ft) from the Columbia River. Figure 1-6 shows the configuration of the original 300 Area Sanitary Sewer Disposal System.

As the number of facilities increased in the 300 Area Industrial Complex during the postwar expansion, the 30 SSS became inadequate. The system was expanded again in 1951 with the addition of two septic tanks and north and south leaching trenches to replace the old tile field. This system remained in service through 1996 when the300 SSS was tied in with the Richland city municipal water treatment system.

The Process Sewer System (300-15), which was built in 1943 by the Manhattan Engineering District and du Pont de Nemours, Inc. during World War II, receive cooling water and low level liquid waste from 300 Area facilities and transferred the waste to various disposal facilities over time, for example the following:

- 316-10–South Process Ponds (1943)
- 316-2–North Process Pond (1948)
- 307 Disposal Trenches (1953)
- 316–5 300 Area Process Trenches (1975)
- 310 Treated Effluent Disposal Facility (TEDF) (1994)

The 300 Area Process Sewer System is extensive, with outside lines estimated at 10 km (6 mi) and interior building waste pipes estimated at 40 km (25 mi). The original system was 20 cm (8 in.) vitrified clay pipes with acid proof joints connecting the buildings to an 46 cm (18 in.) diameter vitrified clay pipe with acid proof joints. However, the 321 Building was connected via a combination of 8 cm (3 in.) stainless steel pipes, 20 cm (8 in.) wrought iron pipes, and 15 cm (6 in.) earthenware pipes (300 Area Historical Compilation [WHC-MR-0388]). Historical flow rates were measured between 3,000 and 4,500 L/min (800 and 1,200 gal/min) with an average rate of 3,520 L/min (930 gal/min) (Technical Baseline Report [BHI-00012]).

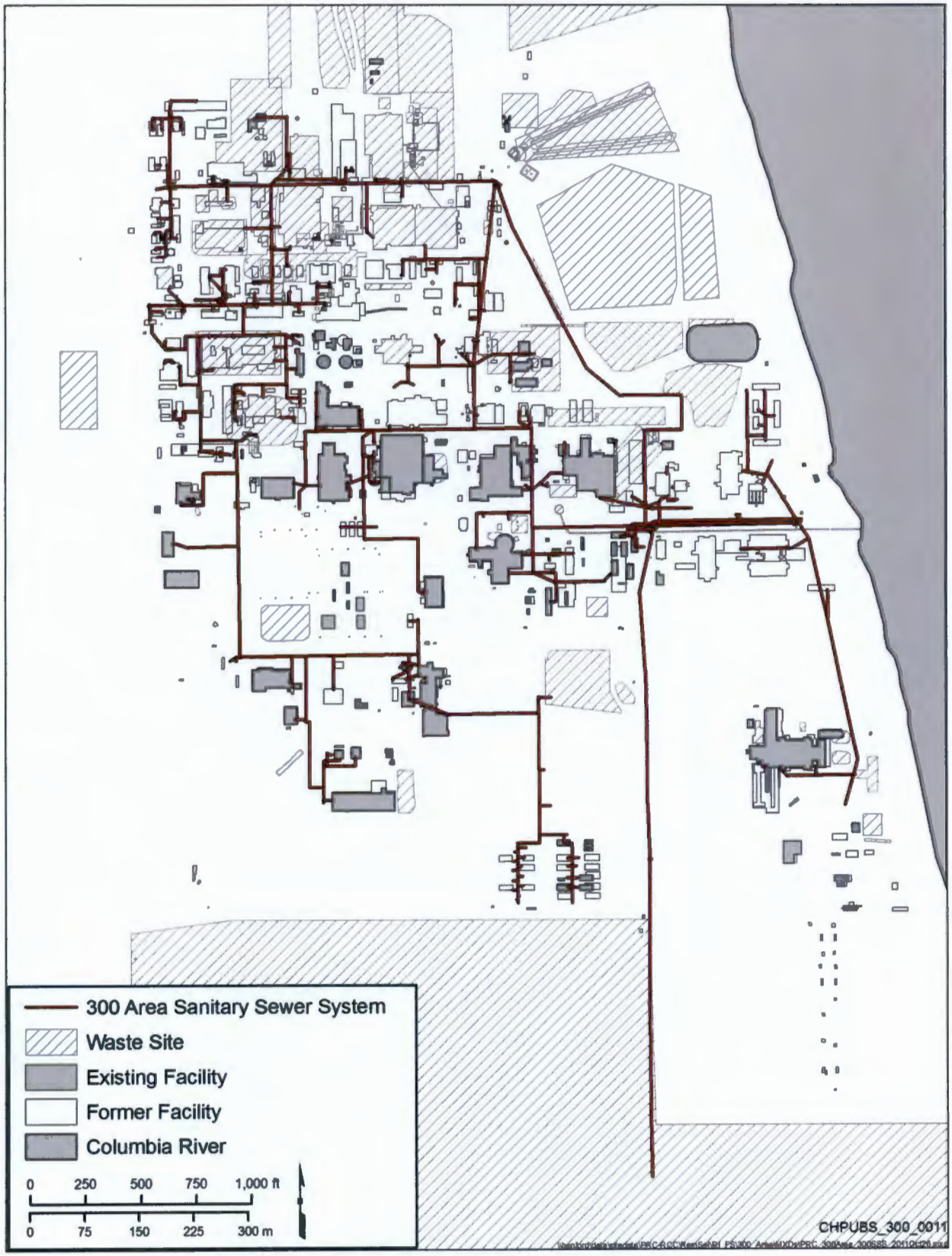


Figure 1-6 Layout of Original 300 Area Sanitary Sewer System

When the Process Sewer System (300-15) was first built (Figure 1-6), all liquid effluent was discharged in desegregated form into the South Process Pond (316-1) (300 Area Historical Compilation [WHC-MR-0388]). In 1948, after the South Pond overflowed, the system was expanded to make use of the newly built North Process Pond (316-2). The system was modified in 1953 to allow for either simultaneous or alternating use of the North and South Process Ponds, and extended again in 1975 to transfer waste to the Process Trenches (316-5) after closing the two ponds (300-FF-1 OU RI/FS Work Plan [DOE/RL-88-31]). The portion of the Process Sewer that served the North and South Process Ponds was retired (i.e., abandoned in place) in 1975 (DOE/RL-96-42, Draft A), while the portion of the process sewer that served the process trenches was retired in 1994. The 300-15 was diverted once again in 1994 to the 342 Lift Station that pumped to the 310 TEDF. The original 300-15 pipelines remained in use except for a number of connections isolated and abandoned between 1990 and 1994 for the planned diversion to the 310 TEDF. Many facilities were disconnected from the 300-15 (and 300 SSS) during this period. Figure 1-7 shows the configuration of the 300-15 Process Sewer System.

The 300 RPS and the 300 Area Radioactive Liquid Waste System (300 RLWS) were built to relieve pressure on the South and North Process Ponds. Additionally, the 300 RPS and 300 RLWS were built to provide a means to dispose of potentially contaminated retention waste liquids from the sumps, sinks, and drains of the new laboratories in a modern, controlled manner (300 Area Historical Compilation [WHC-MR-0388]). These two lines, along with the 340 Complex, 307 Process Trenches, and 307 Retention Basin (307 RB) were constructed to support the large defense production expansion and construction of the 325, 326, 327, and 329 Buildings between 1951 and 1953. Figure 1-8 shows the configuration of the 300 RPS and the 300 RLWS.

The 300 RPS was an underground carbon steel and polyvinyl chloride (PVC) pipeline that initially connected the 325, 326, 327, and 329 Laboratory Buildings, and later the 308 and 324 Buildings, to the 307 RB. In this system, liquid waste that had the potential to be contaminated was routed to the 307 Basins for sampling. If radioactivity was detected below specified limits, these wastes were disposed of in the 307 Trenches (DOE/RL-96-42, Draft A). When radioactivity exceeded the specified limits, the liquids were transferred to one of two 57,000 L (15,000 gal) collection tanks housed (in a 360,000 L [94,000 gal] containment pit below grade) in the 340 Building, then transferred to and hauled by tanker truck or rail car to the 200 Area for disposal, usually in cribs. The 300 RPS system operated independently of the Process Sewer (300-15) until 1963. At that time, the 307 Trenches were removed from service and the two systems were reintegrated, but RBs allow for the screening of wastes too high in radioactivity for final disposal in the North and South Process Ponds (300-FF-1 OU RI/FS Work Plan [DOE/RL-88-31]).

The original 300 RLWS (now called the 300 Area Retired Radioactive Liquid Waste Sewer System or 300 RRLWS) is a network of 5, 8, 10, and 15 cm (2, 3, 4, and 6 in.) single-walled stainless-steel pipe and carbon steel fittings buried between 3 and 6 m (10 and 20 ft) below grade. It is estimated that there are 1,250 m (4,000 ft) of pipe in this system (Technical Baseline Report [BHI-00012]). The 300 RRLWS collected radioactive liquids from the 325, 326, 327, 329, 308 and 309 Buildings and transferred the wastes to two 60,000 L (15,000 gal) storage tanks beneath the 340 Building, and to six 30,000 L (8,000 gal) aboveground stainless steel tanks in the 340-A Building (300-FF-1 OU RI/FS Work Plan [DOE/RL-88-31]). Radioactive wastes were then transported by tanker truck, and later by rail car, to the 200 Area disposal facilities. It is estimated that 300 RRLWS received 400,000 L/yr (100,000 gal/yr) of radioactive liquid waste from assorted facilities and laboratories in the 300 Area (Technical Baseline Report [BHI-00012]).

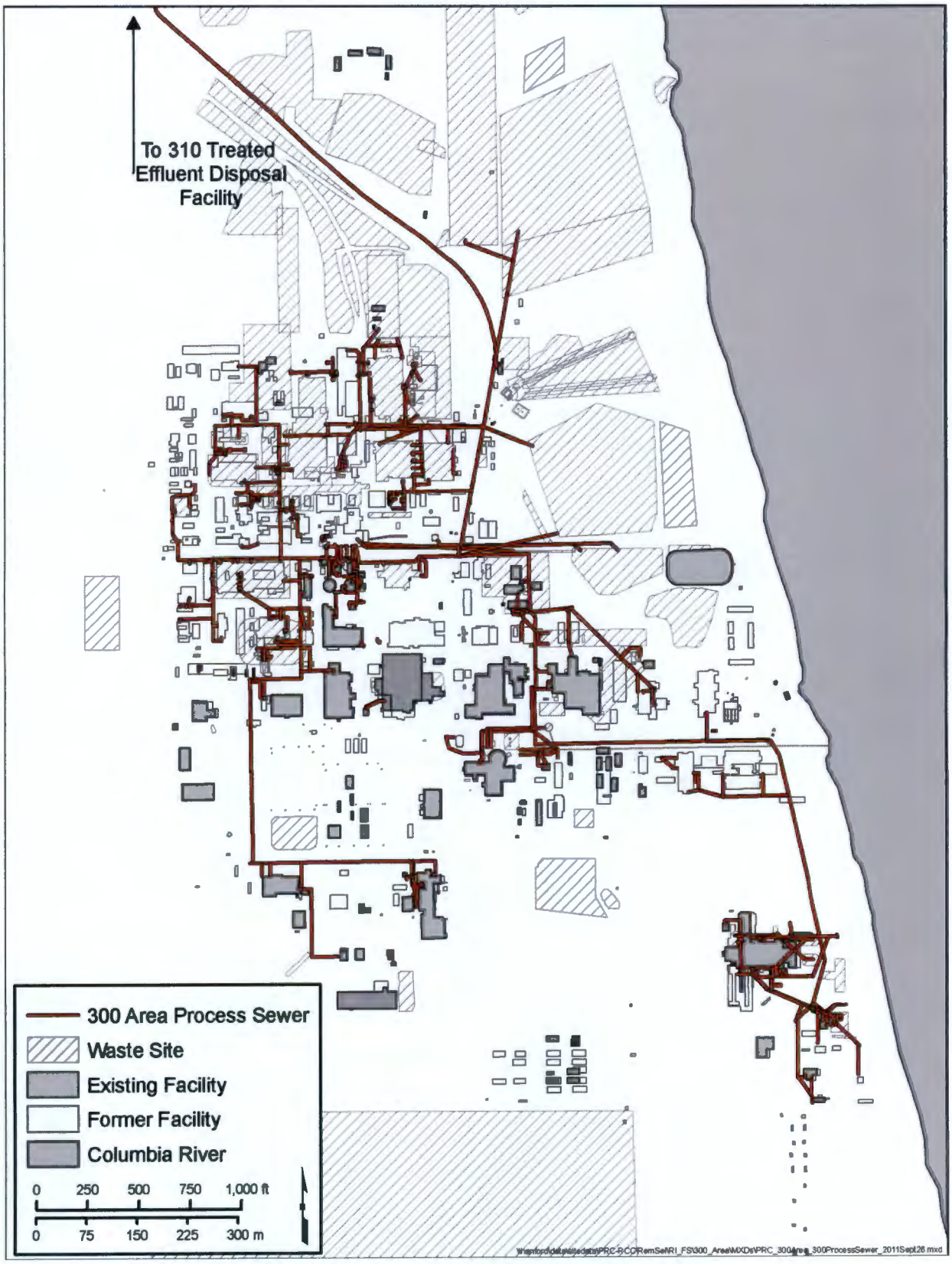


Figure 1-7. Layout of the 300-15 Process Sewer System

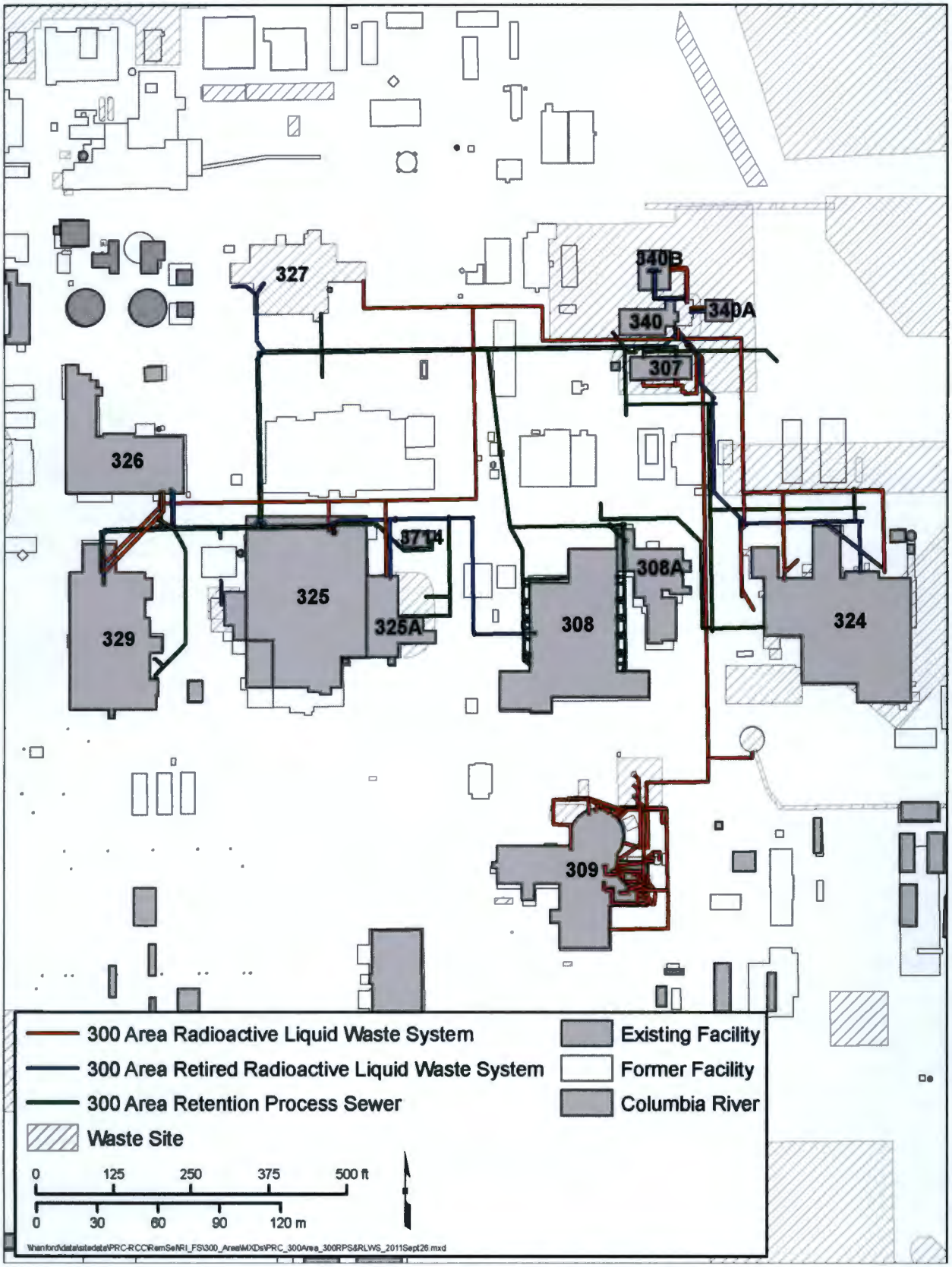


Figure 1-8. Layout of the 300 RPS and the 300 RLWS

In 1976, a leak test of the single-walled 300 RRLWS network demonstrated widespread leaks. The system was replaced with double-walled stainless steel pipes, a leak detection system, and other system upgrades. During the 1978 to 1979 replacement, contaminated soils surrounding the old network were removed, but the 300 RRLWS pipe was abandoned in place, along with local, low level radioactive contaminated soils (300 Area Historical Compilation [WHC-MR-0388]). The 300 RLWS continued to operate and transport radioactive liquid from 1979 until 1998, when it was isolated from the 340 Complex and generating facilities. Closing valves outside of each facility isolated the generating facilities. The 340 Vault tanks and the 340-A tanks were also valve-isolated from the 300 RLWS.

In 1970, the Atomic Energy Commission instituted an accelerated program to reduce radioactive discharges in every operation to the lowest practicable levels (Hanford Plutonium Facilities History [DOE/RL-97-1047]). As a result, the 300 WATS (300-224), was built and used to treat and store non-recoverable uranium-bearing waste acid from reactor fuel fabrication operations. This system was comprised of portions of four buildings and two tank farms connected by PVC pipes in a covered concrete pipe trench: the 334-A, 313, 303-F, and 333 Buildings, and the 334 and 311 Tank Farms (334 TF and 311 TF) (*300 Area Waste Acid Treatment System Closure Plan* [DOE/RL-90-11]). The 300-224 WATS operated for 4 months in 1973 and became operational in January 1975. The primary source of the waste acid was N Reactor fuel fabrication operations that occurred in the 333 Building from 1961 until 1987. Waste acids were stored in the 334 TF and transferred to the 313 Building for neutralization (*300 Area Waste Acid Treatment System Closure Plan* [DOE/RL-90-11]). After neutralization, the waste slurry was pumped to Tank 40 in the 311 TF for storage. Until 1985, the Tank 40 liquid waste was transported to the 183-H Solar Basins by tank trailer. From 1985 to 1988, neutralized waste acid underwent solids separation in the 313 Building by use of a filter and a centrifuge. The solids were contained in the building for later disposal in the 200 Area. The liquid continued to be sent to the 311 TF for storage; however, the effluent was taken to the 340-B Facility by tanker truck and eventually sent by rail car to the 200 Area Double-Shell Tank system for long-term storage. See the *300 Area Waste Acid Treatment System Closure Plan* (DOE/RL-90-11) for additional detailed information concerning WATS. Figure 1-9 provides a schematic of WATS.

The 310 TEDF was constructed as part of the TPA (Ecology et al., 1989a) milestone to cease discharges into the soil column. The facility began operation in December 1994 and continued to operate until 2010. The TEDF collected nonradioactive process wastewater that was discharged to the 300 Area Process Sewer (300-15) from about 45 office buildings, research laboratories, and other support facilities in the 300 Area. The facility removed metals and organic contaminants before the purified water is discharged to the Columbia River (*Removal Action Work Plan for 300 Area Facilities* [DOE/RL-2004-77])

Research and Development Prior to Cessation of Fuel Fabrication (1943 to 1987). As early as 1943, the 300 Area mission expanded to include several R&D activities for improving fuel fabrication processes, finding alternative nuclear fuel materials, developing commercial applications of nuclear energy, and conducting various research activities. Fuel fabrication research focused on improving fuel manufacturing processes and developing reuse methods, and research was dedicated to developing advanced encapsulation methods. During the 1950s and 1960s, peaceful uses of atomic energy were emphasized, such as in the Eisenhower Administration's Atoms for Peace program in 1953, and the *Atomic Energy Act of 1954* (AEA), which allowed atomic energy for commercial use. During this period, research was performed to extend and diversify the uranium fuel supply for commercial nuclear reactors with the oxide fuel blends fabrication. This research involved fabricating blended fuels from both plutonium and uranium oxides in combination with other mixed oxide materials. Fuel fabrication R&D activities occurred primarily in the following buildings. Appendix B includes more information surrounding the following facilities, as well as other buildings, that supported fuel fabrication R&D:

- 305-B Constants Test Reactor and Thermal Test Reactor
- 308 Plutonium Fabrication Pilot Plant
- 309 Plutonium Recycle Test Reactor (PRTR)
- 318 Building High-Temperature Lattice Test Reactor

In addition to R&D activities and fuel fabrication R&D activities, the 300 Area Industrial Complex played a major role in the pilot testing and development of the plutonium extraction methods used in the 200 Area. The following buildings performed R&D activities other than fuel fabrication R&D:

- 3706 Radiochemistry Laboratory
- 321 Separations Building
- 324 Chemical and Materials Engineering Laboratory
- 325-A High-Level Radiochemistry Annex
- 327 Radiometallurgy Building (Post Irradiation Testing Laboratory)
- 328 Engineering Service Building
- 329 Biophysics Laboratory

Research and Development by Pacific Northwest National Laboratory and Current Operations—Post Cessation of Fuel Fabrication. Several R&D activities continue to the present day; consequently, select 300 Area R&D facilities will remain in operation through at least 2011 and others through about 2027 (Chapters 1 and 2 of *300 Area Building Retention Evaluation Mitigation Plan*, [WCH-181]). Table 1-2 lists the long-term facilities that will remain in the 300 Area Industrial Complex, including delayed facilities and long-term facilities and utilities (potentially 2027). Figure 1-10 shows the locations of these buildings and supporting facilities.

1.3.1.1 History and Sources of Contamination in the 300 Decision Area

Wastes from reactor fuel fabrication activities differ substantially from laboratory wastes in content, form, and volume. Wastes from the major 300 Area processes were handled in different ways. Past waste handling practices resulted in a complex distribution of clean and contaminated soils and structures within the 300 Area. Waste streams consisted of liquid from uranium fuel production operations and laboratory facilities, and solids, including contaminated equipment and building renovations/expansions construction debris. Liquid wastes were discharged in large volumes to open ponds and trenches during most of the 300 Area operational history. Solid waste streams from 300 Area operations were disposed of in burial grounds and shallow landfills during the early years (1943 through the 1950s). In later years, highly radioactive wastes, including transuranic[2] (TRU) and other solid process wastes, were disposed of in 600 Area burial grounds. Appendix B provides a description and brief history of the 300 Area waste sites.

[2] Transuranic waste is defined in *Implementation Guide for Use with DOE M 435.1-1* (DOE G 435.1-1).

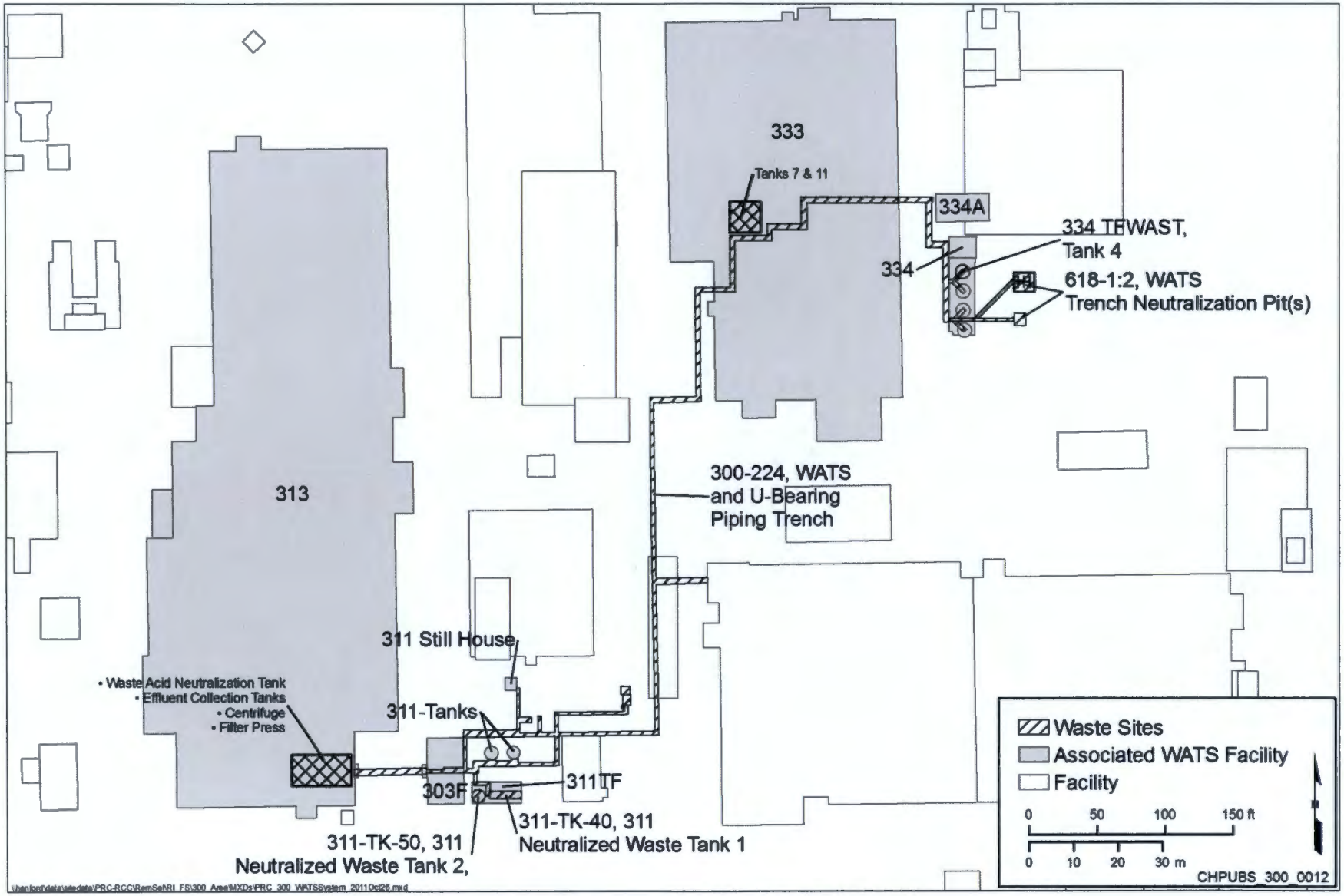


Figure 1-9. 300 Area 311 TF, 334 TF, and WATS

Table 1-2. Long-term Facilities Remaining in the 300 Area

Facility	Disposition
312 River Pumphouse	Retained long term (~2027)
318 Laboratory Complex	Retained long term (~2027)
318-BA Boiler Annex	Retained long term (~2027)
3220 Telecommunications Hub	Retained long term (~2027)
325 Laboratory Complex	Retained long term (~2027)
325-BA Boiler Annex	Retained long term (~2027)
331 Life Sciences Laboratory	Retained long term (~2027)
331 Complex Boiler Annex	Retained long term (~2027)
339-A Hanford Local Area Network Hub	Retained long term (~2027)
350 Maintenance Shop	Retained long term (~2027)
3507 Microwave Tower	Retained long term (~2027)
3508-T1, -T2, -T3 Sirens	Retained long term (~2027)
351-A and -B Electrical Station	Utilities/services retained long term (~2027)
352-F Electrical Substation	Utilities/services retained long term (~2027)
3614A River Monitoring Station	Utilities/services retained long term (~2027)
3709A Fire Station	Retained long term (~2027)
3709B Fire Equipment Storage	Retained long term (~2027)
3906 B Lift Station	Retained long term (~2027)
3906 C Monitoring Station	Retained long term (~2027)

Sources:
WCH-181, *300 Area Building Retention Evaluation Mitigation Plan.*
Waste Information Data System as of January 2010.

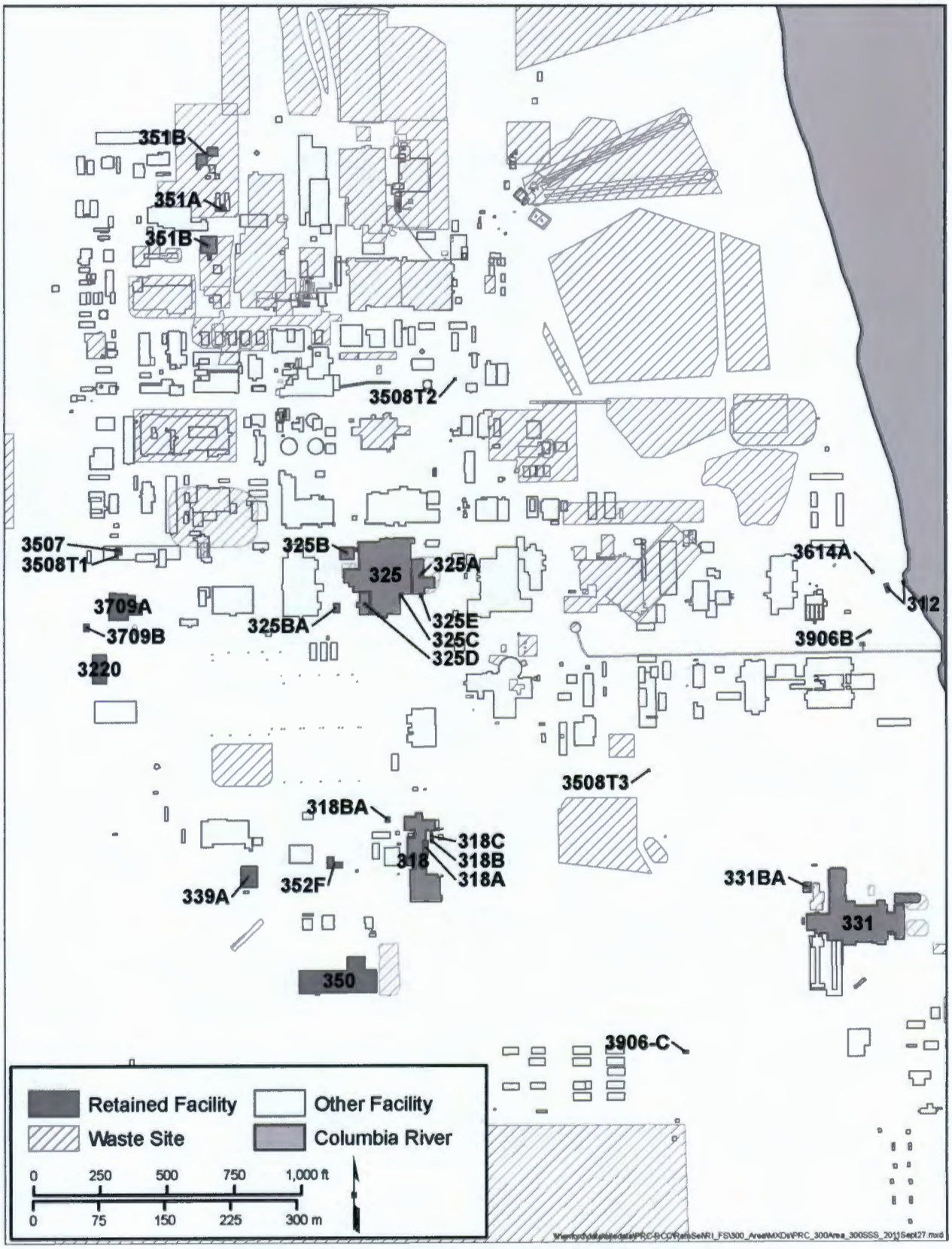


Figure 1-10. Long-term Facilities Remaining in the 300 Area

Liquid Waste Disposal. Liquid waste disposal from 300 Area operations was handled using various systems and facilities that were designated as (or are associated with) WIDS waste sites in the 300-FF-1 and 300-FF-2 OUs. These waste site ID numbers are as follows:

- Process Sewer System (300-15)
- South and North Process Ponds (316-1 and 316-2)
- 300 Area Process Trenches (316-5)
- Sanitary Sewer System (300-276)
- 340 Complex, 300 RPS (300-214), 300 RLWS, 307 Process Trenches (316-3), and 307 RB
- 311 TF, 334 Tank Farm Waste Acid Storage Tank (334 TFWAST), and WATS (300-224)

Figure 1-11 is a map of the 300 Area high volume liquid waste disposal sites (i.e., South and North Process Ponds, 300 Area Process Trenches, and the 307 Process Trenches). Appendix B provides a brief 300 Area liquid waste disposal system history.

1.3.1.2 Solid Wastes

Solid waste management activities in the 300 Area primarily involved burning and disposing of contaminated and uncontaminated solid waste in burial grounds and trenches. Burial grounds were used for waste disposal from 1943 through 1973. Until the release of burial ground records over the past 10 years, little information was available regarding the inventory, locations, and history of early burial grounds because of national security surrounding the Manhattan Project and the undeveloped radioactive waste management knowledge base. Most of the 300 Area burial grounds were located in the 300 Area Industrial Complex and in nearby area locations (see Figure 1-2). However, the 618-11 Burial Ground and the 618-10/316-4 Burial Ground and Crib are located in subregions much further away from the 300 Area Industrial Complex (Figure 1-12). From a CERCLA perspective, the 618-10 and 618-11 Burial Grounds are the most significant. The following subsections briefly describe the uses and present status of the 300 Decision Area burial grounds. Appendix B provides more complete burial ground descriptions.

300-7 Burial Ground—Undocumented Solid Waste Burial Ground Adjacent to 618-8, Possible Early Burial Ground Site. The site contains solid construction debris, such as concrete, metallic waste, asbestos, and uranium contamination. Surface debris piles are visible and subsurface disturbances identified with ground-penetrating radar. Currently, the site is covered with natural vegetation.

300-9 Burial Ground—Possible Early Burial Ground Sites North of 618-8, Solid Waste Burial Ground. The Early Burial Ground site location is not well documented. Uranium-contaminated aluminum shavings are scattered on the surface. Other surface contaminants may include aluminum-silicon alloy and beryllium-contaminated aluminum, but the actual burial inventory is unknown. Process knowledge suggests the burials were uranium-contaminated waste from early 300 Area experimental processes.

300-10 Burial Ground—Burial Trench West of Process Trenches. The site consisted of soil mixed with both clean and contaminated metal shavings. The northwest corner terminates near a dirt road that intersects the midpoint of the west 300 Area Process Trenches. A field walk down on November 18, 1994, reported the site appearance as a soil-covered field with natural vegetation. Remediation of the 300-10 Burial Ground was completed October 1997. Because of the proximity of the site to the 300 Area Process Trenches (316-5) and its relatively small size, the 300-10 Burial Ground remediation was authorized under the 300-FF-1 and 300-FF-5 ROD (EPA/ROD/R10-96/143). Soil in the 300-10 Burial Ground was excavated to a depth of 1.5 m (5 ft), or until radiological survey results indicated no contamination, and disposed of at the Environmental Restoration Disposal Facility (ERDF) (*300-FF-2 Waste Site 300-10 Verification Package* [BHI-01134]).

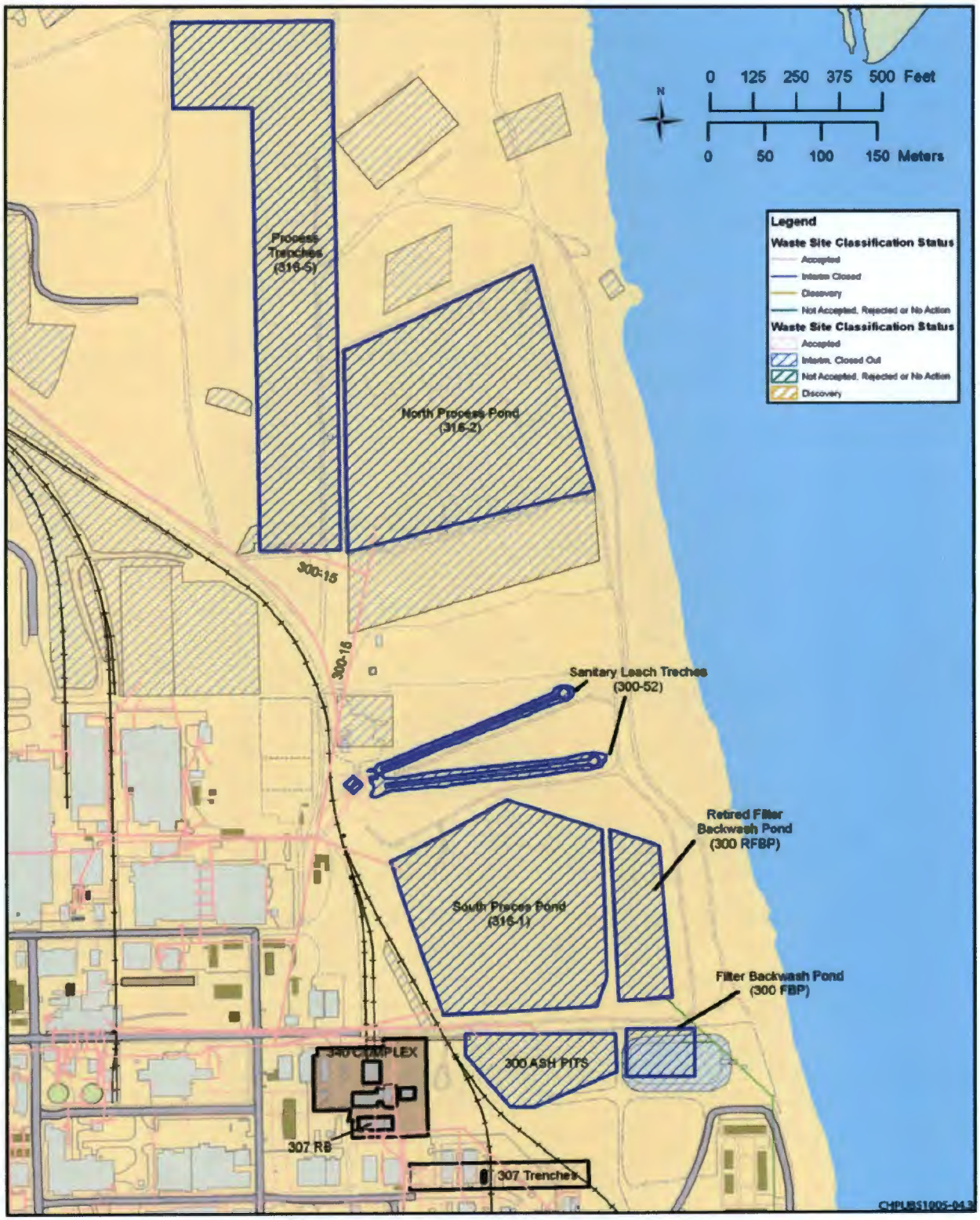


Figure 1-11. 300 Area High-Volume, Liquid Waste Disposal Sites

Figure 1-12. Locations of Solid Waste Burial Grounds

618-1 Burial Ground—Solid Waste Burial Ground No. 1. During its period of operation from approximately 1945 to 1956, the 618-1 Burial Ground was a general purpose burial ground used primarily for the disposal of solid waste from early 300 Area Industrial Complex operations. This reportedly included quantities of uranium from fuel fabrication activities and plutonium and fission products from laboratory operations (*Cleanup Verification Package for the 618-1 Burial Ground*, hereinafter called the 618-1 Burial Ground CVP [CVP-2010-00001]). Remediation of the 618-1 Burial Ground began September 2008 and was completed June 2010. Approximately 47,332 metric tons (52,160 tons) of soil and debris were excavated and disposed of at ERDF (618-1 Burial Ground CVP [CVP-2010-00001]). Waste encountered during excavation of the 618-1 Burial Ground consisted mostly of contaminated soil, metal pipe, crucibles, laboratory glassware, empty metal containers, and some land disposal restricted materials (lead solids contaminated with barium and chromium). Twenty metal drums containing personal protective equipment (PPE) and several bottles of liquid and/or powder were also removed. The 618-1 Burial Ground has been remediated to meet the RAOs in the interim action (300-FF-2 Interim ROD [EPA/ROD/R10-01/119]). The 618-1 Burial Ground does have residual contamination in the deep zone (greater than 4.6 m [15 ft] below ground surface [bgs]); therefore, ICs to prevent uncontrolled drilling or excavation into the deep zone are required (618-1 Burial Ground CVP [CVP-2010-00001]).

618-2 Burial Ground—Solid Waste Burial Ground No. 2. The waste site consisted of three east-west trenches, operated between 1951 and 1954, and received uranium contaminated equipment and materials, plutonium, and fission products from the 300 Area. The typical waste was solid metallic uranium oxides metal cuttings from reactor fuel fabrication facilities in the 300 Area. The plutonium and fission products were derived from 300 Area laboratory facilities. Remediation of the 618-2 Burial Ground began in August 1996 and was completed in November 2004. Approximately 71,203 metric tons (78,488 tons) of material were removed and transported to ERDF for disposal. The site was excavated to approximately 6 m (19.7 ft). A location in the middle trench was excavated to groundwater (between 15 and 11.5 m [49.2 and 3,737 ft] below grade) to remove acid waste mobilized plutonium (*Cleanup Verification Package for the 618-2 Burial Ground* [CVP-2006-00010]). The 618-2 Burial Ground remediation was authorized by the 300-FF-2 Interim ROD (EPA/ROD/R10-01/119).

618-3 Burial Ground—Solid Waste Burial Ground No. 3. The burial ground operated between 1954 and 1955 and consisted of uranium contaminated dry waste, primarily building materials from the remodeling of the 313 Building and waste materials from the 303-J and -K upgrades. The 618-3 Burial Ground consists of one north-south trench approximately 105.2 m (345 ft) long, 30.5 m (100 ft) wide, and 4.6 m (15 ft) deep. In 1986, the volume of contaminated soil was estimated to be 12,549 m^3 (443,160 ft^3), with 12,643 m^3 (446,480 ft^3) of overburden. Remediation of the 618-3 Burial Ground was authorized by the 300-FF-2 Interim ROD (EPA/ROD/R10-01/119). Approximately 30,878 metric tons (34,037 tons) of material from the site were removed and transported to ERDF for disposal (*Cleanup Verification Package for the 618-3 Burial Ground* [CVP-2006-00005]).

618-4 Burial Ground—Solid Waste Burial Ground No. 4. It is believed that the 618-4 Burial Ground operated between 1955 and 1961. Remediation of the 618-4 Burial Ground was authorized by the 300-FF-1 and 300-FF-5 ROD (EPA/ROD/R10-96/143). Excavation and associated waste-disposal operations at the 618-4 Burial Ground, completed in two phases between 1998 and 2003. The total excavation covered an area approximately 7,342 m^2 (79,043 ft^2) and had a maximum depth of approximately 11 m (36 ft) below the surrounding grade. Approximately 46,585 metric tons (51,360 tons) of bulk soil and debris were excavated, transported, and disposed of at ERDF. Additionally, 266 drums of depleted uranium oxide and 520 drums of depleted uranium chips immersed in oil were excavated and transported to ERDF (*Cleanup Verification Package for the 618-4 Burial Ground* [CVP-2003-00020]).

618-5 Burial Ground—Solid Waste Burial Ground No. 5, Regulated Burning Ground. The site was one large (single) pit and received 300 Area waste from 1945 through 1962. It also was used as a burn pit. The *Unconfined Underground Radioactive Waste and Contamination in the 300 Area and Miscellaneous Areas Not Included in Other Reports* (HW-39076) report states that the area was a burning trench as well as a storage area for aluminum silicate containing 17 percent uranium and bronze crucibles with maximum radiation levels of 200 mrem/h. The site was used for the disposal of uranium bearing trash. Characterization test pits dug in 1992 encountered radiologically contaminated lead bricks, steel pipes, wood fragments, and other garbage. Remediation of the 618-5 Burial Ground was authorized by the 300-FF-2 Interim ROD (EPA/ROD/R10-01/119). Excavation of the 618-5 Burial Ground was conducted between March and August 2003. At completion of the excavation, approximately 46,300 metric tons (50,930 tons) of bulk soil and debris were removed from the site and transported to ERDF. The maximum excavation depth was 7.5 m (24.6 ft) (*Cleanup Verification Package for the 618-5 Burial Ground* [CVP-2003-00021]).

618-7 Burial Ground—Solid Waste Burial Ground No. 7. The burial ground consisted of two east-west oriented trenches and one V-shaped pit. The burial ground operated from 1960 to 1973, primarily for the disposal of contaminated equipment, materials, and laboratory waste from the 300 Area facilities including the 313, 321, 333, 3722, and 3732 Buildings. The middle trench operated between 1960 and 1966. Miscellaneous contaminated equipment and hundreds of 114 L (30 gal) drums of Zircaloy chips contaminated with moderate amounts of beryllium and uranium were buried in the trenches from 1960 to 1973 (Technical Baseline Report [BHI-00012]). Remedial activities for the 618-7 Burial Ground were authorized by the 300-FF-2 Interim ROD (EPA/ROD/R10-01/119). Remedial activities for the 618-7 Burial Ground were conducted from January 2008 through November 2008. Approximately 160,920 metric tons (177,380 tons) of material were removed from the site and transported to ERDF (*Cleanup Verification Package for the 618-7 Burial Ground* [CVP-2008-00002]).

618-8 Burial Ground—Solid Waste Burial Ground No. 8, Early Solid Waste Burial Ground. The site is assumed to have been used for the disposal of uranium contaminated construction debris from the remodeling of the 313 Building. The site was in operation between 1943 and 1954. Remediation of the 618-8 Burial Ground was authorized by the 300-FF-2 Interim ROD (EPA/ROD/R10-01/119). Remedial activities for the 618-8 Burial Ground were conducted from November 2004 through September 2005. Approximately 6,462 metric tons (7,125 tons) of material were removed from the site and transported to ERDF (*Cleanup Verification Package for the 618-8 Burial Ground* [CVP-2006-00006]).

618-9 Burial Ground—300 West Burial Ground, Dry Waste Burial Site No. 9. The site was a burial ground composed of a single trench. In 1991, this burial ground was excavated. Approximately 2,600 L (700 gal) of methyl isobutyl ketone, otherwise known as hexone, and 3,400 L (900 gal) of kerosene solvent were recovered from 120 drums in the trench's western end. Severely corroded drums also were found at the eastern end of the trench. Approximately 39.6 m^3 (1,400 ft^3) of debris also was found, including more than 80 empty drums, a wheelbarrow, scrap process equipment, construction debris, two breached bags of ammonium nitrate, unidentified white powders, and several lead bricks (*Engineering Evaluation of the 618-9 Burial Ground Expedited Response Action* [DOE/RL-91-38]).

618-12 Scraping Disposal Area—North Process Pond Scraping Disposal Area. This site received uranium contaminated soil scraped from the 316-2 Pond (North Process Pond) and soils removed from beneath the 321 Building during excavation for hydraulic core mockup (*300-FF-1 Operable Unit, North Process Pond/Scraping Disposal Area Verification Package*, hereinafter called 300-FF-1 OU Verification Package [BHI-01298]). Remediation of the 618-12 Burial Ground was authorized by the 300-FF-1 and 300-FF-5 ROD (EPA/ROD/R10-96/143) in conjunction with 316-2 North Process Pond.

The 618-12 Scraping Disposal Area was considered an undetermined contamination level area (300-FF-1 OU Verification Package [BHI-01298]). In accordance with the *300-FF-1 Remedial Design Report/Remedial Action Work Plan* (hereinafter referred to as the 300-FF-1 RDR/RAWP [DOE/RL-96-70]), test pits were excavated in eight 618-12 locations. Based on the results, a hot spot was identified at one of the test pit locations at about 2.1 m (7 ft) bgs. A statistical analysis of all the test pit results showed that the 618-12 Scraping Disposal Area did not require remediation. However, the hot spot soils where excavated and sent to ERDF (300-FF-1 OU Verification Package [BHI-01298]).

618-13 Burial Ground—300 North Solid Waste Burial Ground. The site was originally a single-use disposal site for contaminated soil removed from the perimeter of the 303 Building in 1950. It is believed that the mound of soil later served as a safety shield (blast shield) for drums of hexone stored in buildings on the west side of the berm before being buried in the 618-9 Burial Trench in 1954. This site received uranium-contaminated topsoil removed from around the 303 Building. Total activity buried in the site is not known. Remediation of the 618-13 Burial Ground was authorized by the 300-FF-2 Interim ROD (EPA/ROD/R10-01/119). Remedial activities for the 618-13 Burial Ground were conducted from January through February 2009. Approximately 4,300 metric tons (4,732 tons) of material were removed from the site and transported to ERDF (*Cleanup Verification Package for the 618-13 Burial Ground and the 600-290:1 Pad and Loading Dock Near 618-13* [CVP-2009-00005]).

618-10 Burial Ground and 316-4 Crib Subregion. The 618-10 Burial Ground (Figure 1-13) operated from March 1954 to March 1962 and from October 1962 to September 1963. It reopened in 1962 to support waste-disposal activities while vertical pipe units (VPUs) were installed in the 618-11 Burial Ground and closed for the final time after the 618-11 Burial Ground was operational. The first VPU was installed in September 1954. The 618-10 site consists of 12 trenches and 94 VPUs. Each VPU consists of five 210 L (55 gal) drums with tops and bottoms removed (Figure 1-14). The drums were stacked vertically, tack welded together, and placed on a concrete footing with the bottom being left open to the soil column. The VPUs were used to dispose of containers holding moderate to high activity solid wastes.

From a review of radiological survey records obtained during an extensive records search, the following four buildings contributed over 90 percent of the 618-10 inventory:

- 327 Building
- 325 Building
- 3706 Building
- 329 Building

An additional 17 buildings contributed less than 10 percent of the total. None of the radiological surveys from these additional buildings indicate the waste disposed from these buildings would be a significant contributor to the radiological inventory, all were low dose rate, low contamination level (*600 Area Remediation Design Solution Waste Volume and Inventory*, hereinafter called the 600 Area Remediation Design Solution [WCH-125]). Records indicate that the 618-10 Burial Ground wastes included radiologically contaminated laboratory instruments, bottles, boxes, filters, aluminum cuttings, irradiated fuel element samples, metallurgical samples, electrical equipment, lighting fixtures, barrels, laboratory equipment and hoods, and low- and high-activity liquid waste sealed in containers (*Sampling and Analysis Plan for 618-10 And 618-11 Nonintrusive Sampling*, hereinafter called the 618-10 and 618-11 SAP [DOE/RL-2008-27]). The site is expected to contain hazardous wastes, radiological wastes and mixed wastes (both low-level and TRU). The total estimated TRU waste volume contained in the 618-10 Burial Grounds is estimated to be 417 m^3 (14,888 ft^3) (600 Area Remediation Design Solution [WCH-125]).

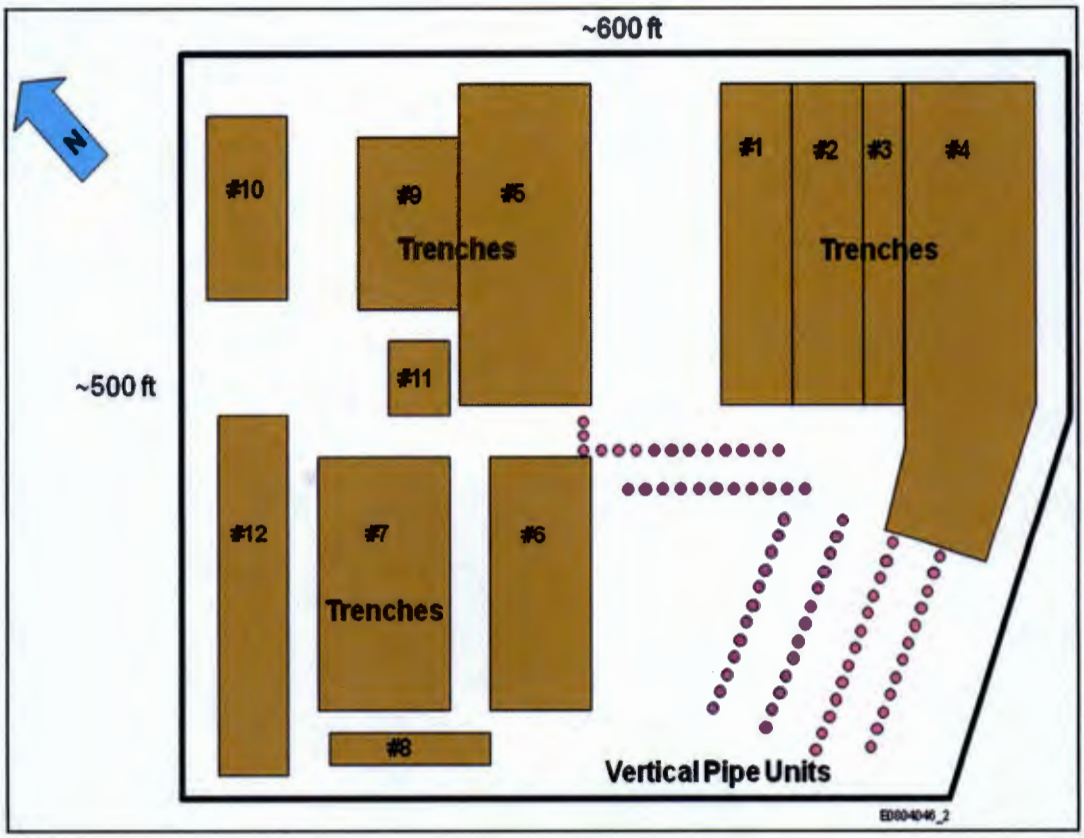
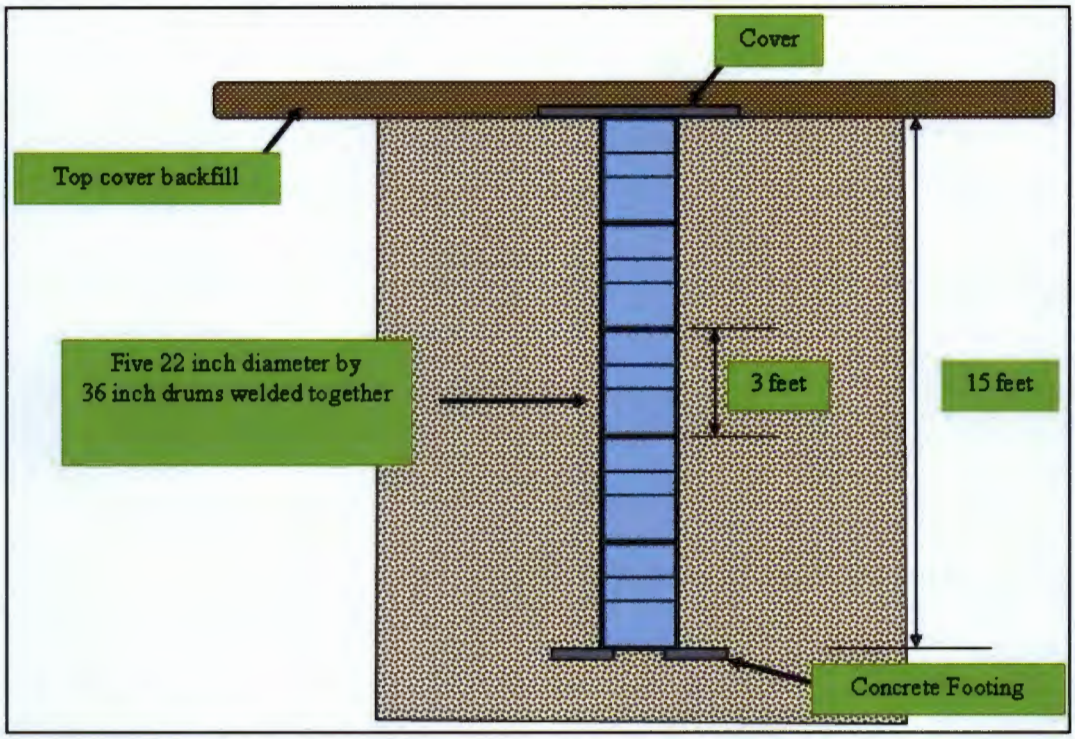


Figure 1-13. Conceptual Layout of 618-10 Burial Grounds



Source: WCH-125, *600 Area Remediation Design Solution Waste Volume and Inventory.*

Figure 1-14. Design for VPUs

316-4 Crib. Known as the 321 Cribs (316-4), this waste site was constructed specifically to manage uranium bearing liquid wastes from the 321 Building. It was built in the 600 Area, about 5.6 km (3.5 mi) north-northwest of the 300 Area, adjacent to the 618-10 Burial Ground. The site consisted of two inverted, bottomless, 0.64 cm (0.25 in.) stainless steel tanks (Figure 1-15). The tanks had concrete footings and sat on a bed of gravel. They were 2.1 m (7 ft) high and 2.4 m (8 ft) in diameter and were approximately 3 m (10 ft) below grade. One tank had an inlet line and a vent riser. The two tanks were 0.61 m (2 ft) apart and were connected by a 5 cm (2 in.) stainless steel overflow pipe. From 1948 to 1955/1956, the site received hexone-bearing uranium wastes and limited amounts of other types of uranium bearing waste from the 321 Building R&D activities (Technical Baseline Report [BHI-00012]). There is some evidence that waste was also received in 1962.

In September 1995, groundwater radioactive contamination was identified in Well 699-S6-E4A during well improvement activities. The well is located adjacent to the 316-4 Crib. Sample analysis of the contamination identified hydrocarbons and uranium. Remediation of the site began in 2004 and the planned excavation completed in April 2005. Further remediation of the site is planned to begin in January 2013.

618-11 Burial Ground. The 618-11 Burial Ground (Figure 1-16) operated from March to October 1962 and from September 1963 until the end of 1967, when it closed. VPUs were installed during the October 1962 to September 1963 closure period. VPUs were for disposing high dose rate waste in the 618-11 Burial Ground until late 1964 or early 1965, when caissons were installed for high dose rate materials. The 618-11 Burial Ground consists of 3 slope-sided trenches, 3 to 5 large caissons, and 50 VPUs. The caissons within the 618-11 Burial Ground are constructed of 2.4 m (8 ft) diameter by 3.1 m (10 ft) tall, corrugated metal cylinders that are buried vertically with their tops about 4.6 m (15 ft) below grade. A 0.9 m (3 ft) diameter angled chute extends from grade to the top of the caisson through a concrete slab lid (Figure 1-17). Like the 618-10 Burial Ground, VPUs were used to dispose containers holding moderate- to high-activity solid wastes.

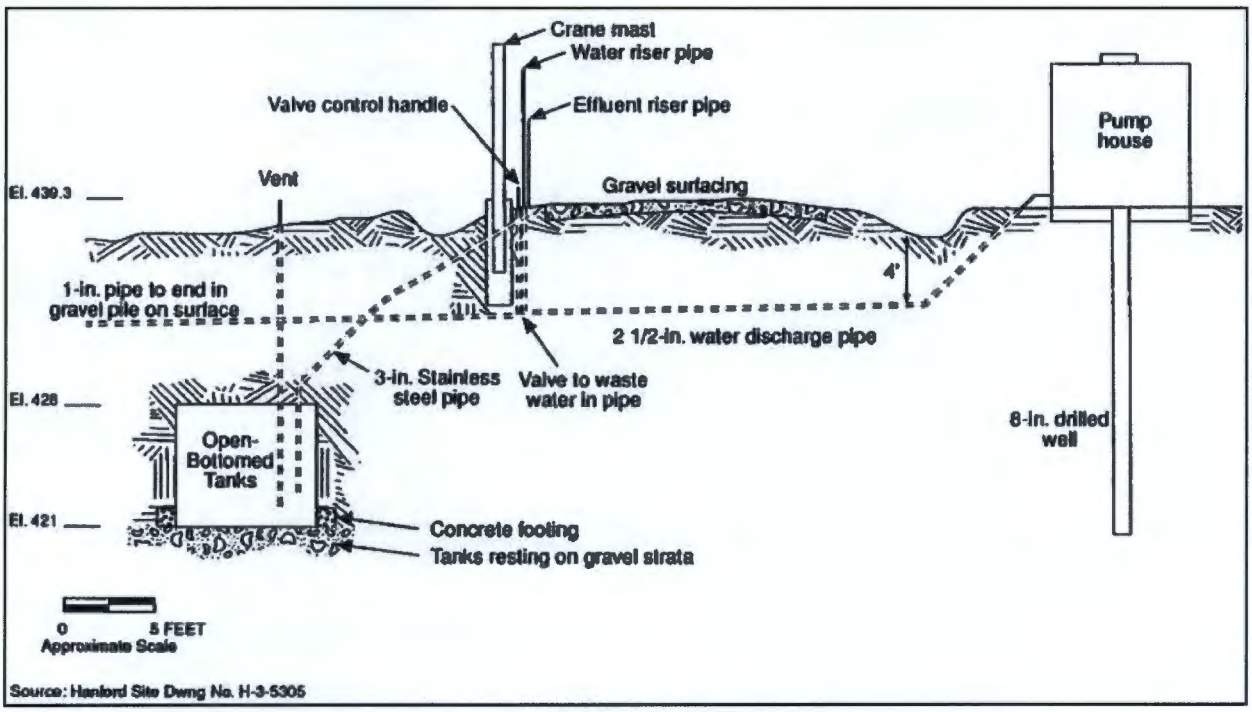


Figure 1-15. Design for the 316-4 Crib

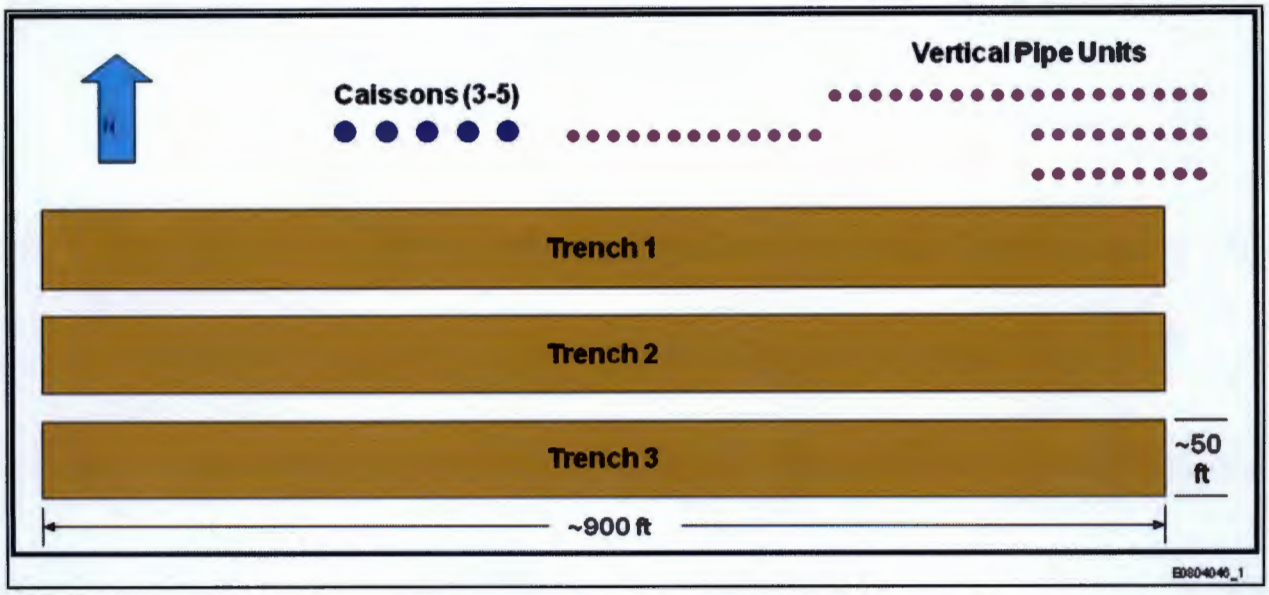
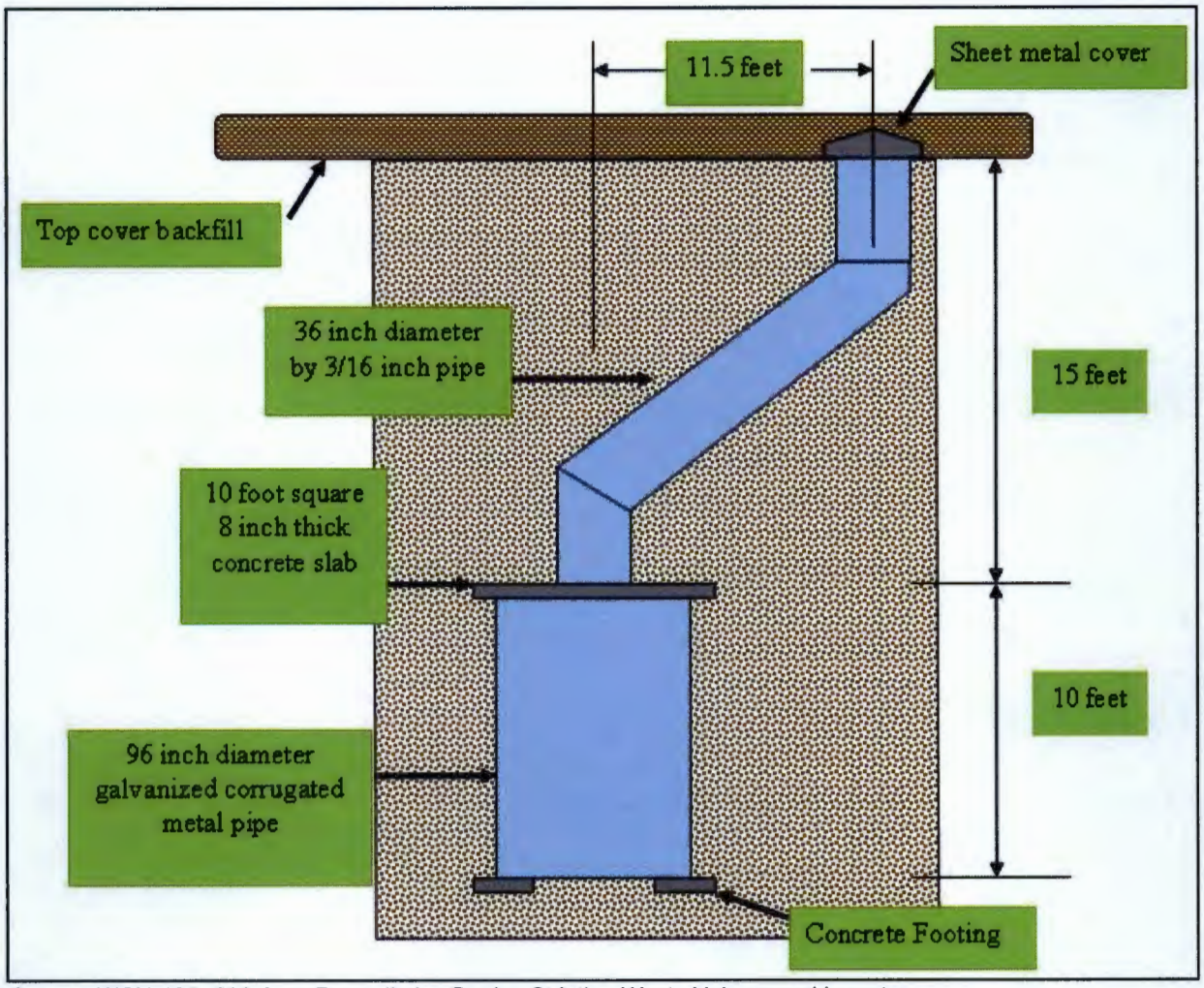


Figure 1-16. Conceptual Layout of 618-11 Burial Grounds



Source: WCH-125, *600 Area Remediation Design Solution Waste Volume and Inventory.*

Figure 1-17. Design for Caissons at the 618-11 Burial Ground

From a review of radiological survey records, the following four buildings contributed over 95 percent of the 618-11 inventory[3]:

- 327 Building
- 325 Building
- 309 Building
- 329 Building

An additional 14 buildings contributed less than 5 percent of the total. Similar to the 618-10 Burial Ground, none of the radiological surveys from these additional buildings indicates the waste disposed from these buildings would be a significant contributor to the radiological inventory; all were low dose rate, low contamination level (600 Area Remediation Design Solution [WCH-125]).

The 618-11 Burial Ground contains a broad spectrum of low-level radioactive waste including fission products, byproduct waste (thorium and uranium), and plutonium, similar to the 618-10 Burial Ground. It was used for the disposal of 300 Area laboratory solid wastes. These facilities handled radioactively contaminated, or potentially contaminated, waste from operations or laboratory areas, including hot cells.

Moderate- and high-activity (remote-handled) wastes were received from the 327 Building (radiometallurgy) hot cells, 325-A hot cells, 325-B (analytical) hot cells, occasionally from the 309 PRTR, and later from 324 Building hot cells (618-10 and 618-11 SAP [DOE/RL-2008-27]). The site is expected to contain mixed low-level radioactive waste and TRU waste. The total volume of TRU waste contained in the 618-11 Burial Ground trenches is estimated to be 499 m^3 (15,393 ft^3) (600 Area Remediation Design Solution [WCH-125]).

1.3.1.3 History and Sources of Contamination for the 400 Area Subregion

Although the FFTF reactor ancillary facilities are waste sources for 400 Area waste sites, the FFTF reactor is not. The FFTF is a 400-megawatt, thermal, sodium cooled, low pressure, high temperature reactor. During operations, 38 facilities supported the FFTF. Figure 1-18 is a map of the 400 Area. Figure 1-19 is a photograph of the FFTF reactor.

FFTF construction began in 1970 and was completed in 1978. The reactor reached initial criticality in February 1980 and began operating at full power in December 1980. The FFTF operated from 1982 through 1992. Following an evaluation of several potential long-term missions, DOE concluded that continuing reactor operations were not justified. In April 1992, the DOE Richland Operations Office (DOE-RL) directed the FFTF placed in standby status pending a further investigation into potential future missions. The plant achieved a steady-state "hot" standby condition in December 1992. After exploring potential missions for FFTF, the Secretary of Energy announced in January 1993 that none was feasible and initiated a 5-year process to place the reactor into "cold" standby. After a recommendation from an independent review team, the reactor was placed into a radiologically and industrially safe shutdown condition (Technical Baseline Report [BHI-00012]). The FFTF reactor is currently in a safe shutdown condition until D4 of the facilities can be completed. After a period of low cost surveillance and maintenance, sodium disposition, decommissioning, and demolition will resume in fiscal year (FY) 2015. According to the *Surveillance and Maintenance Plan for the Fast Flux Test Facility (FFTF)* (DOE/RL-2009-26), decommissioning and demolition is planned to be complete by the end of FY 2030. Appendix B contains additional historical information.

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[3] Information provided in this document differs from the 300 Area RI/FS Work Plan (DOE/RL-2009-30) because of math errors found in reference document.

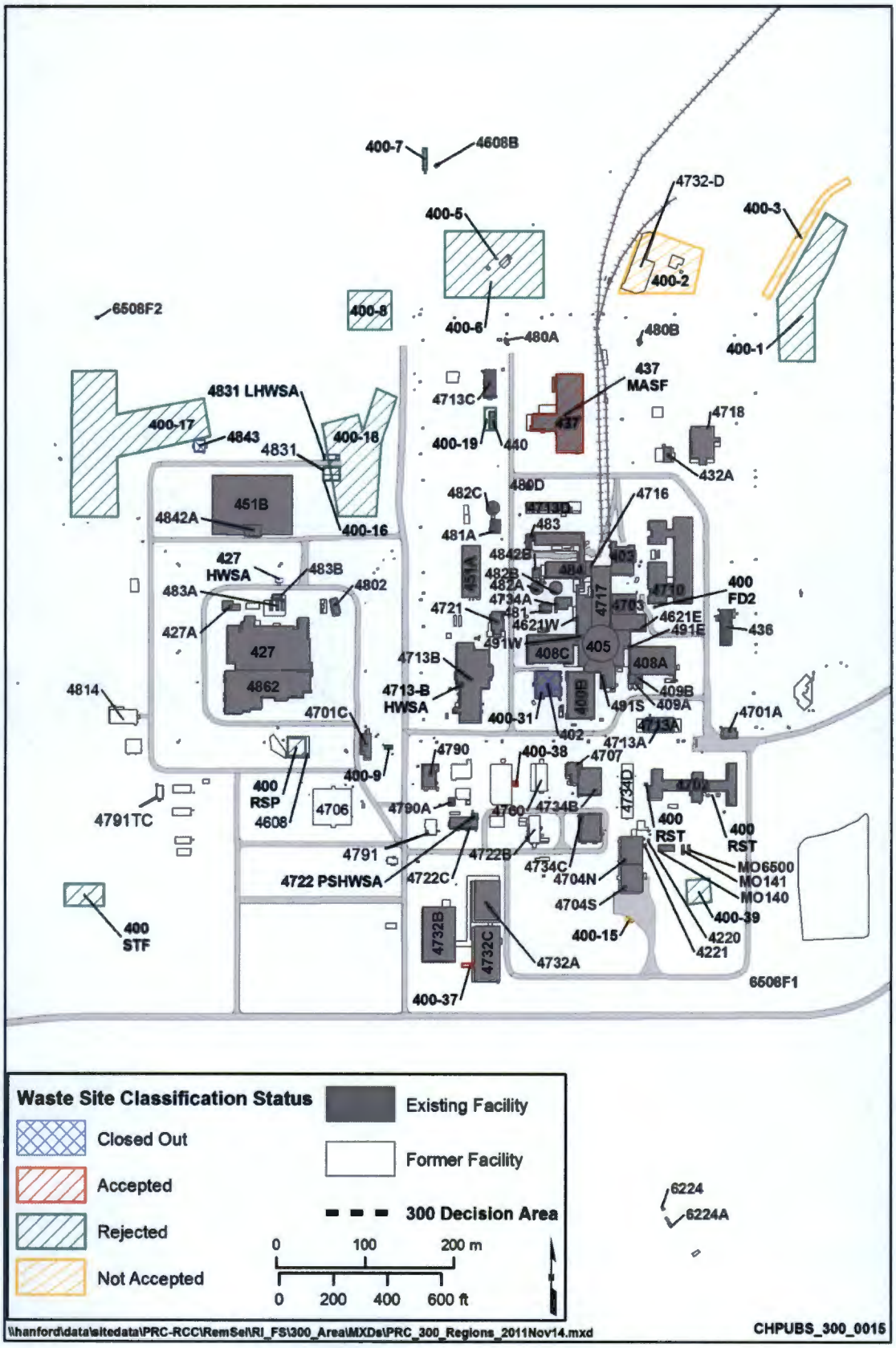

Figure 1-18. 400 Area FFTF and Supporting Structures

E1111044_2

Figure 1-19. Aerial Photo Showing the FFTF Reactor Complex

1.3.1.4 400 Area Sources of Contamination

The FFTF is not a typical commercial power production nuclear reactor. Because of its design, construction, and operation, the type and extent of contamination present is unique. Since the reactor is cooled by liquid sodium, all interfacing equipment and systems are sealed in an inert atmosphere to prevent adverse reactions with the liquid sodium. Because of this, the FFTF is radiologically clean.

Contamination sources associated with FFTF operations are minimal. Various systems within the facility were contaminated to some degree because of activation and corrosion products in the primary sodium system (e.g., manganese-54, sodium-22, and sodium-24). For example, fuel assemblies were run until cladding failure and fission products were released into the primary systems (e.g., cesium-134 and cesium-137). In addition, destructive examination procedures used in the interim examination and maintenance cell caused contamination. The interim examination and maintenance cell is a vertical hot cell located within the Reactor Containment Building that is used to examine recently irradiated core components within 50 days of removal. The secondary systems were not exposed to any of these materials, but were slightly contaminated as a result of tritium migration. Many of the more prevalent radionuclides such as manganese-54, sodium-22, sodium-24, cesium-134, and iron-55 have decayed since the reactor ceased operations in 1992 and no longer present a hazard. The accepted 300-FF-2 OU waste sites are listed below with a brief history.

400 Area Process Pond and Sewer System (400 PPSS). The 400 Area PPSS nonhazardous and nonradioactive liquid-waste-disposal site consists of underground piping (the 4904 Process Sewer System), a control structure (the 4608-B Control Structure and Process Sewer Sampling Station), and two percolation ponds. The percolation ponds and the 4608-B Control Structure and Process Sewer Sampling Station are geographically located north of the 400 Area, while the 4904 Process Sewer runs throughout the 400 Area and is connected to the FFTF, the Fuels and Materials Examination Facility (FMEF), the Maintenance and Storage Facility (MASF), and the 481-A Water Pumphouse. The PPSS began operation in 1979 and received wastewater from cooling systems and non-sanitary drains and sumps in the 400 Area. In the original system design, effluent wastewater entered the process sewer system from the FFTF and FMEF cooling towers (Technical Baseline Report, Section 4.10.13 [BHI-00012]).

Storage Tank (400-37). The site is an underground fuel oil tank used to provide diesel fuel to a standby electric generator. The generator powered fans for inflating a temporary equipment storage facility used during the FFTF construction. The inflatable building was removed in the early 1980s. The tank is located near the southeast corner of the 4732-B Building. There is no visual evidence of the tank on the surface. It is possible the tank has been filled with sand or removed, but documentation has not been found.

Storage Tank (400-38). The site is an underground fuel tank that supported the 4722-A Building. The tank is located east and slightly south of the centerline of the cement pad where the 4722-A Building had been located. There is no visual evidence of the tank on the surface. It is possible the tank has been filled with sand or removed, but documentation has not been found.

437 Maintenance and Storage Facility. The MASF consists of a main building and a two-story service wing. The MASF is a multipurpose service center supporting the specialized maintenance and storage requirements of the 400 Area facilities. This facility currently is used for decontamination of radioactive and/or sodium-contaminated FFTF equipment; repairing contaminated manipulators from the FFTF Reactor Containment Building; staging large pieces of equipment for storage, repair, or testing; and temporary storage of low-level radioactive solid and liquid wastes before shipment.

1.3.2 Previous and Ongoing Investigations and Remediation

Considerable environmental investigation and remediation activities have been completed at the 300 Area. Since the beginning of reactor operations, investigations were conducted to determine impacts to the environment, including the Columbia River. With the issuance of the TPA in 1989 (Ecology, et al., 1989a), activities transitioned to cleanup, which has been ongoing under CERCLA to protect HHE within the River Corridor. These River Corridor activities supplement specific ongoing 300 Area activities.

Scientific and engineering investigations and CERCLA remedial actions have been completed or are ongoing for 300 Area facilities, waste sites, the vadose zone, and groundwater. This subsection summarizes the most relevant investigation and remediation activities that have been performed or are ongoing. Table 1-3 summarizes the 300 Area decision documents. Appendix N presents a summary of investigations completed in the 300 Area.

Table 1-3. 300 Area Decision Documents

Document Title	Date
618-9 Burial Ground Expedited Response Action (DOE, 1991)	1991
Action Memorandum: 316-5 Process Trenches, U.S. Department of Energy (DOE) Hanford Site, Richland, Washington (EPA, 1991)	July 1991

Table 1-3. 300 Area Decision Documents

Document Title	Date
Record of Decision for the 300-FF-1 and 300-FF-5 Operable Units, Hanford Site, Benton County, Washington (EPA/ROD/R10-96/143)	July 1996
USDOE Hanford 300 Area, 300-FF-1 Operable Unit, Hanford Site, Benton County, Washington Explanation of Significant Difference (ESD) (EPA/ESD/R10-00/505)	January 2000
331-A Virology Laboratory Building Action Memorandum (DOE and EPA, 2000)	February 2000
Explanation of Significant Difference for the 300-FF-5 Record of Decision (EPA/ESD/R10-00/524)	June 2000
Interim Remedial Action Record of Decision for the 300-FF-2 Operable Unit, Hanford Site, Benton County, Washington (EPA/ROD/R10-01/119)	April 2001
Explanation of Significant Differences for the 300-FF-2 Operable Unit Record of Decision (EPA, Ecology, and DOE, 2004)	May 2004
Action Memorandum #1 for the 300 Area Facilities (DOE and EPA, 2005)	January 2005
Action Memorandum #2 for the 300 Area Facilities (DOE and EPA, 2006a)	May 2006
Action Memorandum #3 for the 300 Area Facilities (DOE and EPA, 2006b)	November 2006
Action Memorandum for General Hanford Site Decommissioning Activities (DOE/RL-2010-22)	March 2010

1.3.2.1 300 Area Industrial Complex

This section describes the remediation and investigation activities in the 300 Area Industrial Complex. Descriptions of groundwater contamination originating outside the 300 Decision Area are included in the discussion, but are not within the scope of the 300 Decision Area RI/FS Report.

300 Area Industrial Complex Facility Demolition. Figure 1-20 is a 300 Area Industrial Complex aerial photograph (circa 2004) before site remediation and D4 activities occurred. Figure 1-21 is a recent aerial photograph showing the many buildings that have completed D4 along the Stevens Drive 300 Area boundary fence. About 40,914 metric tons (45,101 tons) of D4 materials were transported to ERDF between August 2005 and February 2011. Demolition activities in 300 Area Industrial Complex facilities are ongoing.

300 Area Industrial Complex Vadose Zone and Waste Site Investigations and Remediation. The behavior of contaminants in the vadose zone has been an important consideration in Hanford Site plant operations since the 1940s. Some reports (e.g., *Underground Waste Disposal at Hanford Works: An Interim Report Covering the 200 West Area* [HW-9671]; *The Underground Disposal of Liquid Wastes at the Hanford Works, Washington* [HW-17088]) examined issues related to waste disposal at injection wells, shallow burial cribs, and surface ponds. Groundwater monitoring was undertaken in the late 1940s to evaluate the rate of migration through the vadose zone and aquifer. Waste sites were sometimes designed with wells that would permit geophysical logging to assess radionuclide movement through the aquifer. Continued waste site use was gauged against the vertical migration of contaminants, and waste sites were shut down when contamination reached certain concentrations in groundwater monitoring wells. As such, hydrologic and geochemical processes in the vadose zone were of interest, but were not well understood.

Figure 1-20. Aerial Photo of Central 300 Area in 2004 Showing Facilities before D4 Activities

Figure 1-21. Aerial Photo of Central 300 Area in 2008 Following D4 Activities for Some Major Facilities

Vadose Zone Investigations. The vadose zone at the Hanford Site has been studied extensively since the 1980s. *Unsaturated Water Flow at the Hanford Site: A Review of Literature and Annotated Bibliography* (PNL-5428) provided an overview of the status of vadose zone studies in 1985. By 1992, a significant amount of data had been collected from lysimeters at a wide range of sites at the Hanford Site ("Variations in Recharge at the Hanford Site" [Gee et al., 1992]). This study categorized the recharge response for a variety of surface covers at the Hanford Site for both soil type and vegetation cover. The most striking finding in this study was that recharge of 8.9 of the 16 cm (3.5 of the 6.3 in.) total annual precipitation was measured in vadose zone lysimeters with a clean gravel cover at the surface. In contrast, lysimeters under native vegetation showed no measurable recharge.

Waste Site Remediation. In 1996, as a part of 300-FF-1 and 300-FF-5 ROD (EPA/ROD/R10-96/143), remedies were selected for 15 waste sites. These were mainly the high-volume, liquid waste disposal sites (e.g., South Process Pond [316-1], North Process Pond [316-2], and 300 Area Process Trenches [316-5]), plus the 618-4 Burial Ground and 628-4 Landfill. These original 15 waste sites, plus an additional 23 waste sites, for the 300-FF-1 OU have been closed out or classified as no action.

In 2001, the 300-FF-2 Interim ROD (EPA/ROD/R10 01/119) selected interim remedial actions for waste sites. However, since the issuance of the 300 FF-2-OU Interim ROD, additional waste sites have been identified throughout the 300 Decision Area (Table 1-4). Table 1-5 provides the current list of the 300 Area industrial complex waste sites and their WIDS classification status. A total of 552 potential waste sites have been identified in the 300 Decision Area. Of these, 275 waste sites are classified as either "Not Accepted" or "Rejected", and not evaluated further. Of the remaining 277 waste sites, 85 waste sites are classified as "Closed Out" and 13 waste sites are classified as "No Action" based upon previous investigations or remediation. The remaining waste sites were evaluated in this RI/FS, and include 103 sites classified as "Accepted", 40 sites classified as "Consolidated", and 36 sites that have been "Interim Closed Out". The "Interim Closed Out" waste sites were evaluated in Chapters 5, 6, and 7 to determine whether the concentrations left in place following the interim remedial actions are protective of human health, ecological, groundwater, and surface water when compared against the new preliminary remediation goals (PRGs) developed in this document. Those interim closed sites with concentrations exceeding the new PRGs will carry forward into the FS for remedial evaluation.

Table 1-4. Summary of Waste Sites in the 300 Decision Area

OU	Total Number of Waste Sites[a]	Closed Out[b]	Interim Closed Out[c]	No Action[d]	Not Accepted[e,i]	Accepted[f]	Consolidated[g]	Discovery[h]
300-FF-1	38	33	0	5	0	0	0	0
300-FF-2	373	41	25	5	180	92	30	0
Total 300 Area Industrial Complex	**411**	**74**	**25**	**10**	**180**	**92**	**30**	**0**
300-FF-2	88	6	0	1	78	3	0	0
Total 400 Area	**88**	**6**	**0**	**1**	**78**	**3**	**0**	**0**
300-FF-1	3	2	0	1	0	0	0	0
300-FF-2	54	3	11	1	17	8	10	0

Table 1-4. Summary of Waste Sites in the 300 Decision Area

OU	Total Number of Waste Sites[a]	Closed Out[b]	Interim Closed Out[c]	No Action[d]	Not Accepted[e,i]	Accepted[f]	Consolidated[g]	Discovery[h]
Total 600 Area	**53**	**5**	**11**	**2**	**17**	**8**	**10**	**0**
Total in 300 Decision Area	**552**	**85**	**36**	**13**	**275**	**103**	**40**	**0**

Notes: Appendix B provides additional information for waste sites.

Source: SIS, December 5, 2011.

a. Total number of potential waste sites identified in the 300 Area.

b. Closed Out: A WIDS reclassification status, based on actions taken, indicating a waste management unit meets applicable cleanup standards or closure requirements and no further action is required.

c. Interim Closed Out: A WIDS reclassification status indicating that a waste management unit meets cleanup standards specified in an interim action ROD or action memorandum due to actions taken, but for which a final ROD has not been issued

d. No action: A WIDS reclassification status based on an assessment of quantitative data collected for the waste site indicating that the site does not require further remedial action under RCRA corrective actions, CERCLA, or other cleanup standards.

e. Not accepted: A classification status indicating an assessment was made that a WIDS site is not a waste management unit and, therefore, is outside the scope of the *Hanford Federal Facility Agreement and Consent Order Action Plan* (Ecology et al., 1989b) Section 3.1. This classification requires lead regulatory agency approval.

f. Accepted: The WIDS site is a waste management unit as defined in the *Hanford Federal Facility Agreement and Consent Order Action Plan* (Ecology et al., 1989b) Section 3.1.

g. 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. A consolidated WIDS site requires no further updates after reclassification. All updates are limited to the WIDS site into which it was consolidated

h. Discovery: This is the initial classification of a newly discovered WIDS site based on evidence of a potential site where the assessment is not complete

i. Includes Rejected sites, which is a reclassification status indicating a waste site does not require remediation under CERCLA, or other cleanup standards based on qualitative information such as a review of historical records, photographs, drawings, walk downs, ground penetrating radar scans, and shallow test pits. Such investigations do not include quantitative measurements.

Table 1-5. Classification Status of 300 Area Industrial Complex Waste Sites

Classification Status	Waste Site(s)	Total
	300-FF-1	
Closed Out	300 Ash Pits, 300 RFBP, 300-44, 300-49, 300-50, 316-1[a], 316-2[a], 316-5[a], 332 SF, 618-12, UPR-300-15, UPR-300-19, UPR-300-20, UPR-300-21, UPR-300-22, UPR-300-23, UPR-300-24, UPR-300-25, UPR-300-26, UPR-300-27, UPR-300-28, UPR-300-29, UPR-300-30, UPR-300-32, UPR-300-33, UPR-300-34, UPR-300-35, UPR-300-36, UPR-300-37, UPR-300-47, UPR-300-8, UPR-300-9, UPR-300-FF-1	33
Interim Closed Out	None	0
No Action	300-3, 300-51, 300-52, 300-FBP:1, 300-FBP:2	5
Not Accepted	None	0
Rejected	None	0

Table 1-5. Classification Status of 300 Area Industrial Complex Waste Sites

Classification Status	Waste Site(s)	Total
Accepted	None	0
Consolidated	None	0
Discovery	None	0
	300-FF-2	
Closed Out	300 SE, 300-10, 300-19, 300-223, 300-23,300-231, 300-262, 300-272, 300-278, 300-35, 300-37, 300-45, 300-53, 300-57, 303-K CWS, 304 CF, 304 SA, 305-B SF, 311 MT1, 311 MT2, 311-TK-40, 311-TK-50, 313 CENTRIFUGE, 313 FP, 313 MT, 313 URO, 313-TK-2, 333-TK-11, 333-TK-7, 334 TFWAST, 334-A-TK-B, 334-A-TK-C, 3718-F BS, 3718-F SF, 3718-F TT1, 3718-F TT2, BTTF, PCTTF, TTTF, UPR-300-41, UPR-300-7	41
Interim Closed Out	300 VTS, 300-109, 300-110, 300-16:2, 300-18, 300-218, 300-251, 300-256, 300-258, 300-259, 300-275[b], 300-33, 300-41, 300-8, 300-80, 303-M SA, 303-M UOF, 333 ESHWSA, 3712 USSA, 618-1, 618-1:1, 618-1:2, 618-2, UPR-300-17, UPR-300-46	25
No Action	300-1, 300-253, 300-29, 300-260, 331 LSLDF	5
Not Accepted	300 SSS, 300-100, 300-103, 300-104, 300-107, 300-108, 300-111, 300-115, 300-12, 300-127, 300-128, 300-129, 300-13, 300-130, 300-17, 300-180, 300-184, 300-190, 300-191, 300-204, 300-205, 300-206, 300-207, 300-208, 300-209, 300-21, 300-210, 300-217, 300-220, 300-225, 300-240, 300-241, 300-242, 300-243, 300-244, 300-250, 300-285, 300-36, 300-42, 300-47, 300-63 , 300-72, 300-73, 300-74, 300-77, 300-79, 300-87, 300-93, 300-94, 300-97, 300-98, 313 CRO, UPR-300-18, UPR-300-31	54
Rejected	300 IFBD, 300 PHWSA, 300-101, 300-102, 300-105, 300-106, 300-112, 300-113, 300-114, 300-116, 300-117, 300-118, 300-119, 300-120, 300-122, 300-124, 300-125, 300-126, 300-14, 300-151, 300-152, 300-153, 300-154, 300-155, 300-156, 300-157, 300-158, 300-159, 300-160, 300-161, 300-162, 300-163, 300-164, 300-165, 300-166, 300-167, 300-168, 300-169, 300-170, 300-171, 300-172, 300-173, 300-174, 300-176, 300-177, 300-178, 300-179, 300-181, 300-182, 300-183, 300-185, 300-186, 300-187, 300-188, 300-189, 300-192, 300-193, 300-194, 300-195, 300-196, 300-197, 300-198, 300-199, 300-200, 300-201, 300-202, 300-203, 300-211, 300-212, 300-213, 300-215, 300-222, 300-226, 300-227, 300-228, 300-230, 300-235, 300-236, 300-237, 300-238, 300-239, 300-248, 300-26, 300-261, 300-266, 300-267, 300-27, 300-271, 300-30, 300-55, 300-56, 300-58, 300-59, 300-60, 300-61, 300-62 , 300-64, 300-65, 300-66, 300-67, 300-68, 300-69, 300-70, 300-71, 300-75, 300-76, 300-78, 300-85, 300-86, 300-88, 300-89, 300-90, 300-91, 300-95, 300-96, 300-99, 315 RSDF, 331-C HWSA, 335 & 336 RSDF, 340 CHWSA, 350 HWSA, 3713 PSHWSA, 3713 SSHWSA, 3746-D SR, 618-6, UPR-300-43	126
Accepted	300 RLWS, 300 RRLWS, 300-11, 300-121, 300-123, 300-15, 300-16, 300-16:1, 300-16:3, 300-175, 300-2, 300-214, 300-219, 300-22, 300-224, 300-24, 300-249, 300-25, 300-255, 300-257, 300-263, 300-264, 300-265, 300-268, 300-269, 300-270, 300-273, 300-274[c], 300-276, 300-277, 300-279, 300-28, 300-280, 300-281, 300-282, 300-283, 300-284, 300-286, 300-287, 300-288, 300-289, 300-290, 300-291, 300-292, 300-293, 300-294, 300-295, 300-296, 300-32, 300-34, 300-39, 300-4, 300-40, 300-43, 300-46, 300-48, 300-5, 300-6, 300-7, 300-9, 307 RB, 309-TW-1, 309-TW-2, 309-TW-3, 309-WS-1, 309-WS-2, 309-WS-3, 313 ESSP, 316-3, 323 TANK 1, 323 TANK 2, 323 TANK 3, 323 TANK 4, 325 WTF, 331 LSLT1, 331 LSLT2, 333 WSTF, 340 Complex, 600-117, UPR-300-1,	92

Table 1-5. Classification Status of 300 Area Industrial Complex Waste Sites

Classification Status	Waste Site(s)	Total
	UPR-300-10, UPR-300-11, UPR-300-12, UPR-300-2, UPR-300-38, UPR-300-39, UPR-300-4, UPR-300-40, UPR-300-42, UPR-300-45, UPR-300-48, UPR-300-5	
Consolidated	300-131, 300-132, 300-133, 300-134, 300-135, 300-136, 300-137, 300-138, 300-139, 300-140, 300-141, 300-142, 300-143, 300-144, 300-145, 300-146, 300-147, 300-148, 300-149, 300-150, 300-81, 300-82, 300-83, 300-84, 300-92, 333 ESHTSSA, 333 LHWSA, UPR-300-13, UPR-300-14, UPR-300-44	30
Discovery	None	0

Notes: Appendix B provides additional information for 300 Area wastes sites. Mobile offices were not considered.

Source: SIS, December 5, 2011.

a. Waste sites 316-1, 316-2, and 316-5 are classified as "Closed Out" in WIDS, but were re-evaluated, and are being carried forwarded into the FS for evaluation due to residual uranium contamination beneath the former waste sites.

b. Waste site 300-275 is a potential landfill located within the boundaries of the 300-FF-1 OU, but has been "plugged-in" to the 300-FF-2 OU ROD through the "plug-in" or "analogous sites" approach (*Interim Remedial Action Record of Decision for the 300-FF-2 Operable Unit, Hanford Site, Benton County, Washington* [EPA/ROD/R10-01/119]).

c. Waste site 300-274 has been remediated and is awaiting the completion of the RSVP process.

BS	=	Burn Shed	PSHWSA	=	Paint Shop Hazardous Waste Satellite Area
BTTF	=	Biological Treatment Test Facility	RB	=	Retention Basin
CF	=	Concretion Facility	RFBP	=	Retired Filter Backwash Pond
CHWSA	=	Complex Hazardous Waste Storage Area	RRLWS	=	Retired Radioactive Liquid Waste Sewer
CRO	=	Copper Remelt Operations	RSDF	=	Retired Sanitary Drain Field
CWS	=	Contaminated Waste Storage	RSVP	=	Remaining Sites Verification Package
ESHTSSA	=	East Side Heat Treat Salt Storage Area	SA	=	Storage Area
ESHWSA	=	East Side Hazardous Waste Storage Area	SF	=	Storage Facility
ESSP	=	East Side Storage Pad	SR	=	Silver Recovery
FBP	=	Filter Backwash Pond	SSHWSA	=	Sign Shop Hazardous Waste Satellite Area
FP	=	Filter Press	SSS	=	Sanitary Sewer System
HWSA	=	Hazardous Waste Storage Area	TFWAST	=	Tank Farm Waste Acid Storage Tank
LHWSA	=	Laydown Hazardous Waste Storage Area	TTTF	=	Thermal Treatment Test Facility
LSLDF	=	Life Sciences Laboratory Drainfield	UOF	=	Uranium Oxide Facility
LSLT	=	Life Sciences Laboratory Trench	URO	=	Uranium Recovery Operations
MT	=	Methanol Tank	VTS	=	Vitrification Test Site
PCTTF	=	Physical and Chemical Treatment Test Facility	WSTF	=	West Side Tank Farm

300 Industrial Area Groundwater Investigations and Remediation. No active groundwater contamination removal and/or in situ treatment under CERCLA or RCRA have taken place to date in the 300 Decision Area. CERCLA activities have primarily involved continuing to characterize contamination in the aquifer, and maintaining ICs on groundwater use. In addition, potential remedial technology treatability testing to immobilize subsurface uranium has been initiated in the 300 Area Industrial Complex. Under the CERCLA program, three OUs are associated with groundwater contamination in the 300 Decision Area:

- 300-FF-5 contaminants are from 300 Area Industrial Complex and 600 Area subregion sources.
- 200-PO-1 contaminants are from 200 East Area sources and include the 400 Area subregion groundwater. The 200-PO-1 OU is outside the scope of this document.
- 1100-EM-1 contaminants are from sources southwest of the 300 Area Industrial Complex subregion (the inactive Horn Rapids Landfill and other non-Hanford Site facilities and activities). The 1100-EM-1 OU is outside the scope of this document.

The following subsections summarize remediation decisions currently in place and interim actions concerning these OUs.

300-FF-5 Groundwater Operable Unit. The 1996 ROD for interim actions in the 300-FF-5 Groundwater OU (300-FF-1 and 300-FF-5 ROD [EPA/ROD/R10-96/143])[4] calls for the following:

- Continued monitoring of groundwater contaminated with above-health-based levels to ensure that concentrations continue to decrease
- ICs to ensure that contaminated groundwater use is restricted to prevent unacceptable exposures

The technical basis for this ROD is contained in *Remedial Investigation/Feasibility Study Report for the 300-FF-5 Operable Unit* (DOE/RL-94-85). Interim action implementation was described in *Operation and Maintenance Plan for the 300-FF-5 Operable Unit* (hereinafter referred to as the 300-FF-5 O&M Plan, DOE/RL-95-73, Rev. 0), which included groundwater and surface water sampling and analysis tasks.

In 2001, the first 5-year review of this ROD included an action item to update and expand the original O&M plan for the OU by adding (1) more requirements for monitoring along the river shoreline, and (2) an assessment of natural attenuation processes as a remedy (300-FF-2 Interim ROD [EPA/ROD/R10-01/119]). The expanded 300-FF-5 O&M Plan was released in 2002 (DOE/RL-95-73, Rev. 1]), along with a new SAP (*300-FF-5 Operable Unit Sampling and Analysis Plan* [DOE/RL-2002-11]). The natural attenuation remedy assessment, along with a description of trends for COPCs, was released in 2005 (*Contaminants of Potential Concern in the 300-FF-5 Operable Unit: Expanded Annual Groundwater Report for Fiscal Year 2004* [PNNL-15127]).

Prepared in 2004, TPA Milestone M-016-04-05 contained new initiatives to refine the CSM for uranium and investigate candidate technologies for remedial action (*Uranium Contamination in the Subsurface Beneath the 300 Area, Hanford Site, Washington* [PNNL-17034]). The associated TPA milestone (M-016-68) had deliverables due by March 31, 2005, which resulted in:

- A work plan for a Phase III FS and LFI plan for uranium in the 300 Area:
  - *Work Plan for Phase III Feasibility Study 300-FF-5 Operable Unit* (DOE/RL-2005-41)
  - *300-FF-5 Operable Unit Limited Field Investigation Plan* (DOE/RL-2005-47)
- An expanded groundwater report for FY 2004, to include a description of the CSM for uranium:
  - *Uranium Geochemistry in Vadose Zone and Aquifer Sediments from the 300 Area Uranium Plume* (PNNL-15121)
  - *Contaminants of Potential Concern in the 300-FF-5 Operable Unit: Expanded Annual Groundwater Report for Fiscal Year 2004* [PNNL-15127]

In 2006, the second 5-year review of this ROD included an action item to complete an FS for the 300 Area groundwater to provide better uranium contamination characterization, update the CSM, validate ecological consequences, and evaluate treatment alternatives for uranium (*The Second CERCLA Five-Year Review Report for the Hanford Site* [DOE/RL-2006-20]). The action item requested polyphosphate injection testing into the aquifer as a potential means to immobilize uranium. Progress in response to the second 5-year review action item for renewed FSs associated with uranium includes:

- Improved characterization of contaminant uranium in the subsurface:

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[4] The initial ROD was expanded geographically to include groundwater beneath the 618-11 and 618-10 Burial Grounds in 2000; however, there were no changes in the specified interim actions (*Explanation of Significant Difference for the 300-FF-5 Record of Decision* [EPA/ESD/R10-00/524]).

- 300-FF-5 LFI (PNNL-16435)
- *A Site-Wide Perspective on Uranium Geochemistry at the Hanford Site* (PNNL-17031)
- *Uranium Contamination in the 300 Area: Emergent Data and Their Impact on the Source Term Conceptual Model* (PNNL-17793)

- Updated the CSM for uranium contamination:
  - *Uranium Contamination in the Subsurface Beneath the 300 Area, Hanford Site, Washington* (PNNL-17034)
  - Yabusaki et al., 2008, "Building Conceptual Models of Field-Scale Uranium Reactive Transport in a Dynamic Vadose Zone-Aquifer-River System"
- Validated ecological consequences:
  - *Current Conditions Risk Assessment for the 300-FF-5 Groundwater Operable Unit* (PNNL-16454)
  - *Investigation of the Hyporheic Zone at the 300 Area, Hanford Site* (PNNL-16805)
  - *Risk Assessment Report for the 100 Area and 300 Area Component of the River Corridor Baseline Risk Assessment* (DOE/RL-2007-21, Draft B)
  - *Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River* (DOE/RL-2008-11)
- Evaluated treatment alternatives for uranium:
  - PNNL-16761, *Evaluation and Screening of Remedial Technologies for Uranium at the 300-FF-5 Operable Unit, Hanford Site, Washington*
  - *Remediation Strategy for Uranium in Groundwater at the Hanford Site 300 Area, 300-FF-5 Operable Unit* (DOE/RL-2008-36)
- Tested polyphosphate injection into the aquifer to immobilize uranium:
  - *Treatability Test Plan for 300 Area Uranium Stabilization Through Polyphosphate Injection* (PNNL-16571)
  - *Challenges Associated with Apatite Remediation of Uranium in the 300 Area Aquifer* (PNNL-17480)
  - *300 Area Uranium Stabilization Through Polyphosphate Injection: Final Report* (PNNL-18529)
  - *300-FF-5 Groundwater Operable Unit Infiltration Test Sampling and Analysis Plan* (DOE/RL-2009-16)

During the LFI for uranium in 2006, volatile organic compounds (VOCs) were unexpectedly encountered in the unconfined aquifer in an interval of Ringold Formation sediment not previously sampled or monitored. A work plan was prepared for additional drilling in 2007 to characterize that contamination (*Sampling and Analysis Instructions for TCE Characterization, 300-FF-5 Operable Unit, Fiscal Year 2007* [SGW-32607]).

The results provided additional information on the nature and extent of the trichloroethene (TCE) contamination, and on uranium contamination:

- TCE is in an interval of finer grained Ringold Formation Unit E sediment (*Volatile Organic Compound Investigation Results, 300 Area, Hanford Site, Washington*, hereinafter called the 300 Area VOC Investigation Results [PNNL-17666]).
- Contaminant uranium is associated with sediment collected during drilling (*Uranium Contamination in the 300 Area: Emergent Data and Their Impact on the Source Term Conceptual Model* [PNNL-17793]).

1.3.2.2 600 Area Subregions

As described earlier, the 600 Area subregion focuses on the 618-10 and 618-11 Burial Grounds and the 316-4 Crib. The following sections address previous remediation and investigation in the 600 Area.

600 Area Facilities. No facilities exist in the 600 Area subregion.

600 Area Vadose Zone and Waste Site Investigations and Remediation. Through August 2011, the following waste sites have been closed out or interim closed out in the 600 Area subregion:

- 618-4, Burial Ground No. 4
- 628-4, Landfill 1D
- 600-259, Inactive Lysimeter Site East End
- 600-259:1, Grout Lysimeter Site
- 600-259:2, Grout Lysimeter Site
- 600-278, Bioremediation Pad Within Gravel Pit 9, Oil-Contaminated Soil
- 600-46, Cutup Oil Dump
- 600-47, Dumping Area North of the 300-FF-1 OU
- 618-13, 303 Building Contaminated Soil Burial Site
- 618-3, Solid Waste Burial Ground No. 3
- 618-5, Burial Ground No. 5
- 618-7, Solid Waste Burial Ground No. 7
- 618-8, Solid Waste Burial Ground No. 8
- 618-9, 300 West Burial Ground
- 600-243, Petroleum Contaminate Soil Bioremediation Pad

Table 1-6 presents the 600 Area subregion waste sites and their WIDS reclassification status.

Groundwater Investigations. Before January 1999, groundwater monitoring well 699-13-3A was installed immediately downgradient (east) of the 618-11 Burial Ground to determine if the burial ground had affected groundwater quality in the area. A groundwater sample collected from this location contained tritium at 1,860,000 pCi/L. The well was sampled again in January 2000 and the tritium concentration had increased to 8,140,000 pCi/L (*Evaluation of Elevated Tritium Levels in Groundwater Downgradient from the 618-11 Burial Ground Phase I Investigation* [PNNL-13228]). The Phase I investigation was designed to rapidly provide pertinent information. The investigation was restricted to sampling existing monitoring wells near the 618-11 Burial Ground. Samples were collected from 22 surrounding wells and analyzed for tritium and a host of other contaminants.

Table 1-6. Reclassification Status of 600 Area Subregion Waste Sites

Classification Status	Waste Sites	Total

Table 1-6. Reclassification Status of 600 Area Subregion Waste Sites

Classification Status	Waste Sites	Total
	300-FF-1	
Closed Out	618-4, 628-4	2
Interim Closed Out	None	0
No Action	UPR-600-15	1
Not Accepted	None	0
Rejected	None	0
Accepted	None	0
Consolidated	None	0
Discovery	None	0
	300-FF-2	
Closed Out	600-278, 600-46, 618-9	3
Interim Closed Out	600-243, 600-259, 600-259:1, 600-259:2, 600-290:1, 600-47, 618-13, 618-3, 618-5, 618-7, 618-8	11
No Action	600-22	1
Not Accepted	600-155, 600-210, 600-244, 600-245, 600-248, 600-255, 600-265, 600-276, 600-357, 600-366, 600-64, 600-96, 600-97	13
Rejected	600-1, 600-246, 600-247, 600-249	4
Accepted	316-4, 600-290, 600-290:2, 600-367, 600-63, 618-10, 618-11, UPR-600-22	8
Consolidated	UPR-600-1, UPR-600-10, UPR-600-2, UPR-600-3, UPR-600-4, UPR-600-5, UPR-600-6, UPR-600-7, UPR-600-8, UPR-600-9	10
Discovery	None	0

Notes: Additional information is provided in Appendix B. Mobile offices were not considered.

Potential waste sites 600-58, 600-59, 600-60, and 600-62, which are classified in WIDS as "Accepted", are not included in this site count. They are active facilities leased by Bonneville Power Administration (BPA),which will be active through at least 2027.

Source: SIS, December 5, 2011.

The results of the investigation indicated that the 618-11 burial ground is the source of tritium in the groundwater. However, inventories of the waste from the facilities from which the 618-11 Burial Ground received waste do not specifically state that tritium was disposed there, although hydrogen gas (a possible misnomer) was identified (*Evaluation of the Fate and Transport of Tritium Contaminated Groundwater from the 618-11 Burial Ground* [PNNL-15293]). The wells sampled in Phase I of the investigation placed rough boundaries on the extent of the groundwater tritium contamination.

1.3.2.3 400 Area Subregion

As noted earlier, the 400 Area focuses on the FFTF reactor and its associated facilities and waste sites.

400 Area Facilities. As of August 2011, two facilities were demolished (the 401 FFTF Visitor's Center and the 4722-D Carpenter Shop) and one mobile office was removed.

400 Area Vadose Zone Investigations. As of August 2011, the following waste sites were closed out:

- 400-31, Sodium Storage Facility, 402 Building
- 400-5, Septic Tank or Cistern
- 427 HWSA, 427 Building Fuel Cycle Plant Hazardous Waste Storage Area (HWSA)
- 4831 LHWSA, 4831 Laydown Hazardous Waste Storage Area (LHWSA)
- 4843, 4843 Alkali Metal Storage Facility

Table 1-7 presents the 400 Area waste sites and their WIDS reclassification status.

Table 1-7. Reclassification Status of 400 Area Waste Sites

Classification Status	Waste Sites	Total
	300-FF-2	
Closed Out	4843, 400-31, 400-5, 427 HWSA, 4831 LHWSA, 437 MASF	6
Interim Closed Out	None	0
No Action	400-36	1
Not Accepted	400 FD10, 400 FD10A, 400 RFD, 400 SBT, 400-10, 400-15, 400-2, 400-20, 400-21 , 400-22, 400-26, 400-28, 400-29, 400-29:1, 400-29:10, 400-29:11, 400-29:12, 400-29:13, 400-29:14, 400-29:15, 400-29:16, 400-29:17, 400-29:18, 400-29:19, 400-29:2, 400-29:3, 400-29:4, 400-29:5, 400-29:6, 400-29:7, 400-29:8, 400-29:9, 400-3, 400-34, 400-35	35
Rejected	400 FD1A, 400 FD1B, 400 FD2, 400 FD3, 400 FD4, 400 FD5, 400 FD6, 400 FD7, 400 FD8, 400 FD9, 400 RSP, 400 RST, 400 SS, 400 STF, 400-1, 400-11, 400-12, 400-13, 400-14, 400-16, 400-17, 400-18, 400-19, 400-23, 400-24, 400-25, 400-32, 400-33, 400-39, 400-4, 400-6, 400-7, 400-8, 400-9, 403 FD, 4713-B FD, 4713-B HWSA, 4713-B LDFD, 4721 FD, 4722 PSHWSA, 4722-B FD, 4722-C FD, UPR-400-1	43
Accepted	400 PPSS, 400-37, 400-38	3
Consolidated	None	0
Discovery	None	0

Notes: Additional information is provided in Appendix B. Mobile offices were not considered.

Source: SIS, December 5, 2011.

FD = French Drain
HWSA = Hazardous Waste Storage Area
LDFD = Loading Dock French Drain
LHWSA = Laydown Hazardous Waste Storage Area
MASF = Maintenance and Storage Facility
PPSS = Process Pond and Sewer System
PSHWSA = Paint Shop Hazardous Waste Satellite Area
RFD = Retired French Drain
RSP = Retired Sanitary Pond
RST = Retired Septic TankSBT = Sand Bottom Trench
STF = Sanitary Tile Field

400 Area Groundwater Investigations. Groundwater activities involve monitoring the 400 Area water supply well (well 499-SO-7) under the AEA. Monitoring is conducted to provide information on the potential impact of sitewide contamination (primarily tritium, nitrate, and iodine-129) on the water supply

wells (*Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2* [DOE/RL-2010-11]). The only groundwater analyte exceeding a DWS in the 400 Area water supply well was manganese, with an unfiltered result of 131 µg/L (the secondary DWS is 50 µg/L); a filtered sample collected at the same time had a manganese concentration of 11 µg/L.

1.3.3 Waste Site Consideration in the RI/FS

All 300 Decision Area waste sites were evaluated to determine if they complied with HHE protectiveness criteria. While the unique factors of each waste site were considered, the general evaluation of the waste sites was based on their classification/reclassification status:

- Sites with a "closed out" status were reviewed to confirm that this determination has been made under appropriate regulatory authority. Where a closed out status was appropriate, no further review of site information was performed, and the site was not considered further within the RI/FS.
- Sites with a "rejected" or "not accepted" status were reviewed to determine if new information was available that contradicts the existing documented basis for rejection or nonacceptance. Where the existing classification/reclassification was not found to be inappropriate, the site was not considered further within the RI/FS process. No rejected or not accepted sites at 300 Area were found to have information that contradicted the existing determinations. The existing determinations are documented for each site in accordance with, *Tri-Party Agreement Handbook Management Procedures* (RL-TPA-90-0001) TPA-MP-14, "Maintenance of the Waste Information Data System (WIDS)."
- Sites with a "no action" or "interim closed out" reclassification status based on confirmatory and/or verification data are all considered within the overall RI and have been quantitatively evaluated against preliminary remediation goals (PRGs) as described in Chapters 5 through 7. Sites with a no action or interim closed out reclassification with a basis other than direct data (e.g., historical decommissioning data) were considered on a site-by-site basis.
- Sites with an "accepted" classification status fit within two broad general subcategories:
  - Sites where an interim remedial action requirement has been identified in interim decision documents, but for which interim remedial action had not been completed (via an approved waste site reclassification). These sites were considered within the RI from the standpoint that a remedial action determination has already been made. Because site-specific data were not yet available, these sites were carried into the FS.
  - Any new discovery sites that are identified as interim actions to continue or under future final actions will also be addressed by an additional process established through the final action ROD, but the process is functionally identical to that used under the 300-FF-2 Interim ROD (EPA/ROD/R10-01/119).

1.3.3.1 300 Decision Area Waste Sites Requiring No Further Consideration

Waste sites with a closed out, rejected, or not accepted classification/reclassification status were reconsidered and determined to have sufficient existing basis for these determinations. These sites will not be addressed further in this RI/FS. All waste sites identified in Appendix C of the *Hanford Federal Facility Agreement and Consent Order Action Plan*, hereinafter called the Tri-Party Agreement Action Plan or TPA Action Plan (Ecology et al., 1989b), will be included in the ROD in order for final remedy decision to be documented, even if no further remedial activities are needed.

1.3.3.2 Waste Site Cleanup Documentation

Following completion of the interim remedial actions at a waste site in accordance with the applicable interim action ROD, a cleanup document is prepared. This document contains verification information that the attainment of interim or final remedial action goals (RAGs) and interim or final RAOs have been achieved. These RAOs are contained in the 300-FF-1 ROD and 300-FF-2 ROD. This documentation usually includes a description of the interim remedial action conducted, sampling results, disposal information, and a chronology of events.

The exposure factors and assumptions used in the industrial scenario are defined in remedial action/RD reports. Soil RAGs for protection of groundwater also reflected industrial use. In addition, RAGs were developed to protect aquatic organisms in the Columbia River. However, RAGs were not developed for the protection of terrestrial ecological receptors due to the absence of regulatory guidance at that time. Cleanup verification packages (CVPs) currently consider "Model Toxics Control Act—Cleanup" (hereinafter called MTCA [WAC 173-340]) standards for terrestrial receptors.

1.3.3.3 Orphan Site Evaluation Process

The OSE process is a systematic approach for reviewing land parcels and identifying potential waste sites within the River Corridor that are not currently listed in existing CERCLA decision documents, such as RODs. An OSE scope includes conducting historical reviews and field investigations; identifying information gaps; conducting integration activities, which includes briefing DOE-RL and the lead regulatory agency; completing the TPA-MP-14 process; and issuing a summary report. Table 1-8 provides a general scope for each subtask as it applies to the reactor/operation area orphan sites evaluation. New waste sites identified through the OSE process may be added to the 300-FF-2 ROD through a fact sheet, characterized to determine whether cleanup is required, and addressed in accordance with the selected remedy.

Table 1-8. Orphan Sites Evaluation Subtask Summary

Subtask	Scope
Historical review	Review historical information (e.g., documents, photographs, drawings, and geophysical surveys) associated with facilities, piping systems, operational process, and waste sites to identify orphan sites and target areas for field investigation.
Field investigation	Conduct systematic foot-based land survey of operational and non-operational areas to document potential orphan sites (field-based observation), follow-on potential orphan sites identified from historical review, identify miscellaneous restoration items observed, and identify stewardship elements observed. Geophysical surveys also may be conducted in target areas as part of the field investigation.
Gap analysis	Identify and prioritize any information gaps after completion of historical review and field investigation subtasks. Conduct follow-up in identified areas to address information gaps to the extent possible. This subtask may include supplemental historical review and/or field investigation activities as needed.
Integration	Prepare draft lists of an initial grouping of potential orphan sites, miscellaneous restoration items, and stewardship elements. Conduct briefings of evaluation results with WCH field remediation project, DOE-RL, and the lead regulator. Establish final list of new orphan sites and complete write-up/database entry for orphan sites, miscellaneous restoration items, and stewardship elements. Complete the Discovery Site Checklist for identified sites.

Table 1-8. Orphan Sites Evaluation Subtask Summary

Subtask	Scope
Summary report	Develop report to summarize results from each orphan site evaluation conducted and issue to DOE-RL (RCCC contract deliverable C.2.10).

RCCC = River Corridor Closure Contract
DOE-RL = U.S. Department of Energy, Richland Operation Office
WCH = Washington Closure Hanford

Any potential orphan site is identified during the historical review or field investigation activities and evaluated because it is potentially contaminated. They are a manmade feature, item, or activity area within the river corridor that (1) meets the TPA-MP-14 criteria for waste site identification, (2) is not identified for characterization or cleanup within the existing CERCLA decision documents, and (3) has been presented to and accepted by DOE-RL and the lead regulatory agency (EPA or Ecology).

The OSE for the 300-FF-1 OU started in FY 2004 and was completed in April 2005. The historical review identified additional components of the 300-276, 3607 SSS waste site that required attention. The field evaluation identified two new waste sites: 300-275, Potential Landfill on River Edge and 300-274, 300-FF-1 Scattered Surface Debris. Although these newly discovered waste sites are physically located within the boundary of the 300-FF-1 OU, the sites were addressed with the 300-FF-2 OU scope. The OSE process for the 300-FF-2 OU was identified as a data need in the 300 Area RI/FS Work Plan (DOE/RL-2009-30). Chapter 2 discusses the OSE process in greater detail.

1.3.3.4 Nonoperational Area Evaluation

In 2011, an evaluation of the River Corridor nonoperational areas was completed. The nonoperational evaluation considered the five transport mechanisms, physical features, and climate conditions that could influence transport, and used surface and near surface information from a number of available sources:

- OSEs
- Air emissions reports
- Environmental monitoring programs
- Statistical modeling

Appendix L describes the nonoperational evaluation process for the River Corridor, data and information used, and conclusions and recommendations. It includes specific results and conclusions for the 300 Decision Area.

1.3.4 300 Decision Area Regulatory Basis

The 300 Decision Area has had two RODs issued:

- The 300-FF-1 and 300-FF-5 ROD (EPA/ROD/R10-96/143) includes final remedial actions for the 300-FF-1 Source OU and interim remedial actions for the 300-FF-5 Groundwater OU.
- The 300-FF-2 Interim ROD (EPA/ROD/R10-01/119) includes interim remedial actions for the 300-FF-2 Source OU.

Modifications to these RODs (explanations of significant differences) have been issued to address changes in cleanup standards, expansion of the 300-FF-5 Groundwater OU, and addition of waste sites to 300-FF-2 OU. The remedial actions implemented for the 300-FF-1 waste sites are listed and discussed in this report to provide a complete picture of the potential vadose zone contamination remaining beneath these waste sites.

Industrial future land use was identified in these RODs. This land use is consistent with the current industrial land that includes such facilities Energy Northwest, Hanford Patrol Training Acadamy, HAMMER Training Facility, etc. In addition, R&D activities within the 300 Area Industrial Complex are ongoing and projected to continue within defined facilities through at least 2027. The large amount of current and planned future industrial land use in this area is consistent with the land use identified in the previous RODs.

Since these RODs were issued, DOE has also issued the CLUP (DOE/EIS-0222-F) and corresponding CLUP: Supplemental Analysis (DOE/EIS-0222-SA-01), and the *Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS)* (DOE, 1999a) that establishes an industrial land use for the majority of the 300 Decision Area. The remainder of land is designated as conservation (mining).

Although the future land use in the 300 Area is designated primarly as industrial, DOE has elected to clean up a large portion of the 300 Area to a more protective land use standard of unrestricted for the areas outside the 300 Area Industrial Complex and 618-11 Burial Ground (adjacent to Energy Northwest).

The RI/FS supports the final remedial actions for the 300 Decision Area and will result in a ROD for the 300-FF-2 and 300-FF-5 OUs and depending on the alternative, a ROD amendment for the 300-FF-1 OU. This new ROD will consider the interaction between sources, groundwater, and surface water as a whole system within the 300 Decision Area.

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2 Study Area Investigation

Data needs were identified during the development of the 300 Area RI/FS Work Plan (DOE/RL-2009-30), as a result of document review and evaluation of existing data. The details of the RI/FS scope of work are documented in the 300 Area RI/FS Work Plan (DOE/RL-2009-30) and the 300 Area SAP (DOE/RL-2009-45). Results of the RI/FS activities are presented in Chapters 3 and 4. The sampling program, including the number of samples and associated analytical methods, are presented in the 300 Area SAP (DOE/RL-2009-45).

Highlights

- Eleven groundwater monitoring wells and five temporary groundwater monitoring wells were installed to characterize the vadose zone, unconfined aquifer, and the Ringold Formation lower mud unit.
- 234 soil samples were collected and analyzed from boreholes during drilling of monitoring wells and temporary wells.
- Three rounds of groundwater samples were collected for analysis of all COPCs to address uncertainties associated with the groundwater risk assessment.
- 120 river porewater samples, 8 surface water samples, and 8 sediment samples were collected and analyzed to address the uncertainty related to the nature and extent of groundwater contamination entering the Columbia River.
- Orphan site evaluations were performed in the 300 Area and the 400 Area, yielding 18 and 2 orphan sites in the respective areas.

The following sections describe the RI/FS field activities, beginning in January 2010, as well as other investigations and ongoing activities that contributed to this RI/FS. These additional investigations include those with the potential to affect the development of remedial action alternatives, including the following:

- *Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River* (hereinafter called the Columbia River RI Work Plan [DOE/RL-2008-11])
- *River Corridor Baseline Risk Assessment, Volume I, Ecological Risk Assessment* (DOE/RL-2007-21, Volume I)
- *River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment* (DOE/RL-2007-21, Volume II)
- *Columbia River Component Risk Assessment, Volume I: Screening-Level Ecological Risk Assessment* (DOE/RL-2010-117, Volume I)
- *Columbia River Component Risk Assessment, Volume II: Baseline Human Health Risk Assessment* (DOE/RL-2010-117, Volume II currently in draft)
- Research being conducted by PNNL under the Integrated Field Research Center (IFRC)
- Ongoing groundwater and aquifer tube monitoring

2.1 Remedial Investigation Activities

The RI field effort included drilling and sampling temporary wells; drilling and installing groundwater monitoring wells; sampling of porewater, surface water, and sediment to investigate groundwater upwelling into the Columbia River; and collecting and analyzing groundwater samples to define the nature and extent of contamination and to support risk characterization. The relationship between the 300 Area RI/FS Work Plan (DOE/RL-2009-30) data needs and the corresponding RI field efforts are presented in Table 2-1. Table 2-1 also presents where in this report the results of the investigations are discussed in detail. Table 2-2 summarizes the field activities conducted in accordance with the data needs identified in the 300 Area RI/FS Work Plan (DOE/RL-2009-30). Table 2-3 summarizes the other

investigative work performed to support the RI/FS. The locations of field activities that were conducted specifically under this RI/FS are presented in Figure 2-1.

As described in the 300 Area RI/FS Work Plan (DOE/RL-2009-30), the data needs can be grouped under several categories:

- 300 Area
  - Sources in the vadose zone (data gap 1)
  - Sources for contamination in the groundwater (data gaps 2, 3, 4, and 5)
  - Distribution of contaminants in the vadose zone (data gaps 6, 7, and 8)
  - Distribution of contaminants in the groundwater (data gaps 9, 10, 11, 12)
  - Fate and transport in the vadose zone (data gaps 13, 14, and 15)
  - Fate and transport in the groundwater (data gaps 16, 17, 18, 19, 20, and 21)
  - Treatability tests (data gap 22 and 23)
  - Feasibility study (data gap 24, 25, and 26)
- 400 Area
  - Sources in the vadose zone (data gap 27)
  - Distribution of contaminants in the vadose zone (data gap 28)
- 600 Area
  - Sources in the vadose zone (data gap 29)
  - Distribution of contaminants in the vadose zone (data gap 29, 30, 31, and 32)

Table 2-1 presents the data gaps and the work that was done to fill the need adequately to make a remedial action decision and support the ROD.

2.1.1 Work Plan Deviations

This section provides information on deviations from work proposed in Chapter 3 of the 300 Area RI/FS Work Plan (DOE/RL-2009-30). Table 2-1 presents a summary of the scope of work performed to date (Fall 2011) that is related to the various Data Needs, which are intended to fill gaps in information and data sets, as described in the 300 Area RI/FS Work Plan (DOE/RL-2009-30). Additional information is presented below for those Data Needs where subsequent RI activities deviated from the activities proposed in the 300 Area RI/FS Work Plan (DOE/RL-2009-30). The presentation follows the sequence and terminology as used in the 300 Area RI/FS Work Plan (DOE/RL-2009-30).[1]

[1] "Data gap" refers to information that is missing from the conceptual model and to actual field or laboratory observations; "data need" refers to field and laboratory observations and measurements.

Table 2-1. Data Needs and Sampling Program for the 300 Area Remedial Investigation

Data Gap	Data Need	Scope of Work	Required by SAP*?	Work Conducted/Section with Discussion	Data Gap Filled?
300 Area Sources (Vadose Zone and Groundwater)					
1) Unidentified sources of contamination may exist within and in the soils adjacent to engineered facilities and structures.	Identify new waste sites and potential sources of contamination in the 300 Area.	Complete OSE process in the 300 Area (industrial complex).	No	The OSE process was completed for the 300 Area (industrial complex). Chapter 2, Section 2.1.3.1	Yes
2) The significance of contaminant uranium remaining in the vadose zone and PRZ (current and historical) in areas directly beneath and in the immediate vicinity of remediated waste sites is not fully understood with respect to the persistence of the groundwater plume.	Collect information on (1) the inventory and mobility characteristics of contaminant uranium beneath remediated waste sites, and (2) the current geochemical and hydrologic processes potentially acting to cause that uranium to resupply the groundwater plume.	Drill four boreholes within the footprints of former liquid waste disposal facilities. Samples of sediment and porewater will be collected to determine the contaminant content and contaminant mobility characteristics at various depths in the vadose zone. Drill five boreholes at increasing distances from the footprints of the waste sites to develop transects along potential uranium migration routes.	Yes	Collected sediment samples and groundwater samples from the interstitial spaces in the PRZ above the groundwater plume at the prescribed locations presented below: • Four boreholes were drilled and sampled. Borehole locations included two in North Process Pond (C7653 and C7654), one in South Process Pond (C7660), and one in 300 Area Process Trenches (C7655). These borings were completed as groundwater monitoring wells. • Five boreholes were drilled and sampled. Boreholes (C8026, C8027, C8028, C8029, and C8030) were placed in locations near the seasonal uranium hot spot just south of the 300 Area Process Trenches and North Process Pond. These borings were completed as temporary monitoring wells. Chapter 3, Physical Characteristics Chapter 4, Nature and Extent	Yes
3) Contaminant uranium could potentially sequester on sediment near the Columbia River due to river-induced geochemical condition changes. The magnitude of this phenomenon and its potential to act as a continuing source for resupplying the groundwater plume has not been determined.	Sediment and water samples from the subsurface zone impacted by Columbia River water; determination of the contaminant uranium inventory and laboratory tests to reveal the mobility characteristics of that uranium.	Drill two boreholes near the Columbia River where groundwater interacts with river water. Collect sediment and water samples to determine contaminant content and contaminant mobility characteristics at various depths in the vadose zone and aquifer.	Yes	Two boreholes were drilled and sampled. Boreholes C7656 and C7663 were placed close to the river, east of former sanitary leach trenches, and east of Well 399-3-9. Collected sediment and porewater samples from the near river zone where groundwater interacts with river water. Chapter 3, Physical Characteristics Chapter 4, Nature and Extent	Yes

Table 2-1. Data Needs and Sampling Program for the 300 Area Remedial Investigation

Data Gap	Data Need	Scope of Work	Required by SAP*?	Work Conducted/Section with Discussion	Data Gap Filled?
4) The source is unknown for the original VOC(s) that have degraded to cis-1,2-DCE near Well 399-1-16B, and there is the possibility that DNAPL remains undetected.	Identify the original VOCs and the pathways leading to the cis-1,2-DCE observed at Well 399-1-16B.	(1) Perform computer simulations of the release of PCE similar to historical releases. (2) Collect additional measurements of VOC concentrations in groundwater under conditions of withdrawal at Well 399-1-16B. Hydraulic parameters to be determined as part of withdrawal operations. Include analyses for VOCs for water samples from equivalent aquifer horizons in characterization boreholes 6, 8, and 9.	1) No 2) Yes	A simple flow and transport model, REMChlor, was used to assess whether a PCE release at the southern end of the 300 Area Process trenches could be the source for the observed PCE, TCE, and cis-1,2-DCE groundwater concentrations observed in Well 399-1-16B. A pump test of Well 399-1-16B was not conducted, as proposed in the Work Plan. The low permeability of the sediment monitored by this well's screened interval results in very slow groundwater withdrawal from the well, as shown by the withdrawal rates during purging the well prior to routine groundwater sampling. Routine sampling and analysis of groundwater at this well and nearby wells has continued under the 300-FF-5 O&M Plan (DOE/RL-95-73), and concentration trends for cis-DCE continue to be consistent with historical and expected trends. Chapter 5, Fate and Transport	Yes. The source for cis-DCE in the sediment interval monitored by 399-1-16B remains uncertain, although the possibility that it was caused by a single UPR of 454 L (120 gal) of PCE at the 300 Area Process Trenches (or a similar amount of TCE at a nearby location) has increased support as an explanation. While no evidence for a DNAPL remaining in saturated Hanford gravels is present currently (much higher concentrations of dissolved VOC would be seen in routine groundwater monitoring results), the rapid groundwater movement in the upper unconfined aquifer would likely have transported any such pool away from the secondary source area during the decades since initial release to the environment.
5) The origin of the TCE discovered in the finer grained interval of Ringold Formation is not known.	Additional information regarding the potential source(s) for the VOC contamination observed in an interval of finer-grained Ringold Formation sediment within the unconfined aquifer.	Additional source interim remedial actions in the 300 Area may provide new information to identify a source. However, no specific investigations to identify the origins for this contamination were proposed.	No	Ongoing waste site excavations, facility demolition, and historical investigations did not reveal information to identify a source. In addition, the characterization drilling conducted during the recent RI activities did not reveal any new information regarding specific primary sources for TCE observed in the interval of finer-grained Ringold Formation Unit E sediment. VOC was generally not detected in vadose zone sediment. However, the drilling did reveal the occurrence of cis-DCE, a degradation product of TCE (and PCE) in a separate sediment interval of the unconfined aquifer and in proximity to the TCE occurrence that was the subject of this Data Need. Interpretation of the new distribution data does suggest that the VOC contamination is related to past planned releases or UPRs of TCE/PCE to the infiltration ponds and trenches, and possible as UPR(s) from the process sewer system. Chapter 4, Nature and Extent	Yes. New information has been developed as part of this RI that reduces the uncertainty as to the origin for TCE in the finer-grained interval of Ringold sediment, although precise identification of the primary source may not ever be discovered.
Distribution of Contaminants—300 Area					
6) The extent of contaminant uranium in the shallow vadose zone beneath and adjacent to 300 Area facilities and waste-disposal sites is not defined for waste sites not yet remediated.	Conduct sampling to characterize the extent of contamination in the sediment adjacent to and beneath the sites during remedial actions at future waste sites.	Continue with ongoing interim remedial actions. The strategy has been efficient in obtaining the necessary data during remediation using the observational approach. Data will continue to be obtained that document the extent of residual contamination following completion of the interim remedial action.	No	Limited interim remedial actions have occurred in the 300 Area during the RI period and the characterization data has been incorporated.	Yes

Table 2-1. Data Needs and Sampling Program for the 300 Area Remedial Investigation

Data Gap	Data Need	Scope of Work	Required by SAP*?	Work Conducted/Section with Discussion	Data Gap Filled?
7) The uranium contamination beneath the high volume, liquid waste disposal sites in the vadose zone between the bottom of the excavations and the PRZ is known from a limited number of characterization boreholes. The possibility exists that localized zones of relatively high concentrations of contaminant uranium have gone undetected.	Laboratory analytical results for sediment and groundwater samples from boreholes drilled through the footprints of former liquid waste disposal facilities and adjacent areas along contaminant migration routes.	Drill and collect sediment samples from the vadose zone and the PRZ beneath the high volume, liquid waste disposal sites. These boreholes are the same described as part of Data Need 2.	Yes	See Data Need 2. Analytical results for uranium in sediment samples collected during drilling at locations within the footprints of former liquid waste disposal sites are available for a) total uranium in the sample, and b) uranium leachable by various ratios of water-to-sediment, i.e., 'batch leach tests.' Partial results are available for the initial de-ionized water extractions, but additional extractions using leachants of increasing aggressiveness were not completed. Results for sediment moisture content and geophysical logging at these boreholes are presented in Appendix C. Chapter 3, Physical Characteristics Chapter 4, Nature and Extent	Partially. The batch leach tests were completed and identified a wide range of calculated K_ds. The multiple extractions of uranium from sediment samples were partially completed and identified the distribution of readily leachable uranium in the vadose zone.
8) Data to describe the lateral distribution of uranium in the deeper portion of the vadose zone away from remediated waste sites are very limited. The information available is based primarily on an understanding of historical conditions during the fuels fabrication years, and not on direct observation from characterization boreholes.	Analyses of vadose zone sediment samples from borehole locations away from the footprints of principal liquid waste disposal sites will be used to refine estimates for the distribution of contaminant uranium.	Drill five boreholes in the west and southwest portions of plume. Collect sediment and water samples to determine contaminant content and contaminant mobility characteristics at various depths in the vadose zone and aquifer. Data from boreholes 6 and 7 will also contribute to resolving this data need, as will information from the five temporary transect wells, a to e, from Data Need 2.	Yes	Collected and analyzed soil samples and groundwater samples from the interstitial spaces in the PRZ from the temporary wells (C8026, C8027, C8028, C8029, and C8030) and from permanent wells (C7657, C7658, C7659, C8245 [replacement for C7661], and C7662). Sample results and observations from Monitoring Wells (C7656 and C7663) were also evaluated. Chapter 3, Physical Characteristics Chapter 4, Nature and Extent	Yes
9) Although the distribution of uranium contamination in the aquifer from the existing monitoring well and aquifer tube networks is well described in general terms, details on the vertical distribution are not available.	Discrete measurements of uranium concentrations at various depths in the unconfined aquifer under varying water table conditions.	Perform vertical profiling at eight existing and new wells. The methods include various tests at a subset of the current monitoring network, and new wells completed as part of this RI. Methods include groundwater sampling at discreet depths in the well bore and use of probes to characterize water movement in the well bore.	No	Depth discrete groundwater sampling at individual monitoring wells was described in the Work Plan as potentially providing useful information regarding the vertical distribution of uranium contamination in the unconfined aquifer. Recent research results from IFRC activities have revealed that significant vertical mixing can occur in the well bore because of fluctuations in water table elevation, as driven by river stage fluctuations. Also, a technology to do vertical sampling within a well bore is not yet available that provides samples with an acceptable level of uncertainty as to what the sample actually represents in the aquifer outside of the well bore. For these reasons, depth discrete groundwater samples were not collected from existing wells during the 2010/2011 remediation investigation field activities. However, numerous depth discrete groundwater samples were collected from the unconfined aquifer during drilling at the eleven new RI locations. These samples provide new information on the vertical distribution of uranium in the aquifer, and complement vertical distribution information provided by samples from aquifer tubes beneath the 300 Area shoreline. Chapter 4, Nature and Extent	Yes. Information obtained under the 300-FF-5 O & M Plan (DOE/RL-95-73), along with research conducted under the IFRC, is deemed sufficient to meet this Data Need for the purpose of the RI, and to assist in identifying the long-term monitoring needs.

Table 2-1. Data Needs and Sampling Program for the 300 Area Remedial Investigation

Data Gap	Data Need	Scope of Work	Required by SAP*?	Work Conducted/Section with Discussion	Data Gap Filled?
10) Monitoring well coverage of the hydrologic unit presumed to contain the bulk of uranium contamination is uneven, with principal weaknesses in coverage at the footprints of former liquid waste disposal sites and near the perimeter of the plume, especially the west and southwest portions.	Fill coverage gaps in the groundwater monitoring network for the uranium plume by completing monitoring wells at each of the 11 characterization borehole sites.	Complete each of the 11 characterization boreholes as a groundwater monitoring well. Unless other than expected conditions are encountered during characterization, well screens will be positioned to monitor the uppermost hydrologic unit (i.e., saturated Hanford formation sediment). New wells include two in the North Process Pond; one in South Process Pond; one in 300 Area Process Trenches, five in the west and southwest portions of uranium plume, and two near the Columbia River. Conduct quarterly sampling of each new monitoring well for the first year, with a reduction in frequency for subsequent years if warranted.	Yes	Eleven new groundwater monitoring wells have been installed at locations that will fill coverage gaps in the existing 300-FF-5 OU monitoring network. Most of the new wells have screened intervals that cover the uppermost portion of the unconfined aquifer, where essentially all contamination is contained that has potential for further migration along environmental pathways. Chapter 4, Nature and Extent	Yes.
11) The extent of VOC contamination to the north and northwest of Well 399-1-16B is not clearly defined by the current monitoring well network.	Additional field observations of water quality in groundwater from the lower portion of the unconfined aquifer near Well 399-1-16B, particularly upgradient from the well and within the flow path from potential sources.	Collect groundwater samples for VOC analysis during characterization borehole drilling at locations 8 and 9 (North Process Pond), location 10 (300 Area Process Trenches), and location 6 (a near river site east of the former sanitary leach trenches) from depths that reach a comparable hydrologic unit in the unconfined aquifer as at Well 399-1-16B.	Yes	Collected and analyzed groundwater samples during drilling at groundwater monitoring wells C7653, C7654, and C7655 (399-1-54, 399-1-55, and 399-1-56.) Analyses included VOCs, uranium, major anions (including nitrate and nitrite) and cations, and field parameters (temperature, pH, turbidity, specific conductance, and dissolved oxygen). Chapter 4, Nature and Extent	Yes. The additional drilling locations and results for groundwater samples collected during drilling lend support to the conclusion that the cis-DCE observed at 399-1-16B is a localized occurrence in relatively low permeability sediment (i.e., very low potential for use as a water supply aquifer, especially considering the nearby availability of more productive hydrologic units for supplying groundwater).
12) The lateral extent of the contaminated portion of the finer-grained interval of Ringold Formation sediment is based on a limited number of observation locations that do not cover the potential extent beneath the 300 Area and exposure locations in the Columbia River.	Additional analytical results for groundwater collected from the finer-grained interval from areas beneath the 300 Area where data do not currently exist, and from the adjacent Columbia River substrate.	New information on the contamination extent will be provided by the characterization drilling at the proposed 11 locations and by work under the RCBRA (Columbia River RI Work Plan [DOE/RL-2008-11]). Information from geophysical research activities that focus on defining areas where groundwater preferentially discharges from the aquifer to the riverbed (DOE-sponsored research using fiber optic cables to reveal temperature anomalies) will contribute to identifying riverbed locations where this contamination may be released.	No	New information on the distribution of TCE in the finer-grained interval of Ringold Unit E sediment has been obtained from samples collected during drilling at the eleven characterization borehole locations. Analytical results for groundwater samples collected during drilling are presented in Chapter 4. Stratigraphic information on the distribution of the sediment interval of interest has been incorporated into a geographical information system (EarthVision™) and new subsurface conditions maps prepared that present a refined depiction of this interval. Analytical results for riverbed sediment porewater samples collected under the RCBRA/Hanford Site Releases to the Columbia River RI are now available for further interpretation activities. U.S. Geological Survey research using geophysical methods to outline areas of preferential groundwater discharge through the riverbed adjacent to the 300 Area confirm previous concepts and estimates. Chapter 4, Nature and Extent	Yes. Analytical results from drilling samples and riverbed sediment porewater sampling are available on the distribution of this contamination. Interpretation of the new field observations confirm that the occurrence of TCE in this interval of Ringold Formation Unit E sediment is relatively localized and that the sediment interval has very low permeability with essentially no potential to act as a water supply aquifer.

Table 2-1. Data Needs and Sampling Program for the 300 Area Remedial Investigation

Data Gap	Data Need	Scope of Work	Required by SAP*?	Work Conducted/Section with Discussion	Data Gap Filled?
Fate and Transport of Contaminants—300 Area					
13) The physical, geochemical, and hydrogeologic characteristics of the vadose zone sediment beneath the high volume, liquid waste disposal sites between the bottom of the excavations and the PRZ are not sufficiently characterized to understand the transport mechanisms for uranium. These sites were remediated as part of *Record of Decision for the 300-FF-1 and 300-FF-5 Operable Units, Hanford Site, Benton County, Washington* (EPA/ROD/R10-96/143), but the uncertain relationship between residual amounts of uranium at the bottom of the excavations to dissolved concentrations in the underlying groundwater remains	Additional sediment samples from beneath remediated high volume, liquid waste disposal sites, extending from the bottom of the excavation to groundwater. Additional evaluation of physical properties, geochemical properties, and the hydraulic characteristics, with particular emphasis on the region near the PRZ.	Drill four boreholes and collect sediment and porewater samples from the vadose zone and the PRZ beneath the high volume, liquid waste disposal sites. The locations are to be the same as for Data Needs 2 and 7.	Yes	Collected and analyzed vadose zone sediment and interstitial water during the drilling of Boreholes C7653, C7654, C7660, and C7655 located in the former high-volume liquid discharge waste sites. However, laboratory analyses of sediment samples intended to reveal information on the mobility characteristics of uranium in the sample were only partially successful. The batch leach tests that were conducted on some vadose zone sediment samples did not produce results to date that can be reliably used to infer uranium mobility characteristics for contamination in those sediments. Treatability testing involving use of polyphosphate in the vadose zone to immobilize uranium was cancelled during the early phase of the testing due to funding constraints. Chapter 4, Nature and Extent Chapter 5, Fate and Transport	Partially. New field data on the distribution of uranium in the vadose zone has been collected. The batch leach tests were completed, resulting in a wide range of calculated K_ds. The multiple extraction tests were partially completed and identified the readily leachable uranium content. This information is used to address this data gap.
14) The hypothesis that labile or extractable uranium is present in the vadose zone away from the footprints of the remediated high volume, liquid waste disposal sites is not well tested, yet those subsurface areas may play a role in the long-term resupply of the groundwater plume. The physical, geochemical, and hydrogeologic characteristics of the vadose zone sediment that influence transport away from the liquid waste disposal sites are inferred, but direct observational data are limited.	Additional sediment analyses collected from the deeper portions of the vadose zone, especially the historically PRZ, away from waste sites, including borehole logging using geophysical methods.	Collect and analyze vadose zone sediment and porewater from characterization borehole locations inland of the former liquid waste disposal facilities (Locations 1 through 4 on Figure 3-5 of the 300 Area RI/FS Work Plan [DOE/RL-2009-30]). Collect and analyze sediment and porewater from samples collected during drilling at temporary well locations (a) through (e) as shown in Figure 3-5 of the 300 Area RI/FS Work Plan [DOE/RL-2009-30]). Collect and analyze sediment samples from future excavations that penetrate to depths of historical high water table conditions.	Yes	Collected and analyzed vadose zone sediment and interstitial water during the drilling of Wells C7657, C7659, C7658, and C8245 (399-1-58, 399-1-59, 399-6-3, and 399-6-5), which are inland of the former liquid waste disposal facilities and from temporary Well locations C8026, C8027, C8028, C8029, and C8030 (399-1-61, 399-1-62, 399-1-63, 399-1-64, and 399-3-38), as shown in Figure 2-1). Chapter 4, Nature and Extent Chapter 5, Fate and Transport	Yes. There is no clear evidence of widespread uranium contamination in the historical PRZ based upon the new data.

Table 2-1. Data Needs and Sampling Program for the 300 Area Remedial Investigation

Data Gap	Data Need	Scope of Work	Required by SAP*?	Work Conducted/Section with Discussion	Data Gap Filled?
15) Assumptions inherent in the conceptual model used to predict future levels of uranium contamination in the vadose zone and groundwater were based on very limited observational information, resulting in large uncertainty in the predictions based on computer simulation of future conditions.	Additional observational information on the inventory, geochemical environment, and potential transporting medium for uranium contamination.	Review assumptions made and input parameters used during the analysis of protectiveness levels presented in BHI-01667 in light of new information that has become available since about 2002. Provide conclusions and recommendations regarding protectiveness levels for contaminant uranium remaining in environmental pathways.	No	Abundant new observations of uranium in the vadose zone and upper portion of the unconfined aquifer have been acquired during recent RI drilling. The new vadose zone information has been used to define input parameters for computer simulation of uranium transport along likely environmental pathways (see Chapter 5). In addition, relevant new insights on uranium behavior, as revealed by research activities conducted under the IFRC program, have been used in developing the uranium transport simulation. Additional activities involving laboratory analysis of potentially contaminated sediment remain to be completed; research projects involving the controls on the mobility of contaminant uranium are continuing. Treatability testing of injecting polyphosphate solutions into the unconfined aquifer has been completed, and provided insight as to the viability of the method. Chapter 4, Nature and Extent	Yes. The new data collected during RI characterization drilling has been used to develop the 2-D computer simulations of uranium transport from suspected source locations to exposure locations, including predictions of future concentrations. In addition, the new data have contributed to calculating PRGs for various contaminants, including uranium, remaining in the environment away from existing, known contaminated zones.
16) Lithologic characteristics, stratigraphic contact data, and hydraulic head measurements define the spatial framework through which groundwater flows. The coverage throughout the extent of the 300 Area uranium plume is incomplete.	Additional descriptions of sediment characteristics that will fill gaps and expand the current model domain for the 300 Area. Additional hourly hydraulic head measurements at strategic locations for flow model validation.	1) Install and operate additional pressure transducers at 10 wells throughout the domain of the model and monitor throughout the investigation period. 2) Incorporate into the spatial framework new information from drilling associated with recent investigations. Validate the flow model being used with hourly data for water levels at multiple locations and throughout at least one seasonal hydrologic cycle.	No	Abundant new information on the spatial distribution of subsurface features has been obtained via drilling at the eleven characterization borehole locations. New data on the stratigraphy and key subsurface horizons have been acquired via interpretations of drilling logs and inspection of samples collected. These new data have been incorporated into the 3-D subsurface database for the 300 Area, currently maintained using EarthVision™ software. Although the newly constructed monitoring wells have not been equipped with pressure transducers to record high frequency water level data, numerous existing wells have been equipped, thus providing comprehensive coverage of the area impacted by uranium contamination in groundwater. The latter project is a joint effort with the IFRC; the principal objective is to obtain an 18-month record of hourly water level data from a network of wells that spans the extent of the groundwater plumes beneath the 300 Area. Chapter 4, Nature and Extent Chapter 5, Fate and Transport	Ongoing. A comprehensive record of hourly water level data that spans the extremes during the annual seasonal cycle of hydrologic conditions for at least one full cycle is currently being monitored.

Table 2-1. Data Needs and Sampling Program for the 300 Area Remedial Investigation

Data Gap	Data Need	Scope of Work	Required by SAP*?	Work Conducted/Section with Discussion	Data Gap Filled?
17) Current inventory estimates of contaminant uranium in the vadose zone and aquifer are based on limited observational data, and include numerous assumptions and inferences. The estimates can be refined by incorporating new information from sampling at remedial action sites, research activities at the IFRC, and characterization associated with treatability testing sites.	Update inventory box model and investigate how the inventory might vary under the influence of seasonal groundwater conditions.	Collect groundwater samples from the water table during periods of high water table conditions, along with additional samples from discrete depths below the water table.	Yes	Data from IFRC research has been used to provide best available estimates for mobility parameters in computer simulations of uranium transport (Chapter 5). A large number of new analytical results for uranium in sediment and groundwater samples, obtained as part of the RI drilling campaign, validated the transport model for the 300 Area. IFRC continues to investigate the mobility characteristics of uranium in various subsurface compartments, with results to date corroborating earlier suggestions that those characteristics are highly variable in time and space. The unusually high water table conditions during spring/early summer 2011, combined with optimal timing for collection of groundwater samples, has also provided new data for determining where contaminant uranium is likely to be entering groundwater. Chapter 5, Fate and Transport	Partially. The primary objective for the update, i.e., adding information that describes the proportion of the total uranium in the various compartments that is available for further movement via environmental pathways, has not yet been realized. However, abundant new data to do so has been collected during his RI and is incorporated into the CSM.
18) The amounts of uranium lost to the river via groundwater discharge through the riverbed and via withdrawal at Well 399-4-12 have been estimated using limited observational data and several significant assumptions, which create uncertainty.	Reduce the uncertainty in estimates for the removal of dissolved uranium from the groundwater plume by discharge to the Columbia River and withdrawal at a water supply well.	Revise the groundwater flow model as new data become available from a variety of investigations underway at the 300 Area, including characterization drilling conducted as part of the RI. Run the model to provide updates on the rate of groundwater discharge to the river. Incorporate withdrawal rate data for Well 399-4-12 and discharge data for the Life Sciences Building aquariums into the estimates. Incorporate results from the RCBRA, as they become available (Columbia River RI Work Plan [DOE/RL-2008-11]. Provide estimates for the rate of uranium loss from the groundwater plume using the most up-to-date input parameters.	No	The 3-D groundwater flow model was not updated, so the estimate of the flux of uranium to the Columbia River has not changed. The assumed range for representative concentrations and most likely net annual groundwater loss to the river remain the same. Records of groundwater withdrawal, and uranium concentrations in that withdrawal, are being maintained for the water supply well at the PNNL Life Sciences Building (well 399-4-12). Chapter 4 of this report contains estimates made during the previous several years of groundwater monitoring and characterization under the 300-FF-5 O&M Plan (DOE/RL-95-73). Chapter 4, Nature and Extent	Partially. The current estimate for the flux of uranium from the aquifer to the Columbia River is based on an existing 3-D groundwater flow model, which indicated that groundwater passes through the aquifer beneath the 300 Area shoreline at a net rate of 315 m^3/mshore/year (water moves back and forth across this interface). The current flux estimate presented in Chapter 4 is based on this rate, and a representative uranium concentration of 60 µg/L. Additional water level recorders have been installed during the period of renewed RIs to 1) expand the coverage of locations throughout the plume area where hourly data for 3-D model calibration are being conducted, and 2) acquire an 18-month record of current conditions, which will improve the accuracy of the 3-D groundwater flow simulation. Also, new groundwater monitoring results obtained during the period of renewed RIs confirm that the value for a representative uranium concentration is still valid for estimating the uranium flux to the Columbia River

Table 2-1. Data Needs and Sampling Program for the 300 Area Remedial Investigation

Data Gap	Data Need	Scope of Work	Required by SAP*?	Work Conducted/Section with Discussion	Data Gap Filled?
19) Existing simulation of uranium transport through the vadose zone and aquifer pathways is based on limited observational information.	Refined simulation input parameters for the following: • Inventories of labile contaminant uranium in various subsurface regions • Exchange rates between dissolved and solid forms • The form, capacity, and timing of a transporting medium (e.g., infiltration of moisture). • Additionally, consensus on appropriate modeling algorithms, especially with regard to model assumptions.	3-D groundwater flow and uranium transport modeling involving the vadose zone and uppermost aquifer at the 300 Area has been under development as part of the DOE SciDAC program. Additional detailed modeling for this purpose was not proposed as part of the 300 Area RI/FS Work Plan (DOE/RL-2009-30).	No	Research involving 3-D simulation of groundwater flow and uranium transport has been completed as part of the DOE SciDAC program. The simulation, using best available algorithms and simulation input parameters, is described in *Field-Scale Modeling for the Natural Attenuation of Uranium at the Hanford 300 Area using High Performance Computing* (Hammond and Lichtner, 2010) and *Stochastic Simulation of Uranium Migration at the Hanford 300 Area* (Hammond et al., 2010). Chapter 5, Fate and Transport	Yes. To reduce uncertainty in the existing conceptual model for uranium in the subsurface at the 300 Area requires being able to describe the potential for uranium in the vadose zone and aquifer to be mobilized under current and expected geochemical and hydrologic conditions, including the infiltration of moisture from the ground surface. To date, efforts to simulate the transport of uranium through the vadose zone and unconfined aquifer accurately have been severely limited by the heterogeneity in these environmental pathways (geology and hydrology, including physical and chemical heterogeneity) and the highly complex behavior of uranium. Accurate simulations are made exceedingly difficult by the multiple processes that influence the exchange between dissolved and solid forms of uranium (there are several), and processes that sequester uranium, including dissolved uranium, within sediment.
20) The cause for the persistence of cis-1,2-DCE contamination in the lower portion of the unconfined aquifer at Well 399-1-16B is uncertain.	Additional geochemical and microbiological data for groundwater samples, including oxygen levels, organic carbon, and nutrients from the contaminated interval at Well 399-1-16B.	Continue to collect and analyze groundwater samples from the deeper portion of the unconfined aquifer near Well 399-1-16B (and any newly constructed wells that have open intervals in the hydrologic unit that is continuous with Well 399-1-16B), per the objectives described in the 300-FF-5 O&M Plan (DOE/RL-95-73) for characterizing VOC contamination and trends.	Yes	Subsequent to preparation of the Work Plan, it was determined that analysis of groundwater samples regarding microbes present would not be productive. Those who conduct research on microbial activity in the subsurface, particularly with regard to the potential for degrading VOCs, have advised that sediment samples are required for this purpose, which is not possible to obtain from an existing well. Based on the outcome of the REMChlor modeling (see Data Need 4) and the Risk Assessment (Chapters 6 and 7), the concentration of VOCs do not pose a threat to human health or the environment. As a result, the proposed geochemical/microbial analysis of samples from 399-1-16B and was not performed. Chapter 4, Nature and Extent Chapter 5, Fate and Transport	Yes

Table 2-1. Data Needs and Sampling Program for the 300 Area Remedial Investigation

Data Gap	Data Need	Scope of Work	Required by SAP*?	Work Conducted/Section with Discussion	Data Gap Filled?
21) Contaminant movement within the finer-grained interval of sediment and release from the interval to overlying and underlying sediments are not well characterized.	Rates of lateral movement of VOC contamination through the finer grained interval of Ringold Formation sediment, and rates of release from the finer grained interval to the overlying saturated Hanford formation sediment.	A comprehensive evaluation of the various possibilities for VOC movement within, and release from, the finer grained interval of Ringold Formation can be acquired by additional analyses of existing and newly acquired information from characterization boreholes.	No	Interpretation of analytical results collected during 300 Area RI drilling has provided greater definition of the nature and extent of VOC contamination in the interval of finer-grained sediment in the unconfined aquifer. Direct monitoring of the contamination level in this interval has continued during the RI via use of one aquifer tube (AT-3-3-D), the only sampling port available to do so, and indirectly via riverbed porewater samples collected under the Hanford Releases to the Columbia River RI (work conducted under a WCH assignment). Completion of 300 Area RI characterization borehole C7656 as groundwater monitoring well C7656 (399-1-57) included positioning the screen to cover the interval immediately above the contaminated finer-grained interval, which is intended to provide insight on the level of contamination that may be routinely released from the finer-grained interval.	Yes
22) Initial tests using a polyphosphate solution to immobilize uranium in the aquifer have not revealed an optimal method for delivering the solution.	Laboratory and field-scale testing of methods to deliver uranium-immobilizing solutions to the vadose zone and unconfined aquifer.	New information on the distribution and characteristics of contaminant uranium in various subsurface regions as developed under the Work Plan will be used to anticipate the type of delivery mechanism most likely to result in reducing mobility. If necessary, additional bench and field-scale tests will be performed to augment results from tests already underway or planned. Experience gained at other sites contaminated by uranium will be factored into the analysis of appropriate delivery methods.	No	Treatability tests were performed to evaluate the efficacy of using polyphosphate injections to treat uranium-contaminated groundwater in the saturated zone. The test was located southeast of the 300 Area process trenches. The test had limited success due to high groundwater velocity in the 300 Area unconfined aquifer and unfavorable geochemical and hydrogeologic conditions. Section 2.1.10.4 Chapter 8, Identification and Screening of Technologies	Yes. The treatability tests to date have not demonstrated a successful delivery mechanism for polyphosphate.
23) Testing of in situ methods to immobilize contaminant uranium in the subsurface environment is in progress at other waste sites. Knowledge acquired at sites other than the Hanford Site can contribute to the technical basis for selecting a remediation alternative for uranium at the 300 Area.	Technical information from research activities and remedial action experience at sites contaminated by uranium.	Review work conducted at other sites where uranium has contaminated environmental pathways. Incorporate appropriate information obtained in interpretations and conclusions presented in the RI/FS Report. A search for activities separate from Hanford Site activities will be maintained during the duration of the RI/FS, to identify solutions developed for similar problems. Potential contributors include research involving uranium in the environment at sites in Rifle, Colorado, and Oak Ridge, Tennessee under the DOE's Integrated Field-Scale Research Challenge program (Note: The Hanford Site 300 Area is also part of this program). Cleanup experience gained under the Uranium Mill Tailings Remedial Action program will also be reviewed.	No	Potential technologies for remediation of uranium at other sites such as Rifle, Colorado; Oak Ridge, Tennessee; and the Uranium Mill Tailings Remedial Action program were reviewed and evaluated during the FS. Chapter 8, Identification and Screening of Technologies	Yes

Table 2-1. Data Needs and Sampling Program for the 300 Area Remedial Investigation

Data Gap	Data Need	Scope of Work	Required by SAP*?	Work Conducted/Section with Discussion	Data Gap Filled?
24) New information generated by the RI activities described in this work plan could be used to validate and potentially update the detailed analysis of remediation technology alternatives completed thus far.	Incorporate new information on the distribution and mobility characteristics of contaminant uranium in various subsurface regions beneath the 300 Area into the FS process.	Revisit the technology evaluation, screening, and selection activities, to incorporate new information obtained during the RI activities, including treatability testing. Apply computer simulation models to evaluating the effectiveness of alternative technologies as directed toward individual subsurface compartments. Timeframes for reducing levels of uranium contamination to meet ARARs under natural environmental processes will be estimated using models.	No	Technologies for uranium remediation were evaluated and screened during the FS. A 2-D groundwater flow and transport model was developed and used for simulations to support the FS. Chapter 5, Fate and Transport Chapter 8, Identification and Screening of Technologies	Yes
25) Existing groundwater flow and uranium transport simulations are not sufficiently developed to (1) simulate the performance of various remedial action alternatives, (2) predict timelines for achieving RAOs, and (3) evaluate post-remediation land-use and environmental scenarios. The latter may involve irrigation of land areas where waste sites have not been remediated because of continuing use of certain buildings and infrastructure for the near future.	Computer simulation runs to evaluate remedial action alternatives, especially with regard to the effectiveness at reducing uranium concentrations in groundwater and the period required to do so.	Refine the existing computer model for simulating groundwater movement and uranium transport using information collected during this RI.	No	A 2-D model was used to simulate the performance of various remedial action alternatives and predict timelines for achieving RAOs. Chapter 5, Fate and Transport	Yes. A 2-D model was used to achieve the objectives described in the data need.
26) Information on the lateral and vertical distribution of contaminant uranium in various subsurface compartments, and the mobility and potential transport processes, is insufficient to complete the engineering design and cost estimating aspects for the FS.	Updated information on the mass and mobility characteristics of contaminant uranium in various subsurface compartments.	Using new information on the lateral and vertical distribution of contaminant uranium from characterization drilling at eleven locations during the RI, update details on the mass of uranium and mobility characteristics in each subsurface compartment where contaminant uranium may be found.	Yes	See FS described in Chapters 8, 9, and 10.	
400 Area Sources					
27) Unidentified sources of contamination may exist within and in the soils adjacent to engineered facilities and structures.	Identify new waste sites and potential sources of contamination in the 400 Area.	Data need will be fulfilled as part of the OSE process.	No	The OSE process was completed for the 400 Area. Chapter 2, Section 2.1.3.2	Yes
Distribution of Contaminants—400 Area					
28) The nature and extent of contamination in the shallow vadose zone beneath and adjacent to 400 Area facilities and waste-disposal sites are needed to assess groundwater protection.	Characterize below unremediated waste sites to assess nature and extent of contamination in the vadose zone.	Continue conducting interim remedial actions and collecting data documenting the remaining residual contamination following completion of interim remedial action.	No	This is an ongoing interim action. Contaminated soil is removed and waste sites are sampled as remediation continues.	Yes

Table 2-1. Data Needs and Sampling Program for the 300 Area Remedial Investigation

Data Gap	Data Need	Scope of Work	Required by SAP*?	Work Conducted/Section with Discussion	Data Gap Filled?
600 Area Sources					
29) Unidentified sources of contamination may exist within the soils adjacent to engineered facilities within the 600 Area.	Identify new waste sites and potential sources of contamination in the 600 Area.	The data need will be fulfilled as part of the OSE process.	No	The OSE process for the 600 Area continues through the end of calendar year 2011. Chapter 2, Section 2.1.3.3	Yes
Distribution of Contaminants—600 Area					
30) There is uncertainty associated with the contents of the 618-10 and 618-11 Burial Grounds. Operational records and history associated with past waste-disposal practices of 300 Area waste streams are incomplete.	Characterize contents of the 618-10 and 618-11 Burial Grounds. Complete planned nonintrusive and intrusive sampling of the burial ground disposal sites.	The data need will be fulfilled as part of *Sampling and Analysis Plan for 618-10 and 618-11 Nonintrusive Sampling* (DOE/RL-2008-27).	No	Work to be completed after the waste sites are remediated.	Pending; this information will be evaluated follow waste site remediation.
31) The nature and extent of contamination in the shallow vadose zone beneath and adjacent to unremediated 600 Area waste disposal sites are not well defined. This includes the 618-10, 618-11, 618-7, and 618-13 Burial Grounds and the former 316-4 Crib.	Characterize below unremediated waste sites to assess nature and extent of contamination in the vadose zone.	The data need will be fulfilled as part of the field remediation and verification sampling process, and to some extent by the characterization borehole that is planned at each of these waste sites following excavation and removal actions.	No	Work to be completed after the waste sites are remediated.	Pending, this information will be evaluated follow waste site remediation.
32) The distributions of contamination in the vadose zone beneath the 618-10 and 618-11 Burial Grounds, and the former 316-4 Crib excavation site, are not well understood.	Following excavation of the sites during the interim remedial action, drill, and collect soil samples from beneath engineered facilities (bottom of excavation) to groundwater. Perform laboratory and field analyses to determine the nature and extent of contamination beneath the remediated waste sites from the bottom of the excavation to groundwater. Elevated tritium in the groundwater near the 618-11 Burial Ground may require further evaluation after characterization and remediation.	Characterization boreholes will be drilled into the vadose zone and sediment samples collected following excavation activities and prior to backfilling during interim remedial action.	Yes	Work to be completed after the waste sites are remediated.	Pending, this information will be evaluated follow waste site remediation.

Table 2-1. Data Needs and Sampling Program for the 300 Area Remedial Investigation

Data Gap	Data Need	Scope of Work	Required by SAP*?	Work Conducted/Section with Discussion	Data Gap Filled?
33) Existing groundwater data sets and the strategies currently in place to monitor groundwater conditions do not meet the RI needs for determining spatial and temporal risk uncertainty for potential human and ecological receptors.	Groundwater samples from a subset of wells selected to provide representative samples of aquifer conditions throughout the 300 Area; laboratory analysis of the samples to include contaminants of potential concern as identified in Section 4.5.2 of the Work Plan; and multiple rounds of sampling to characterize the temporal variability in aquifer conditions.	Collect groundwater samples from a subset of 300 Decision Area groundwater monitoring wells to (1) spatially represent current conditions, (2) collect samples from those wells during at least three rounds of sampling that encompass seasonal variability in water table and Columbia River conditions, and (3) analyze those samples for constituents deemed to be of potential concern for human and ecological receptors.	Yes	A subset of groundwater wells in the 300 Area was sampled for three rounds to assess risk. Chapter 6, Human Health Risk Assessment Chapter 7, Ecological Risk Assessment	Yes

Sources:

BHI-01667, *Protection of 300 Area Groundwater from Uranium-Contaminated Soils at Remediated Sites.*

DOE/RL-95-73, *Operation and Maintenance Plan for the 300-FF-5 Operable Unit.*

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

DOE/RL-2008-27, *Sampling and Analysis Plan for 618-10 and 618-11 Nonintrusive Sampling.*

DOE/RL-2009-30, *300 Area Decision Unit Remedial Investigation/Feasibility Study Work Plan for the 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units.*

EPA/ROD/R10-96/143, *Record of Decision for the 300-FF-1 and 300-FF-5 Operable Units, Hanford Site, Benton County, Washington.*

Hammond and Lichtner, 2010, "Field-Scale Modeling for the Natural Attenuation of Uranium at the Hanford 300 Area Using High Performance Computing."

Hammond et al., 2010, "Stochastic Simulation of Uranium Migration at the Hanford 300 Area."

2-D = two-dimensional
3-D = three-dimensional
ARAR = applicable or relevant and appropriate requirement
cis-DCE = cis-dichloroethene
cis-1,2-DCE = cis-1,2-dichloroethene
DNAPL = dense non-aqueous phase liquid
K_d = distribution coefficient
PCE = tetrachloroethene
PRZ = periodically rewetted zone
RCBRA = River Corridor Baseline Risk Assessment
REMChlor = Remediation Evaluation Model for Chlorinated Solvents
SciDAC = Scientific Discovery through Advanced Computing
WCH = Washington Closure Hanford

* Work performed in accordance with DOE/RL-2009-45, *300 Area Remedial Investigation/Feasibility Study Sampling and Analysis Plan for the 300-FF-1, 300-FF-2 and 300-FF-5 Operable Units.*

Table 2-2. Summary of 300 Area RI Field Characterization Activities

Type				Number
New monitoring wells				11
C7653 (399-1-54)	C7654 (399-1-55)	C7655 (399-1-56)	C7656 (399-1-57)	
C7657 (399-1-58)	C7658 (399-6-3)	C7659 (399-1-59)	C7660 (399-3-32)	
C7661 (399-6-4)[a]	C7662 (399-4-15)	C7663 (399-3-33)	C8245 (399-6-5)	
New temporary wells				5
C8026 (399-1-61)	C8027 (399-1-62)	C8028 (399-1-63)	C8029 (399-1-64)	
C8030 (399-3-38)				
Soil samples collected and analyzed from drilling of monitoring wells and temporary wells				234
Groundwater samples collected from new wells and analyzed for nature and extent characterization				45
Monitoring wells sampled to support risk characterization[b]				32

Note: Work performed in accordance with DOE/RL-2009-30, *300 Area Decision Unit Remedial Investigation/Feasibility Study Work Plan*, and DOE/RL-2009-45, *300 Area Remedial Investigation/Feasibility Study Sampling and Analysis Plan for the 300-FF-1, 300-FF-2 and 300-FF-5 Operable Units.*

a. C7661 was decommissioned and not completed as a monitoring well. It was replaced by C8245.

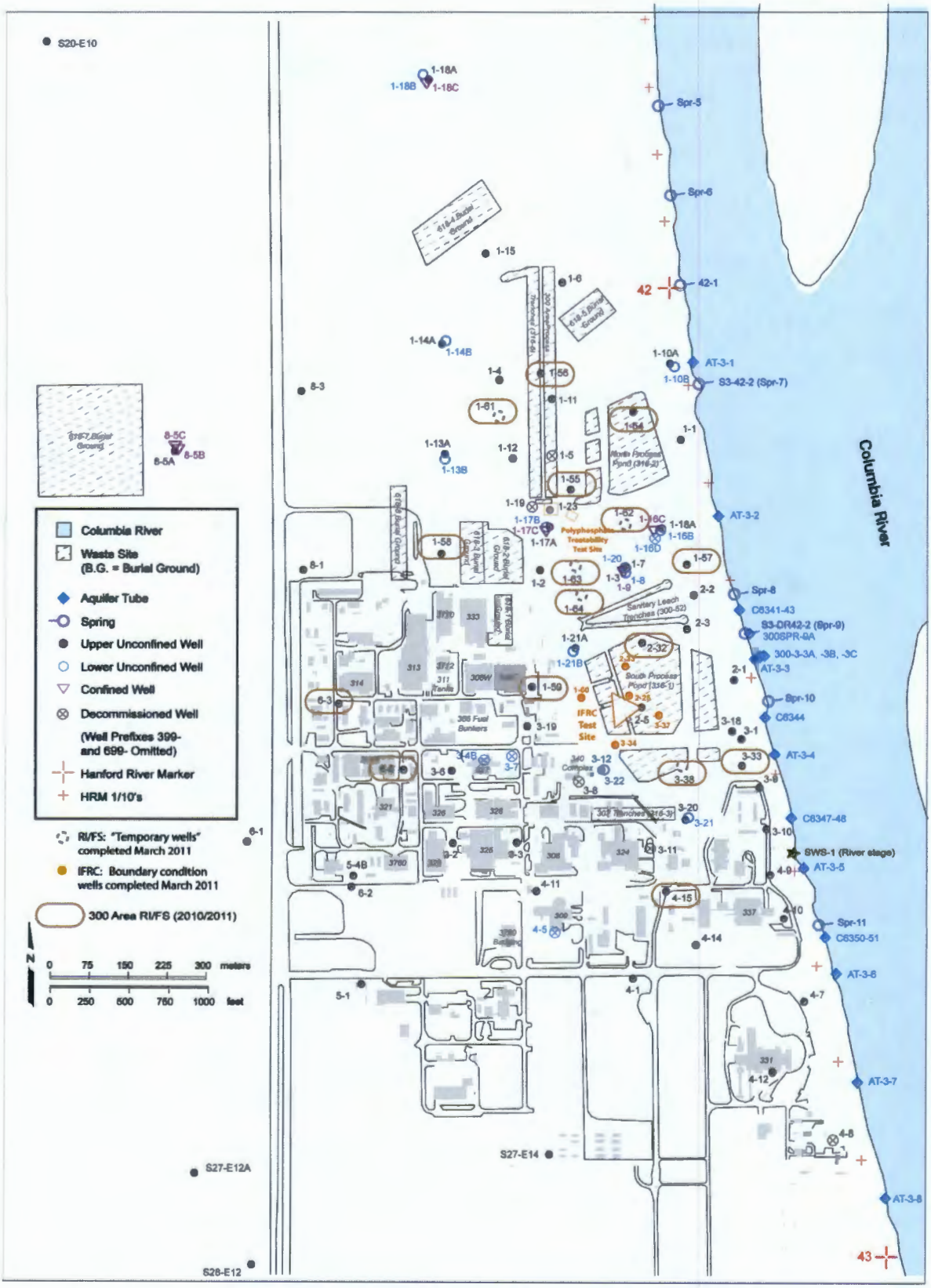
b. Work performed in accordance with DOE/RL-2009-45, *300 Area Remedial Investigation/Feasibility Study Sampling and Analysis Plan for the 300-FF-1, 300-FF-2 and 300-FF-5 Operable Units.*

Table 2-3. Summary of Other 300 Area Investigation Activities

Type	Number
Porewater samples collected as part of groundwater upwelling investigation[a]	120
Surface water samples collected as part of groundwater upwelling investigation[a]	8
Sediment samples collected as part of groundwater upwelling investigation[a]	8
Groundwater samples collected from existing wells and analyzed for nature and extent characterization[b]	899

a. Work performed in accordance with DOE/RL-2008-11, *Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River.*

b. Work performed in accordance with DOE/RL-95-73, *Operation and Maintenance Plan for the 300-FF-5 Operable Unit*, includes samples collected between January 1, 2010 and December 31, 2010.



300-Index-Map_062911-rep.ai (gwf10_218)

Figure 2-1. 300 Area Field Characterization Sampling Locations

2.1.1.1 Sources for Contamination (300 Area)

Data Need 4. This data need pertains to the sources for contamination data gap regarding the origin for the persistent cis-dichloroethene (cis-DCE) contamination observed at well 399-1-16B.

Computer simulation of a tetrachloroethene (PCE) release was conducted (see Chapter 5), with the conclusion that it would be possible for a pure-product release of 454 L (120 gal) to migrate downward through the vadose zone and upper portion of the unconfined aquifer as a dense non-aqueous phase liquid (DNAPL). Upon encountering the stratigraphic contact between saturated Hanford gravels (overlying) and Ringold Formation Unit E sandy gravels (underlying), some portion of the contamination could be entrained within the lower permeability Ringold sediment. Migration of this contamination would be slow, and the pathway followed would be highly dependent on the location where it was introduced to Ringold sediment. Therefore, the migration simulation as presented in this report contains uncertainty.

A pump test of well 399-1-16B was not conducted as proposed in the 300 Area RI/FS Work Plan (DOE/RL-2009-30). The low permeability of the sediment monitored by this well's screened interval results in very slow groundwater withdrawal from the well, as shown by the withdrawal rates during purging the well prior to routine groundwater sampling. Routine sampling and analysis of groundwater at this well and nearby wells has continued under the 300-FF-5 O&M Plan (DOE/RL-95-73, Rev. 1), and concentration trends for cis-DCE continue to be consistent with historical and expected trends.

Subsequent to release of the 300 Area RI/FS Work Plan (DOE/RL-2009-30), it was determined that analysis of groundwater samples regarding microbes present would not be productive, an activity also proposed in the 300 Area RI/FS Work Plan (DOE/RL-2009-30) (Data Need 20). Those who conduct research on microbial activity in the subsurface, particularly with regard to the potential for degrading VOCs, have advised that sediment samples are required for this purpose, which is not possible to obtain from an existing well.

The source for cis-DCE in the sediment interval monitored by 399-1-16B remains uncertain, although the possibility that it was caused by a single UPR of 454 L (120 gal) of PCE at the 300 Area Process Trenches (or a similar amount of TCE at a nearby location) has increased support as an explanation. While no evidence for a DNAPL remaining in saturated Hanford gravels is present currently (much higher concentrations of dissolved VOC would be seen in routine groundwater monitoring results), the rapid groundwater movement in the upper unconfined aquifer would likely have transported any such pool away from the secondary source area during the decades since initial release to the environment. Additional insight on the localized occurrence of cis-DCE will evolve as groundwater continues to be monitored under the 300-FF-5 O&M Plan (DOE/RL-95-73, Rev. 1).

2.1.1.2 Distribution of Contaminants (300 Area)

Data Need 7. This data need is associated with the contaminant distribution data gap for uranium and is related to the amount and mobility of contaminant uranium remaining in the vadose zone beneath remediated waste sites and the water table.

Analytical results for uranium in sediment samples collected during drilling at locations within the footprints of former liquid waste disposal sites (see Data Need 2) are available for total uranium in the sample and uranium leachable by various ratios of water-to-sediment, referred to as batch leach tests (see Chapter 4). Additional laboratory work involving uranium extractions from sediment using progressively more aggressive leachants has not been completed. A description of the batch leach tests and work completed to date on multiple extraction tests is presented in Chapter 5. Results for sediment moisture content and geophysical logging at these boreholes are presented in *Borehole Summary Report*

for the Installation of Eleven Wells to Support RI/FS in the 300-FF-5 Operable Unit (hereinafter called the 300 Area RI/FS Borehole Summary Report [SGW-50054]) and Appendix C, respectively.

Data Need 9. This data need is associated with the contaminant distribution data gap for uranium and involves the vertical distribution of uranium in the unconfined aquifer.

While collecting field data to characterize the vertical distribution of groundwater contamination is hampered whenever observations using monitoring wells are attempted, some progress in understanding what a sample from a well represents has been made. Results from use of an electronic borehole flow meter test at the IFRC site have revealed extensive vertical mixing in a 300 Area well, as a consequence of subtle differences in stratigraphy in the upper portion of the unconfined aquifer and the variable hydraulic gradients created by fluctuations in Columbia River stage. For these and other reasons, an effort to conduct sampling in existing wells, using sampling devices intended to collect a sample from a discreet interval, was not undertaken. The results using existing wells would still suffer from uncertainty as to whether the sample represented aquifer conditions adjacent to the well. However, collecting samples from aquifer tubes with 6-in. screens installed at three depths in the uppermost portion of the unconfined aquifer (i.e. the contaminated hydrologic unit) beneath the 300 Area shoreline has continued, with the most recent samples obtained in March 2011, and additional sampling scheduled for Fall 2011. Results from monitoring these tubes provide the most direct evidence for the vertical distribution of uranium contamination in the unconfined aquifer near the river.

Sampling existing wells during very specific periods related to the position of the water table was accomplished to some degree during June 2011 (the strategy for sampling wells during periods when uranium is most likely to be released from the vadose zone is presented in the 300-FF-5 O&M Plan [DOE/RL-95-73, Rev. 1]). Field sampling of some wells was conducted during the optimum period when the unusually high water table conditions in June 2011 occurred, and revealed higher than typical uranium concentrations. These data are being used to map areas where the lower portion of the vadose zone is most likely to contain contaminant uranium that is mobilized when the sediment becomes saturated with groundwater.

Information obtained under the 300-FF-5 O&M Plan (DOE/RL-95-73, Rev. 1), along with research conducted under the IFRC, is deemed sufficient to fill the data gap for the purpose of the RI, and to assist in modifying the groundwater SAP for the 300-FF-5 OU to accommodate long-term monitoring needs. The strategy for future compliance monitoring under CERCLA will include requirements related to the timing and method of collecting groundwater samples such that they accurately represent conditions along the environmental pathways.

2.1.1.3 Fate and Transport of Contaminants (300 Area)

Data Need 16. This data need is associated with the fate and transport of uranium data gap for the groundwater plume and involves the spatial framework and hydraulic characteristics of the unconfined aquifer system.

Abundant new information on the spatial distribution of subsurface features has been obtained via drilling at the 11 characterization borehole locations (Chapter 3). New data on the stratigraphy and key subsurface horizons have been acquired via interpretations of drilling logs and inspection of samples collected. These new data have been incorporated into PNNL's database for subsurface features for the 300 Area, which is currently maintained using EarthVision™ software.

Although the newly constructed monitoring wells have not been equipped with pressure transducers to record high frequency water level data, numerous existing wells have been equipped, thus providing comprehensive coverage of the area impacted by uranium contamination in groundwater. The latter

project is a joint effort with the IFRC; the principal objective is to obtain an 18-month record of hourly water level data from a network of wells that spans the extent of the groundwater plumes beneath the 300 Area. This record will be subsequently used to refine the existing computer model that simulates groundwater flow beneath the 300 Area.

Data Need 17. This data need is associated with the fate and transport of uranium data gap for the groundwater plume. The data gap involves estimates for the inventory of contaminant uranium remaining in the vadose zone and unconfined aquifer.

Although abundant new data were obtained during the RI characterization drilling, some proposed laboratory work related to the mobility of uranium in various subsurface compartments was not completed. Consequently, the "box model" presented in an earlier description of the conceptual model for uranium (PNNL-17034) has not been updated as of Fall 2011. The existing box model provides insight regarding the relative proportions of uranium inventory in various media along subsurface environmental pathways.

Data Need 18. This data need is associated with the fate and transport of uranium data gap for the groundwater plume. The data gap involves estimates for uranium lost from the groundwater plume to the Columbia River and through removal at a water supply well.

No new work has been completed on the three-dimensional (3-D) computer model of the uranium plume in groundwater. However, new hourly data from a comprehensive well network that covers the uranium plume is being collected, with the objective of recording for at least one complete seasonal cycle. The code and processors available to run the model have been improved as part of other work; they will be able to take advantage of the new hourly water level record for future use in 3-D flow simulation. The current estimate of uranium flux to the Columbia River, which is based on an earlier model, continues to be used.

Data Need 20. This data need is associated with the fate and transport of uranium data gap for the groundwater plume. The data gap is related to the persistence of cis-DCE at well 399-1-16B (see also the status described for Data Need 4).

Groundwater samples for VOC analysis have continued to be collected from the lower portion of the unconfined aquifer under the 300-FF-5 O&M Plan (DOE/RL-95-73, Rev. 1) monitoring during the recent RI. Subsequent to release of the RI Work Plan, it was determined that analysis of groundwater samples regarding microbes present would not be productive. Those who conduct research on microbial activity in the subsurface, particularly with regard to the potential for degrading VOC, have advised that sediment samples are required for this purpose, which is not possible to obtain from an existing well.

2.1.2 Data Sets

A large amount of historical data, along with new data collected as part of the current RI activities, were used in this report. The following subsections list the historical data that were used and the newly collected RI data that were compiled for the RI/FS dataset. Additional details regarding the latter data set, along with actual data set, are provided in Appendix D and available from the Hanford Environmental Information System (HEIS).

2.1.2.1 Historical Data

The following list identifies the historical data (i.e., prior to May 2010) that were assembled as part of ongoing site sampling programs, existing environmental monitoring activities, and previous RI activities. The list includes brief comments regarding how and where historical data were used in the 300 Area RI/FS report.

- Soil analytical data from interim waste site remedial actions (CVP and Remaining Sites Verification Package [RSVP] data). These data were used for evaluating the nature and extent of vadose zone contamination (Chapter 4), evaluation of groundwater protection (Chapter 5), human health risk assessment (HHRA) (Chapter 6), and ecological risk assessment (Chapter 7).

- Soil analytical data from prior field investigations (i.e., LFI and VOC investigation data). These data, coupled with the newly collected RI data, were used in the evaluation of the nature and extent of contamination in the vadose zone (Chapter 4).

- Groundwater analytical data collected during routine groundwater monitoring since the CERCLA process began in the late 1980s, with emphasis on results collected between January 1, 2006 and June 30, 2011 for describing current conditions. These data were used to describe the nature and extent of contamination in groundwater (Chapter 4), and to provide the basis for the initial delineation of contaminant plumes for groundwater modeling (Chapter 5 and Appendix F).

- Well and borehole drilling and construction information from prior drilling investigations. These data were used in the development of the geologic cross sections (Chapter 3) and groundwater model development (Chapter 5 and Appendix F).

- Geochemical data, hydrogeologic data (e.g., hydraulic conductivity), and soil physical property data. These data were used in the development of the vadose zone and groundwater models, and the fate and transport evaluations (Chapter 5 and Appendix F).

- Geologic information from prior field investigations. These data were used in the development of the geologic framework and preparation of geologic cross sections (Chapter 3), and the development of the two-dimensional (2-D) groundwater model (Chapter 5 and Appendix F).

- Groundwater levels from routine monitoring, pressure transducer, and river stage data. These data were used in the development of groundwater flow maps (Chapter 3) and for calibration of the groundwater flow model (Chapter 5 and Appendix F).

- Riverbed sediment porewater data. These data were used to evaluate upwelling of contaminated groundwater into the Columbia River (Chapter 4).

- Ambient air data from routine air quality monitoring. These data were used for evaluation the nature and extent of airborne contamination (Chapter 4.7)

- Data obtained under a variety of DOE-sponsored research projects at the Hanford Site, including data acquired under the ongoing IFRC project. These data and project interpretations were used to refine the existing CSM (Chapter 4) and fate-and-transport evaluations (Chapter 5).

2.1.2.2 Remedial Investigation Data

The following list identifies data collected during the most recent RI/FS field investigation activities that occurred between May 2010 and June 2011, and some earlier data collected during the LFI for uranium (2006), VOC investigation (2007), and treatability tests involving use of polyphosphate solutions to reduce uranium concentrations in groundwater (field tests in 2007). Information is provided on how and where the data were used in the document.

- Soil analytical data for samples collected during drilling at the RI characterization boreholes
  - Depth-discreet sampling results were used to describe contaminant distribution in the vadose zone and periodically rewetted zone (PRZ).

  - Presence or absence of certain contaminants, along with an assessment of their mobility in environmental pathways, contributed to refining the CSMs for individual contaminants (Chapter 4).

- Groundwater analytical data
  - Spatial and temporal groundwater monitoring data were used in the HHRA (Chapter 6). They complemented routine monitoring results for the description of nature and extent (Chapter 4).
  - Groundwater samples collected during drilling at the RI characterization boreholes, along with data collected earlier under the LFI and VOC drilling campaigns, were used to describe the vertical distribution of contaminants in the unconfined aquifer (Chapter 4).
  - The nature and extent of contamination, as revealed by the samples collected during drilling, contributed to refining the CSMs for individual contaminants (Chapter 4).
- Soil physical properties (i.e., grain size, moisture content, and porosity) data were used in the groundwater model development (Chapter 3 and Chapter 5).
- Hydrogeologic data (i.e., hydraulic conductivity) were used in the development of the groundwater flow model (Chapter 3 and Appendix F).
- Geophysical logging data were used to refine the characterization of stratigraphy beneath the 300 Area, which establishes the spatial framework for computer simulation of contaminant movement through environmental pathways (Chapter 5). The geophysical logs acquired from the RI boreholes are presented in Appendix C.
- Injection of polyphosphate solutions into the unconfined aquifer produced abundant data to describe the behavior of this amendment with respect to dissolved forms of uranium (Chapter 5). Subsequent monitoring revealed that phosphate could be used as a tracer for the expected movement of uranium via the aquifer pathway (Chapter 5).
- Batch-leach test data were used to calculate the distribution coefficients (K_ds), which were used in the evaluation of fate and transport of metals (Chapter 5).
- Sequential leach test data, acquired during the LFI and VOC investigations, were used to estimate the amount of uranium in 300 Area vadose zone sediment that is available for transport under expected environmental conditions (Chapter 5). A subset of sediment samples collected from the vadose zone during the more recent drilling campaign is also being subjected to sequential leach testing, with results for initial leaching by water currently available to aid in describing the nature and extent of contamination (Chapter 4).

Analytical data used in the RI/FS were collected and analyzed in a fixed laboratory using approved methods with specific QA/QC requirements. Detection limits, precision, accuracy, and completeness were assessed to determine whether the chemical and radiochemical data obtained were the right type, quality, and quantify to support regulatory decision-making. Data validation for the RI/FS is provided in Appendix D.

2.1.3 Historical Information Review

Historical information on 300 Area was researched and reviewed during the 300 Area RI/FS Work Plan (DOE/RL-2009-30) preparation. This information was considered during the 300 Area RI/FS Work Plan

(DOE/RL-2009-30) development and those reports containing relevant or significant information are summarized in Section 1.2.3.

2.1.4 Surface Features

Surface feature mapping, such as high-resolution topography, was conducted at the 300 Area using a Light Detection and Ranging (LIDAR) mapping technology in 2008. LIDAR is an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target. The accuracy of the LIDAR mapping is estimated at 0.011 m (4.3 in.). LIDAR data were used to create a topographic map of the 300 Area for defining surface relief/elevation differences. Surface topography establishes part of the framework needed to evaluate contaminant fate and transport.

2.1.5 Contaminant Source Investigations

The contaminant source investigation is an essential element of the RI. It is performed to characterize and identify known and potentially undocumented contaminant sources. The contaminant source investigation for the 300 Area RI was performed in tandem with the vadose zone investigation, geologic investigation, and groundwater investigation to satisfy the data needs identified in the 300 Area RI/FS Work Plan (DOE/RL-2009-30). These investigations included borehole drilling, geophysical logging, soil sampling and analysis, nonintrusive characterization, and the performance of the OSE. These tasks were performed at or near known and suspected historical waste sites to better identify sources, characterize the nature and extent of chemical and radiological contamination, and assess the physical conditions above and below the water table. As such, the data collected for the contaminant source investigation addresses multiple data needs applicable to geology, hydrology, nature and extent of contamination, fate-and-transport, and source interim remedial actions. Characterization was performed as outlined by the data needs identified in the 300 Area RI/FS Work Plan (DOE/RL-2009-30), the 300 Area SAP (DOE/RL-2009-45).

Table 2-1 identifies the data needs from the 300 Area RI/FS Work Plan (DOE/RL-2009-30) directing the contaminant source investigation and a brief description of the work completed. Details of the RI applicable to soil sampling and analysis are described in the 300 Area RI/FS Borehole Summary Report SGW-50054), and *Borehole Summary Report For The Installation Of Five Wells In The 300-FF-5 Operable Unit To Support RI/FS In FY 2011*, hereinafter called the Borehole Summary Report for Five 300-FF-5 OU Wells (SGW-50087). Details on the OSE process are documented in the *300 Area Orphan Sites Evaluation Report* (OSR-2010-0002). Findings from the evaluation will be incorporated into a decision document in accordance with *Tri-Party Agreement Handbook Management Procedures* (RL-TPA-90-0001), Guideline Number TPA-MP-14 (hereinafter called TPA-MP-14). Source interim remedial actions continue in the study area. The actions are being implemented in accordance with the *Remedial Design Report/Remedial Action Work Plan for the 300 Area* (hereafter referred to as the 300 Area RDR/RAWP [DOE/RL-2001-47]). Nonintrusive efforts at the 618-10 and 618-11 Burial Grounds are also ongoing and outlined in the 618-10 and 618-11 SAP (DOE/RL-2008-27).

2.1.5.1 300 Area Contaminant Source Investigation

The 300 Area contaminant source investigations consisted of three main tasks:

1. Soil sampling and analysis and geophysical logging in conjunction with drilling
2. An orphan sites evaluation
3. Interim remedial actions of sources

Drilling, Sampling, and Geophysical Logging. Seventeen boreholes (Table 2-2) were drilled and sampled for the contaminant source investigation. Each borehole was drilled with a roto-sonic drill rig. A split-spoon sampler was used for collecting chemical, radiological, and physical property soil samples.

The collection of soil was conducted ahead of the sonic drive head with the split-spoon sampler. Borehole C7661 was not advanced beyond 13 m (43 ft) due to the loss of a split-spoon sampler at the bottom of the borehole. It was abandoned and backfilled with bentonite chips in accordance with "Minimum Standards for Construction and Maintenance of Wells" (WAC 173-160) requirements. Borehole C8245 was drilled as a replacement.

Each borehole was drilled across the thickness of the vadose zone to provide source data. After the source investigation was completed, the boreholes were drilled into the aquifer, sediment sampling was performed, and groundwater monitoring wells were installed. Thus, some information in this section describing drilling operations will also apply to characterization of the aquifer. Figure 2-1 shows boreholes and wells drilled/installed for the RI in accordance with the 300 Area RI/FS Work Plan (DOE/RL-2009-30).

Borehole geophysical logging was performed in 16 boreholes drilled for the RI. Logging was performed using the Radionuclide Logging System, which provides information on the vertical and lateral extent of gamma-emitting radiological contamination. Detailed reports of logging operations are provided in the borehole summary reports (300 Area RI/FS Borehole Summary Report [SGW-50054]; Borehole Summary Report for Five 300-FF-5 OU Wells [SGW-50087]). The reports include summaries of the calibration requirements, processing data, log plots, and results.

Boreholes were geodetically surveyed; the data were recorded in the *North American Vertical Datum of 1988* (NAVD88) and the Washington State Plane (South Zone) *North American Datum of 1983* (NAD83), with the 1991 adjustment for horizontal coordinates. Survey data are presented in the borehole summary reports (300 Area RI/FS Borehole Summary Report [SGW-50054]; Borehole Summary Report for Five 300-FF-5 OU Wells [SGW-50087]).

Soil samples collected from boreholes were screened in the field prior to sample collection for indications of contamination and to assist with determining discrete sample locations or depths. Samples were screened for volatile organic contamination, beta-gamma activity, and alpha activity. Radiological activity greater than two times background was used as a screening indicator of contamination. Field screening data can be found in the borehole summary reports (300-FF-5 OU Borehole Summary Report [SGW-50054]; Borehole Summary Report for Five 300-FF-5 OU Wells [SGW-50087]).

Soil samples were collected for chemical and radiological analysis and determination of physical properties. Sample collection was guided by the sample schedule in the 300 Area SAP (DOE/RL-2009-45). The sampling approach generally required collection of samples every 1.5 m (5 ft) beyond the depth of remedial action and continuous sampling within 3.0 m (10 ft) of the water table. Boreholes C8026, C8027, C8028, C8029, and C8030 were only sampled within 3.0 m (10 ft) of the aquifer at 0.76 m (2.5 ft) intervals. Some samples could not be collected or, in some cases, sample analysis was limited due to poor sample recovery. In those cases where inadequate recovery precluded the collection of samples for all the specified analyses, the sampling priority as outlined in Section 3.6 of the 300 Area SAP (DOE/RL-2009-45) and clarified in *Change Notice for Modifying DOE/RL-2009-45, Rev. 0: 300 Area Remedial Investigation/Feasibility Study Sampling and Analysis Plan for the 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units* (TPA-CN-352) was followed. Table 2-4 summarizes the number of soil samples collected and the analyses performed for each borehole and the table notes describe the analytical methods used for each.

Surface geophysical surveys were conducted at each site using ground-penetrating radar prior to excavation. The surveys were performed to verify the locations of waste sites and to identify potential underground hazards. Surface geophysical survey reports are found in the borehole summary reports

(300 Area RI/FS Borehole Summary Report [SGW-50054]; Borehole Summary Report for Five 300-FF-5 OU Wells [SGW-50087]).

Table 2-4. Summary of Samples Collected for Chemical and Radiological Analyses

Borehole ID	Total Depth (ft)	Number of Soil Samples Collected	Analytes															
			Gamma Energy Analysis[a]	Isotopic Plutonium	Liquid Scintillation Tritium	Liquid Scintillation Technicium-99	Isotopic Uranium	ICP Metals[b]	Total Uranium[c]	Mercury Cold Vapor[d]	Nonhalogenated VOCs[e]	PCBs by GC[f]	VOCs[g]	SVOCs[h]	PAHs[i]	Anions by Ion Chromatography[j]	Total Carbon[k]	Inorganic Carbon[l]
C7653	118.5	13	7	-	7	-	9	8	2	8	8	6	8	6	6	8	8	8
C7654	113.0	14	11	-	11	-	14	14	3	11	14	11	14	11	11	14	11	11
C7655	123.5	13	7	-	7	-	9	9	2	9	8	7	8	7	7	9	8	8
C7656	118.5	40	9	-	9	9	4	12	4	4	10	7	10	-	7	11	11	11
C7657	126.0	14	-	11	11	11	13	12	2	2	12	-	12	-	-	12	12	12
C7658	128.6	14	-	12	12	12	15	14	2	14	12	-	12	-	-	6	14	14
C7659	148.7	21	-	13	13	13	17	17	4	5	16	-	16	-	-	4	17	17
C7660	121.0	18	8	-	9	-	3	12	3	12	9	9	9	9	9	12	12	12
C7661/ C8245	156.0	18	-	12	12	12	16	15	4	15	15	-	15	-	-	4	15	15
C7662	146.0	15	-	11	11	11	14	15	4	6	12	-	12	-	-	15	15	15
C7663	135.0	12	8	-	10	8	12	12	2	2	9	10	9	-	10	12	12	12
C8026[m]	58.0	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C8027[m]	48.0	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C8028[m]	55.5	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C8029[m]	48.0	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C8030[m]	56.8	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note: - indicates that no analysis was required.

a. Gamma Spectroscopy, Germanium High-Energy Detectors.

b. EPA 6010 – "Inductively Coupled Plasma-Atomic Emission Spectrometry." 6020 – "Inductively Coupled Plasma-Mass Emission Spectrometry" (SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*, hereinafter called Test Methods for Evaluating Solid Waste [SW-846]) or EPA 200.8 Determination of Trace Elements in Waters and Wastes by In Waters and Wastes by Inductively Coupled Plasma Mass Spectrometry (MS) (Test Methods for Evaluating Solid Waste [SW-846]).

c. Total Uranium by Kinetic Phosphorescence Analysis.

d. EPA 7471 – Mercury in Solid or Semisolid Waste (Manual Cold-Vapor Technique) (SW-846, Test Methods for Evaluating Solid Waste [SW-846]), or EPA 200.8 Determination of Trace Elements in Waters and Wastes by In Waters and Wastes by Inductively Coupled Plasma Mass Spectrometry (MS).

Table 2-4. Summary of Samples Collected for Chemical and Radiological Analyses

Borehole ID	Total Depth (ft)	Number of Soil Samples Collected	Analytes															
			Gamma Energy Analysis[a]	Isotopic Plutonium	Liquid Scintillation Tritium	Liquid Scintillation Technicium-99	Isotopic Uranium	ICP Metals[b]	Total Uranium[c]	Mercury Cold Vapor[d]	Nonhalogenated VOCs[e]	PCBs by GC[f]	VOCs[g]	SVOCs[h]	PAHs[i]	Anions by Ion Chromatography[j]	Total Carbon[k]	Inorganic Carbon[l]

e. EPA 8015—"Nanhalogenated Organics by Gas Chromatography" or 8260 – "Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry" (Test Methods for Evaluating Solid Waste [SW-846]).

f. EPA 8082—"Polychlorinated Biphenyls (PCBs) by Gas Chromatography" (Test Methods for Evaluating Solid Waste [SW-846]).

g. EPA 8260—"Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)" (Test Methods for Evaluating Solid Waste [SW-846]).

h. EPA 8270—"Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)" (Test Methods for Evaluating Solid Waste [SW-846]).

i. EPA 8310—"Polynuclear Aromatic Hydrocarbons" (Test Methods for Evaluating Solid Waste [SW-846]) or EPA 8270—"Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)" (Test Methods for Evaluating Solid Waste [SW-846]).

j. EPA 300.0—*Determination of Inorganic Anions by Ion Chromatography* (EPA-600/4-84-017).

k. Total Carbon—Carbon Dioxide Coulometer.

l. Inorganic Carbon—Carbon Dioxide Coulometer.

m. Saturated samples were analyzed for batch leach and physical properties; Unsaturated samples were analyzed for batch leach.

ICP = inductively coupled plasma

PAH = polycyclic aromatic hydrocarbon

SVOC = semi-volatile organic compound

Orphan Sites Evaluation. The OSE process is a systematic approach for reviewing land parcels and identifying potential waste sites within the River Corridor that are not currently listed in existing CERCLA decision documents as well as determining the nature and extent of contamination from Hanford Site releases. The scope of this effort includes conducting historical reviews and field investigations, identifying information gaps, conducting integrations activities, which includes briefing DOE-RL and the lead agency, completing the TPA-MP-14 (RL-TPA-90-0001) process, and issuing a summary report. New waste sites (i.e., discovery/orphan sites) are added to decision documents by way of a fact sheet and characterized as necessary to determine if cleanup is required. The OSE for the 300 Area, which started in October 2008, was completed in September 2010 (*300 Area Orphan Sites Evaluation Report* [OSR-2010-0002]). Field investigation activities conducted between May 2009 and November 2009 covered the 300-FF-1 OU to document potential miscellaneous restoration items and stewardship elements. Final categorization of the items and features documented during the 300 Area OSE includes the following:

- 18 orphan sites
- 13 miscellaneous restoration items

- 143 stewardship elements
- 8 locations investigated through geophysics
- 2 physical hazard locations

Of the 18 orphan sites identified, 2 were combined into one new discovery site, resulting in 17 new waste sites. Table 2-5 contains a list of the 17 new discovery sites. The *300 Area Orphan Sites Evaluation Report* (OSR-2010-0002) provides further discussion of miscellaneous restoration and stewardship items are provided in *300 Area Orphan Sites Evaluation Report* (OSR-2010-0002). Figure 2-2 shows the outline of the area surveyed and the orphan sites.

Table 2-5. 300 Area Orphan Site Groupings

Waste Site	General Description	Corresponding Orphan Site Feature Number(s)
300-279	3716 Automotive Repair Building Fuel Tanks	300FF2-001
300-280	Construction Debris Disposal Pit West of George Washington Way	300FF2-002
300-281	Septic Tank Near 325 Building	300FF2-004
300-282	Crib Near 3717-B Building	300FF2-011
300-283	Contaminated Light Water Disposal Site 2	300FF2-012
300-284	Sand Blasting Area Near 3221 Building	300FF2-013
300-285	300 Area Steam Condensate French Drains/Dry Wells, Ten French Drains and Dry Wells in 300 Area	300FF2-018
300-286	Three 300 Area Potentially Contaminated French Drain/Drywells	300FF2-019 and 300FF2-156
300-287	Transite Debris West of Route 4 South	300FF2-041
300-288	Piles of Garnet Sand/Soil Mixture Within Gravel Pit 6	300FF2-048
300-289	Stained Soil Area North of 300 Area	300FF2-081
300-290	Radiological Debris Area East of Horn Rapids Disposal Landfill	300FF2-121
300-291	Garnet Sand West of 350-A Paint Shop	300FF2-258
300-292	315 Water Filter Plant Waste Pipeline Segments	300FF2-266
300-293	300 Area Miscellaneous Pipelines	300FF2-267
300-294	Garnet Sand East of 350 Building	300FF2-268
300-295	384 Powerhouse Coal Ash Waste Pipeline Segments	300FF2-269

Source Interim Remedial Action. Investigation of contaminant sources included efforts to complete interim remedial actions as guided by the 300 Area RDR/RAWP (DOE/RL-2001-47). The scope of this effort includes performing historical research, sampling and analysis, removing and treating contaminated site structures and debris as necessary, disposing of contaminated materials, and contouring and backfilling of excavated areas. As of January 2010, 89 accepted waste sites and 1 discovery site in the 300 Area Industrial Complex required evaluation, remedial action, or both. As of October 17, 2010, eight additional waste sites were reclassified with a status of interim closed. Waste sites designated as interim closed include 300-109, 300-110, 300-259, 303M-SA, 303M-UOF, 333-LHWSA, 333-ESHWSA, 618-1, and UPR-300-17.

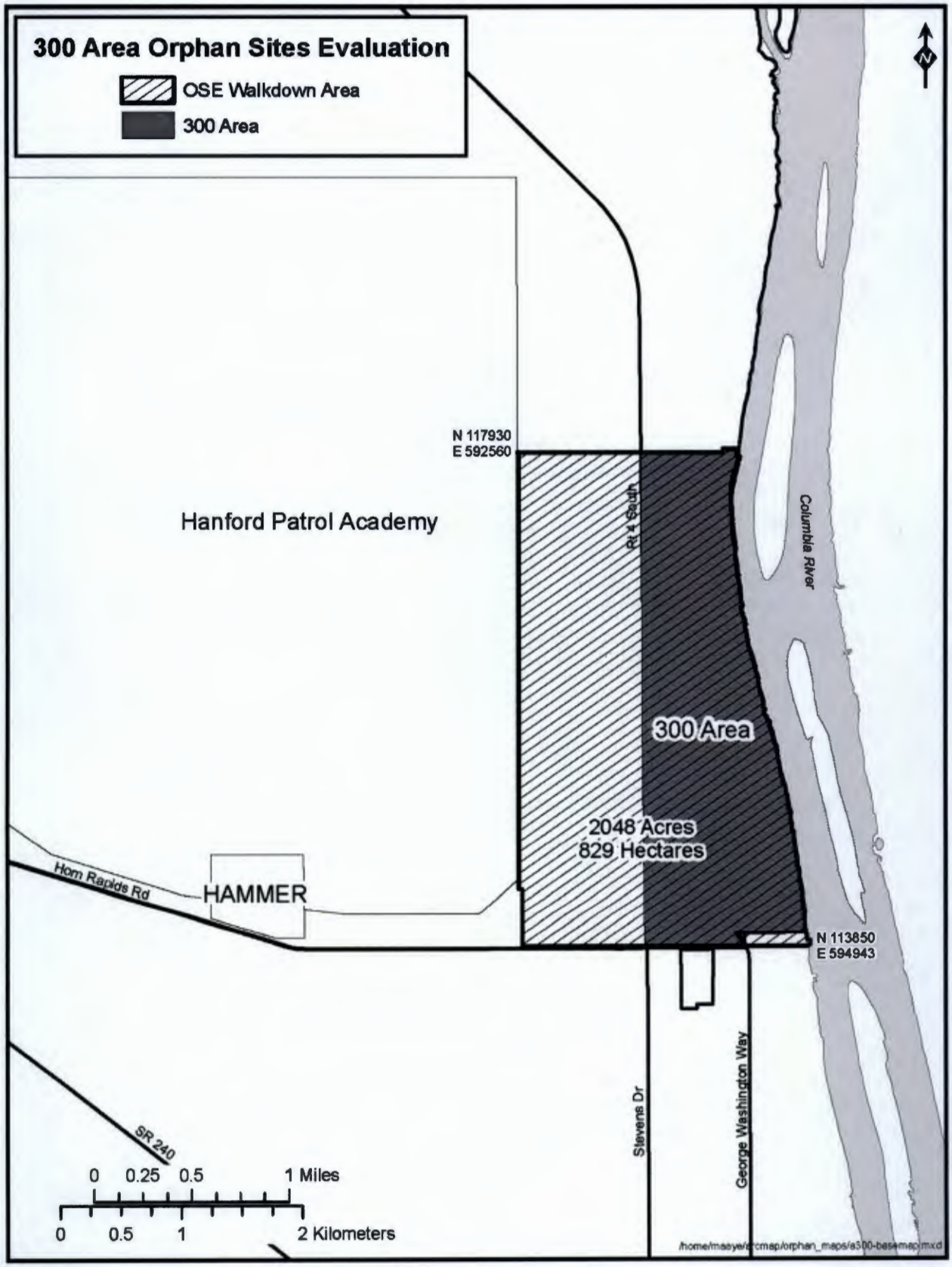


Figure 2-2. Orphan Sites Map—300 Area

2.1.5.2 400 Area Industrial Complex Contaminant Source Investigation

The 400 Area contaminant source investigations consisted of an OSE and source interim remedial actions.

Orphan Site Evaluation. The scope of the 400 Area OSE includes the administrative areas outside the triple-fenced exclusion area for the FFTF and the FMEF, plus an expanded walk down area around the entire site, as depicted in Figure 2-3. The OSE for the 400 Area, which started in May 2009, was completed in November 2010 (*400 Area Orphan Sites Evaluation Report* [OSR-2010-0003]). Field investigation activities were conducted between October 2009 and January 2010. The OSE final categorization of the items and features documented during the 400 Area orphan sites evaluation includes:

- 2 orphan sites identified
- 8 miscellaneous restoration items identified
- 24 stewardship elements identified
- 3 locations investigated through geophysics
- No physical hazard locations were identified

The two orphan sites identified include a sand blasting area with corresponding orphan site feature numbers of 400-003 and 400-056, and a flammable liquids storage area with a corresponding orphan site feature number of 400-014. Two orphan site feature numbers were assigned to the sand blasting area because it was identified as an active sandblasting area supporting the 4722-C Painters Shop (feature 400-056) and was also discovered during historical evaluation and recorded as feature 400-003. The site status of the two orphan sites will be determined according to the TPA-MP-14 (*Tri-Party Agreement Handbook Management Procedures* [RL-TPA-90-0001]) process and incorporated into various decision documents, as appropriate. For further discussion of miscellaneous restoration and stewardship items, see the *400 Area Orphan Sites Evaluation Report* (OSR-2010-0003).

Source Interim Remedial Action. Since preparation of the 300 Area RI/FS Work Plan (DOE/RL-2009-30), source remedial actions have not been completed in the 400 Area. Four accepted sites that require evaluation, remedial action, or both, remain in the 400 Area: 400 PPSS, 400-37, 400-38, and 437 MASF.

2.1.5.3 600 Area Contaminant Source Investigation

The 600 Area contaminant source investigation consisted of an OSE, nonintrusive investigation of the 618-10 and 618-11 Burial Grounds, and source interim remedial action.

Orphan Site Evaluation. The 600 Area OSE is in process and completion is scheduled in FY 2012. The 600 Area OSE is being performed as part of the evaluation of the IU-2/IU-6 OUs, and is discussed in the RI/FS report associated with those OUs. The evaluation is being performed in five segments. To date, three of the five segments have been completed. The fifth segment that will address the portion of the 600 Area surrounding the 300 Area will be completed by the end of calendar year (CY) 2011. New waste sites identified in the process will be added to decision documents by way of a fact sheet and characterized to determine if cleanup is required.

Nonintrusive Investigation—618-10 and 618-11 Burial Grounds. Nonintrusive investigation of the 618-10 and 618-11 Burial Grounds are an important part of the contaminant source investigation. Information from this ongoing task will provide data and information for planning future intrusive remedial action, if required. Two boreholes will be drilled and sampled following completion of interim remedial action at this site following remedial action. The borehole planned for the 316-4 Crib location will be delayed until the remediation of 618-10 and 618-11 is completed because its proximity to 618-10 site precludes access to the crib location.

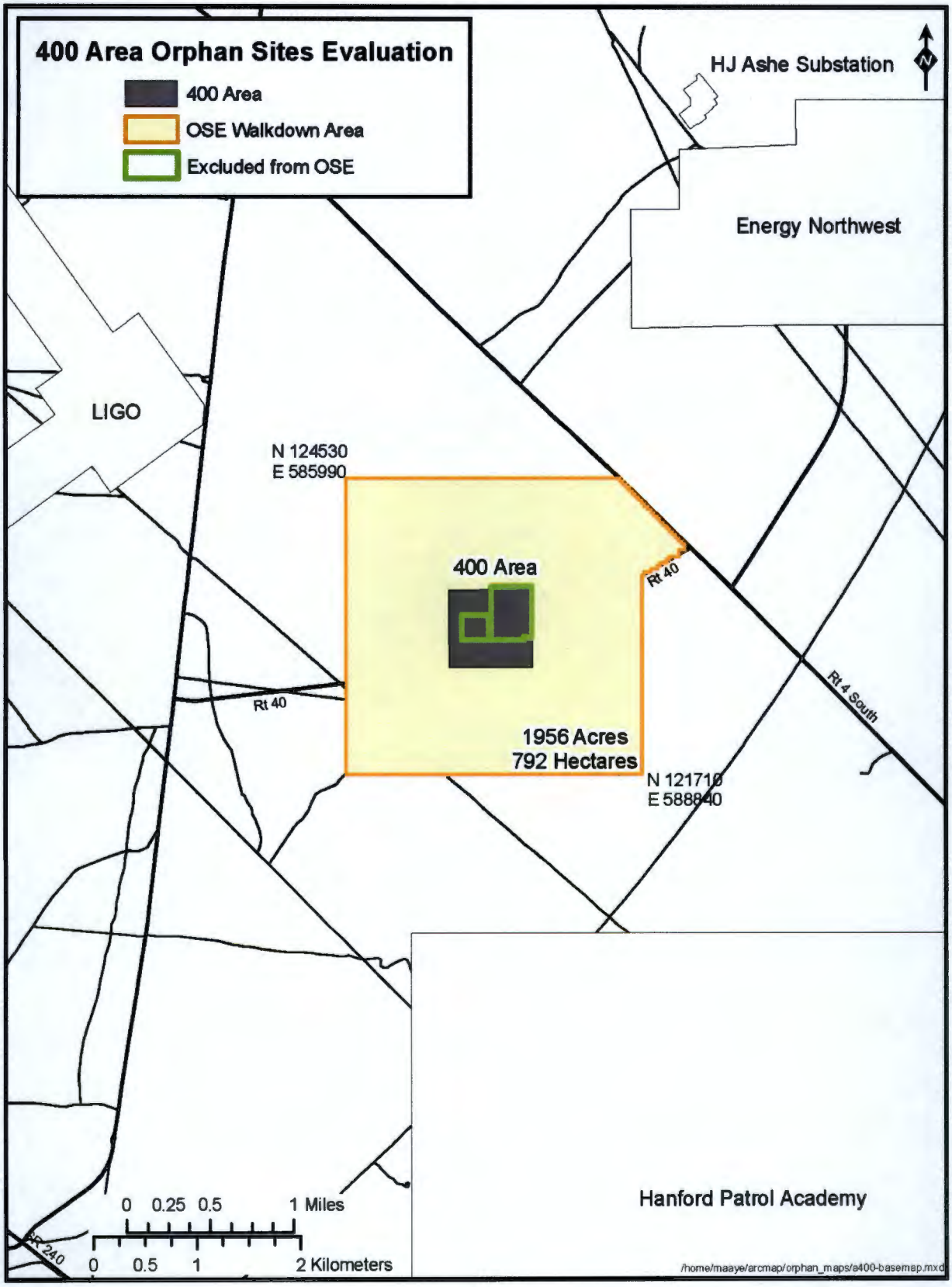


Figure 2-3. Orphan Sites Map—400 Area

Source Interim Remedial Actions. Since preparation of the 300 Area RI/FS Work Plan (DOE/RL-2009-30), remedial actions have not been completed at any 600 Area waste sites; however, remedial planning and excavation in the 600 Area are ongoing. Ten accepted waste sites (316-4, 600-276, 600-58, 600-59, 600-60, 600-62, 600-63, 618-10, 618-11, and UPR-600-22) and one discovery site (600-290) that require evaluation, remedial action, or both remain had been identified as of January 2010.

2.1.6 Meteorological Investigations

The Hanford Meteorological Station (HMS) is operated by Mission Support Alliance (MSA) for DOE. The HMS provides a range of Site weather forecast products, real-time meteorological data, and an extensive historical database of meteorological and climatological data. Meteorological measurements have been made at HMS since late 1944. Information specific to precipitation and wind speed, which have the potential to affect remedial actions, are discussed in Chapter 3. No additional meteorological data were collected as part of this RI/FS.

2.1.7 Air Investigations

Hanford Site contractors monitor airborne emissions from site facilities through several programs. The Near-Facility Environmental Monitoring Program measures concentrations of radionuclides in the ambient air on the Hanford Site in or near facilities and operations. The Hanford Site Environmental Surveillance Program measures the ambient air at sitewide locations away from facilities, offsite around the site perimeter, and in nearby and distant communities. In addition, emissions from stacks, vents, or other types of point sources are monitored individually by analyzing samples extracted from the outflow at each point of release. The data collected by each program are used to assess the effectiveness of emission treatment and control systems and pollution management practices, and to determine compliance with state and federal regulatory requirements. These regulations include a radiological standard, which requires that Hanford Site emissions will be controlled such that no member of the public in any area of unrestricted access receives greater than 10 mrem/yr total effective dose equivalent. In some cases, remedial activities are provided with project-specific point source and/or ambient air sampling to assemble project-specific data. For informational purposes, DOE provides information to the Washington State and EPA clean air offices describing the emissions and resultant maximum public dose from ongoing CERCLA activities. This information addresses contributions both from point sources and from all fugitive or diffuse sources of airborne emissions of radionuclides.

Nonradioactive air pollutants are emitted from a variety of sources at the Hanford Site. These emissions are monitored at the source when activities are known to actually or potentially generate pollutants of concern. For informational purposes, DOE provides information describing the emissions to the Washington State and EPA clean air offices. The following text summarizes the most recently published information regarding Hanford Site air monitoring activities (*Hanford Site Environmental Report for Calendar Year 2009*, hereinafter called the 2009 Sitewide Environmental Report [PNNL-19455]). Section 4.2.6 summarizes results of air monitoring. Figure 2-4 shows the ambient air monitoring sampling locations within the 300 Area.

While not a required action for the CERCLA remedial action, the Washington State Department of Health also conducts independent sampling and analysis of various media, including ambient air, soil, and biota, both on and off the Hanford Site. This independent sampling and analysis routinely confirms little or no environmental impacts to the public.

No additional air monitoring, with the possible exception of in-process monitoring at the immediate worksite during select borehole, well, and test pit activities have been conducted as part of this RI/FS.

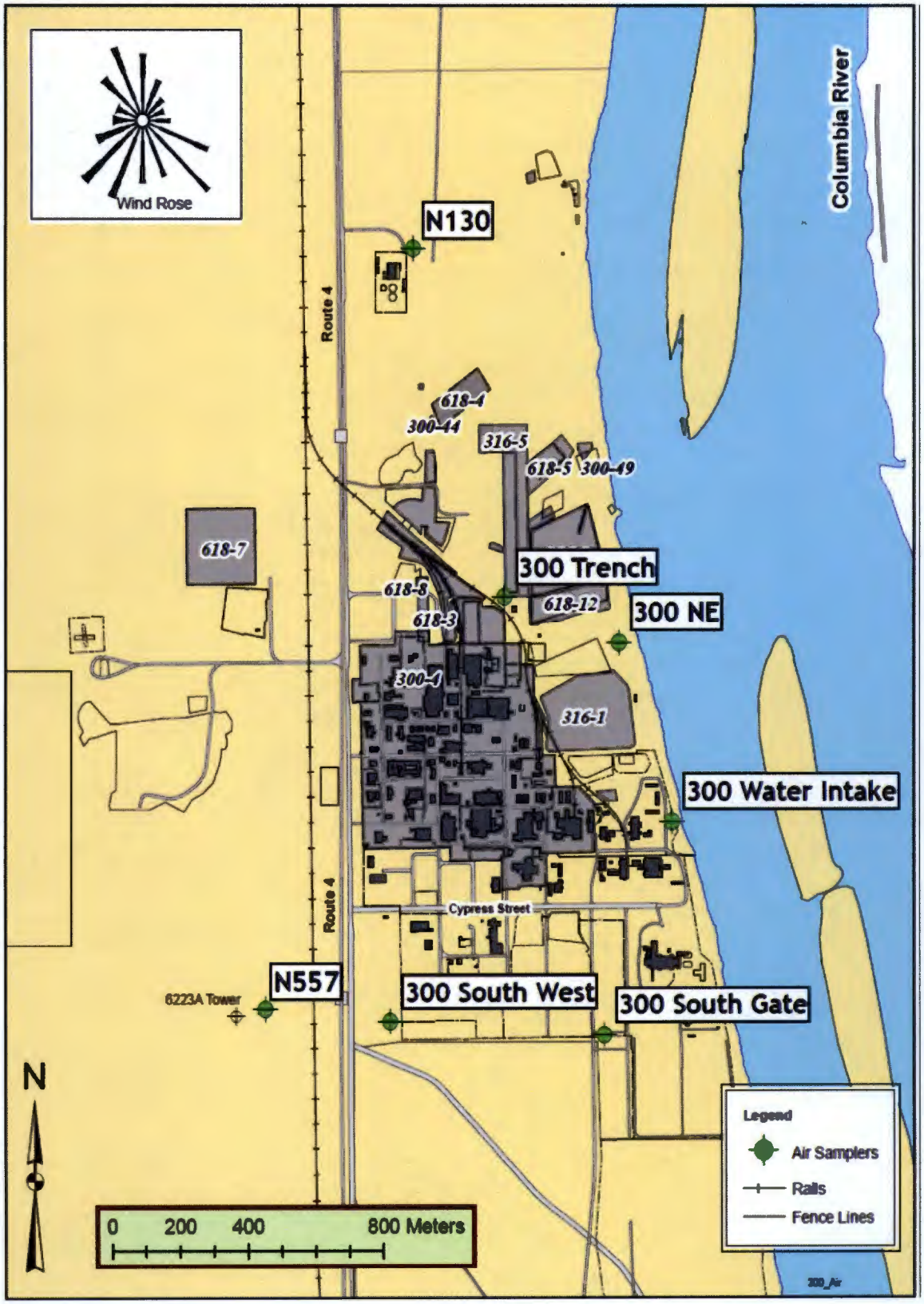


Figure 2-4. 300 Area Near-Facility Ambient Air Monitoring Locations

2.1.7.1 Air Monitoring Near Facilities and Operations

In CY 2010, ambient air was monitored at 91 locations on the Hanford Site near facilities and operations. Samplers were located primarily within approximately 500 m (1,640 ft) of projects or facilities having a known potential for, or a history of, environmental radiation releases. This ambient monitoring is termed near-facility environmental monitoring. Monitoring locations are associated primarily with major nuclear facilities and waste storage, disposal, or cleanup activities that provide the potential to disperse radioactivity. Occasional adjustments are made in the number or location of the monitoring stations as changes in the sources of emissions may occur. Two locations in the 300 Area were monitored during CY 2010.

2.1.7.2 Air Monitoring at Hanford Sitewide and Offsite Locations

During CY 2010, as part of the Hanford Site Environmental Surveillance Program, samples were collected using a network of 40 ambient air samplers, with 21 samplers onsite, 11 samplers operated at locations representing the Hanford Site perimeter, along with 7 monitoring stations in nearby communities, and 1 in a distant community considered a background location. Three ambient air monitoring locations are currently being sampled in the 300 Area. The surveillance network is located around the 300 Area functions as the near-facility network, as well.

Samples were collected from known or expected air transport pathways, which are generally downwind of potential or actual airborne releases and downgradient of liquid discharges. Airborne particle samples are collected at each station biweekly and monitored for gross alpha and gross beta concentrations. Biweekly samples are combined into quarterly composite samples and analyzed for gamma emitting radionuclides. Samples of atmospheric water vapor are collected every four weeks and analyzed for tritium at approximately 20 locations. All air sample results showed very low radiological concentrations in 2010, with resultant exposure to any public individual remaining well below the dose standard of 10 mrem/yr total effective dose equivalent. A detailed discussion of the air sampling and results are presented in the 2009 Sitewide Environmental Report (PNNL-19455) in Section 8.2, and Table 8.2.3 of the same report provides sample locations and a list of analyses collected at each location.

Ambient air sampling is the primary method used in monitoring fugitive emissions. Hanford Site contractors also monitor for other impacts from airborne emissions or other releases from site facilities. This is done through sampling of various environmental media besides the air, as part of the Surface Environmental Surveillance Program. Routine monitoring includes sampling of surface contamination, external radiation doses, soil, vegetation, and animals. All estimated and measured environmental doses from Hanford Site activities remain much lower than EPA and DOE standards. Chapter 4 presents a discussion of the nature and extent of air contaminants in Section 4.3.4.

2.1.8 Surface Water and Sediment Investigations

In 2004, a process was established to compile, classify, and manage environmental data (e.g., surface water and sediment) associated with the Columbia River in the *Columbia River Component of the River Corridor Baseline Risk Assessment: Basis and Assumptions on Project Scope* (DOE/RL-2004-49). The Columbia River Component database was created as a result of these efforts and was documented in *Existing Source Information Summary Report Compilation/Evaluation Effort: December 2004 to September 2005* (WCH-64). The subsequent *Columbia River Component Data Evaluation Summary Report* (WCH-91) described the activities that were undertaken to evaluate the data collected in the compilation effort and to assist in defining the extent of Hanford Site-related contamination. The compiled data was utilized to identify potential data gaps in the spatial, temporal, and chemical composition of the existing data set. The *Columbia River Component Data Gap Analysis* (WCH-201) presented the results of that analysis and formed the foundation for the sampling plan that was documented in the Columbia River RI Work Plan (DOE/RL-2008-11).

During this period, sampling was already underway supporting the *Risk Assessment Work Plan for the 100 Area and 300 Area Component of the RCBRA* (DOE/RL-2004-37). Samples of surface water, groundwater, near shore sediment, soil, and biota were being collected and analyzed to support the River Corridor Baseline Risk Assessment (RCBRA). Evaluation of that data is summarized in *Columbia River Component Risk Assessment, Volume II: Baseline Human Health Risk Assessment* (DOE/RL-2007-21, Volume II).

Sampling to fulfill the needs defined in the Columbia River RI Work Plan was initiated in October 2008 and was completed in June 2010. Media sampled included surface water, porewater, sediment (i.e., shoreline, shallow, cores), island soils, and six species of fish. The RI field activities associated with the collection of sediment, river water, and island soil adjacent to and downstream of the Hanford Site and in nearby tributaries are documented in the *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, River Sediments, and Island Soils* (WCH-352). The summary report describes the sampling locations, identifies samples collected, and describes modifications and additions made to the SAP. Groundwater upwelling field activities and data collection are documented in the *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling* (hereinafter called the Columbia River RI Report [WCH-380]). The data collected and presented in the summary reports supported *Columbia River Component Risk Assessment, Volume I: Screening-Level Ecological Risk Assessment* (DOE/RL-2010-117, Volume I, Part 1), and *Columbia River Component Risk Assessment, Volume II: Baseline Human Health Risk Assessment* (DOE/RL-2010-117, Volume 2 currently in draft).

Additional investigations of groundwater discharge from the Hanford Site to the Hanford Reach have been sponsored by DOE under various research programs. These include investigations at the 300 Area by PNNL, and collaborators from the U.S. Geological Survey (USGS) and academic institutions. The following sections provide the 300 Area surface water and sediment investigation details, including those conducted for the Columbia River RI.

2.1.8.1 Remedial Investigation of Groundwater Upwelling into the Columbia River

To address the uncertainty related to the nature and extent of groundwater contamination entering the Columbia River, including the transport mechanisms for individual contaminants, data were collected adjacent to the 300 Area in 2009 and 2010. Riverbed sediment porewater samples were collected during three phases, as outlined in the Columbia River RI Work Plan (DOE/RL-2008-11). Sampling efforts included river porewater, surface water, and sediment as outlined below.

Porewater Sampling. The first phase of the Columbia River RI porewater sampling, termed Phase II(a), focused on identification of riverbed areas where groundwater was entering the Columbia River. The second phase, termed Phase II(b), returned to a subset of the Phase II(a) sample locations to collect samples of porewater for indicator contaminant analysis. For the 300 Area, the indicator contaminants were uranium and VOCs. Porewater samples were collected using a multi-sensor water-sampling probe capable of being inserted approximately 30.5 cm (12 in.) into the riverbed, and measuring conductivity and temperature in situ. Data were collected from five sample locations on six cross-river transects (30 locations). Additionally, up to 10 locations surrounding each transect were sampled.

Porewater sampling for Phase II(b) was conducted at a subset of the Phase II(a) locations that clearly showed groundwater upwelling based on conductivity and temperature variances between the river and porewater, and were deemed most likely to show contamination. Thirty-four sample locations were sampled for total uranium during Phase II(b) near the 300 Area. Out of these 30 sample locations, 11 were sampled for VOCs (Figure 2-5).

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

Figure 2-5. Phase II(b) Sample Locations Selected near the 300 Area

Phase III identified a subset of the previous sample locations for characterization sampling and analysis of porewater, surface water (defined as water 0.3 m [1 ft] above the riverbed, and collocated sediment for the contaminants shown in Table 2-6.

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

Media	Analyses/Number of Samples																
	Metals (Filtered)[a]	Metals (Unfiltered)[a]	Metals (Solid)[a]	Hexavalent Chromium	Nitrate and Anions	AVS/SEM	Hardness/DOC/Alkalinity	VOC	TIC/TOC/Grain Size[b]	Isotopic Thorium	Isotopic Plutonium	Tritium	Strontium-89/90	Isotopic Uranium	Radionuclides, GEA[c]	Total Uranium	Field Parameters[d]
Porewater	8	8	-	8	8	-	-	8	8	-	-	8	-	-	-	8	-
Surface Water	8	8	-	8	-	-	8	8	-	6	6	-	-	6	6	-	8
Sediment	-	-	8	8	-	5	-	8	8	7	7	-	1	7	7	-	-

Note: - indicates that no analysis was required.

a. Inductively coupled plasma (ICP) metals including uranium (method 6010TR) and mercury (methods 7470/7471).

b. Grain Size analysis will be performed only for sediment samples.

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

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

Porewater samples for Phase III were collected from upwelling locations, with the focus on sites where the indicator contaminants (uranium and VOCs) were detected in the Phase II(b) porewater samples. The Tri-Parties selected nine locations for Phase III sampling near the 300 Area. Samples were successfully obtained from eight of nine 300 Area Phase III sample locations (Figures 2-6 and 2-7) and analyzed for a range of radiological and nonradiological analytes, as shown in Table 2-6. Not all analyses were conducted for each sample location due to site-specific sample volume constraints.

Table 2-7 presents sample collection information for porewater, surface water, and sediment samples attained during each sampling phase.

Surface Water Sampling. During Phase III, the influence of contaminants on the water immediately above groundwater upwelling locations was determined by taking surface water samples. River water was collected concurrently during porewater sample collection at about 0.3 m (12 in.) above the riverbed. At the 300 Area, surface water sample analysis included the analytes presented in Table 2-6 at eight of the nine sample locations.

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

Figure 2-6. Phase III Sample Locations Selected near the 300 Area (Upstream Segment)

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

Figure 2-7. Phase III Sample Locations Selected near the 300 Area (Downstream Segment)

Table 2-7. Summary of 300 Area Sample Collection during Columbia River Remedial Investigation

Sample Collection Phase	Media Collected/Number of Samples Collected			300 Area Sample Collection Period
	Porewater	Surface Water	Sediment	
Phase II(a) (Conductivity mapping)	94	--	--	January/February/March 2009
Phase II(b) (Indicator contaminant screening)	34	--	--	August/September 2009
Phase III (Groundwater Upwelling Characterization)	9	9	8	January/February 2010

Sediment Sampling. Sediment samples, collected from the locations shown on Figures 2-6, and 2-7 were analyzed for a range of radiological and nonradiological analytes, as described in Table 2-6. Sediment samples were obtained as close to the porewater sample locations as reasonably possible, with a preference given to locations with fine sediment deposits. Sample volume was limited in some locations due to the dominance of cobbles on the riverbed. In locations where sediment sample volume was limited, not all analyses were performed at each location.

2.1.8.2 Research Activities Involving Groundwater Upwelling into the Columbia River

DOE has sponsored several research activities associated with groundwater discharge to the Columbia River under various programs within the Office of Biological and Environmental Research. Some of these investigations are continuing; details regarding progress on them are provided in the following sections.

Geophysical Investigations to Characterize Surface Water—Groundwater Exchange. In July 2008, high-resolution continuous water-borne electrical imaging methods were used to map heterogeneity in riverbed sediment adjacent to the 300 Area. The results can be used to infer greater or lesser permeability of sediment at the aquifer-river channel interface to help identify areas of preferential groundwater upwelling into the river. A second method to achieve a similar objective involved laying fiber optic cables on the riverbed at various distances out from the shoreline. Temperature along these cables, which were up to 1.6 km (5.2 ft) long, was recorded at 1 m (3.3 ft) intervals. Contrasts in temperature along the length of the cables were used to infer areas of preferential groundwater discharge. The results have confirmed earlier estimates of areas of riverbed most likely to be impacted by discharge of contaminated groundwater, but have added important details to reduce uncertainties, and have expanded the area of coverage. The results are described in "Use of Electrical Imaging and Distributed Temperature Sensing Methods to Characterize Surface Water—Groundwater Exchange Regulating Uranium Transport at the Hanford 300 Area, Washington" (Slater et al., 2010).

Use of Uranium Isotopes to Track Hanford Site Uranium in the Columbia River. Numerous samples of Hanford Site groundwater and Columbia River water have been collected during the past several years. The samples were analyzed using very high-precision measurements of uranium isotopes. Among the various objectives for the research are to develop isotopic ratio 'signatures' that help identify sources, and to track the migration of Hanford Site uranium that has entered the river via the groundwater pathway. Contaminant uranium from Hanford Reactor operations contains the isotope uranium-236, which is produced when uranium fuel is irradiated. The isotope has been identified at low concentrations in water samples from as far downstream as Bonneville Dam. Isotopic ratios from this study have also been used to infer contaminant flux rates from the 300 Area groundwater plume to the river. Initial results of

isotopic studies associated with the 300 Area plume are presented in "Identifying the Sources of Subsurface Contamination at the Hanford Site in Washington Using High-Precision Uranium Isotopic Measurements" (Christensen et al., 2004).

Digital Elevation Model for the Columbia River Channel. A high-resolution bathymetric survey was conducted in the Hanford Reach several years ago as part of a U.S. Fish and Wildlife Service (USFWS) investigation involving salmon (*Effects of Hydropower Operations on Spawning Habitat, Rearing Habitat, and Stranding/Entrapment Mortality of Fall Chinook Salmon in the Hanford Reach of the Columbia River* [Anglin et al., 2006]). These data have been combined with more recent topographic survey data to compile a complete digital elevation model for the Hanford Reach channel and adjacent lands. The model can be used to support a variety of investigations in the channel, including analysis of areas where contaminated groundwater is most likely to upwell through the channel bottom. The effort is described in *Development of a High-Resolution Bathymetry Dataset for the Columbia River through the Hanford Reach* (PNNL-19878).

Surface Environmental Surveillance Project. The Surface Environmental Surveillance Project (SESP) is part of DOE's Public Safety and Resource Protection Program (*Environmental Monitoring Plan United States Department of Energy Richland Operations Office* [DOE/RL-91-50]). The project collects water and sediment samples from 300 Area riverbank springs; near shore river water; and river water along transects that cross the river, including one at the 300 Area and one just upstream from the city of Richland water intake. These samples are analyzed for chemical and radiological contamination indicators. The results from the project are presented in the annual Hanford Site Environmental Report (most recent is the 2009 Sitewide Environmental Report [PNNL-19455]).

Activities under the Public Safety and Resource Protection Program have been conducted at PNNL for the last several decades. During 2010, the work scope was transferred to the Hanford Site's MSA.

2.1.9 Geologic Investigations

The geologic investigation consists of the activities described in Section 2.1.3, Contaminant Source Investigation, and in Table 2-1. Geologic characterization and physical and hydraulic property data needs were identified to support development/refinement of the site conceptual model and performance of analytical and numerical modeling within the 300 Area. In addition, geologic data were needed to gain a better understanding of the hydrogeologic conditions, aquifer interactions, and uranium mobility through the vadose zone.

2.1.9.1 Bathymetric Evaluation

Contaminant flow paths from the 300 Area to the Columbia River are related to the geology of the site and the locations of the various geologic units both on shore and within the Columbia River. The preliminary evaluation of the near river well geology indicates that the top of the aquitard lies approximately 12 m (40 ft) beneath the bottom of the Columbia River. This indicates that the aquitard does not intersect the bottom of the Columbia River at the 300 Area.

The CSM for river-aquifer interaction assumes that the groundwater flow is primarily above the top of the aquitard. In order to evaluate flow paths of contaminants to receptors (particularly from beneath the unconfined aquifer), updated and accurate bathymetric data for the river were used.

A high-resolution topographic/bathymetric dataset for the upper portion of the Hanford Reach (River Miles 377 to 395) was collected in 2003. Additional data were collected in 2008 and evaluated in 2010. To complete the interpretations, key hydrogeologic unit surfaces are projected beneath the footprint of the river. The river bathymetry (river bottom elevation) is then overlain onto the hydrogeologic unit

structure maps. The maps define areas where the geologic units are elevated above the river channel. The line formed by the intersection of the two surfaces is defined as the truncation boundary (i.e., the area where the river has eroded into and removed that unit). The river bathymetry becomes the unit surface within those areas of overlap. If the two surfaces do not cross, the particular unit is either too deep to intersect the river bottom or not present. Figures 3-1, 3-2, and 3-3 in Chapter 3 present the bathymetry for the entire 300 Area NPL area, the 300 Area industrial complex subregion, and the 400 Area subregion, respectively.

2.1.9.2 Geologic Characterization

Seventeen boreholes were initiated for installation of groundwater monitoring wells. Of these, 16 groundwater monitoring wells were installed and completed to provide data for geologic and hydrogeologic investigations. One boring was abandoned after reaching a depth of 10 m (34 ft). Geologic investigations included installing and sampling new wells and boreholes and conducting geophysical logging, described as follows. Table 2-8 summarizes the soil samples collected and analyzed for soil physical properties and batch leaching (Section 2.1.10).

Table 2-8. Summary of Samples Collected for Soil Physical Properties

Borehole Location ID	Total Depth (ft)	Number of Soil Samples Collected	Analysis			
			Grain Size Analysis[a]	Moisture Content[b]	Inorganic Carbon[c]	Batch Leach Analysis[d]
C7653	118.5	14	2	6	8	0
C7654	113.0	14	2	2	11	2
C7655	123.5	11	1	1	8	0
C7656	118.5	42	2	4	11	9
C7657	126.0	14	2	2	12	11
C7658	128.6	16	2	12	14	12
C7659	148.7	21	2	13	17	13
C7660	121.0	16	4	8	12	9
C7661/C8245	156.0	18	3	7	15	12
C7662	146.0	16	4	11	15	11
C7663	135.0	11	5	10	12	9
C8026	58.0	10	4	-	-	4
C8027	48.0	7	4	-	-	3
C8028	55.5	8	2	-	-	4
C8029	48.0	8	3	-	-	4
C8030	56.8	8	3	-	-	5

Note: - indicates that no analysis was required.

a. Grain size analysis: *Standard Test Method for Particle-Size Analysis of Soils* (ASTM D422-63) or an equivalent field procedure.

b. Sediment moisture content: *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass* (ASTM D2216-05).

c. Bulk density by *Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method* (ASTM D2937-04).

d. Batch leach analysis using *Standard Test Method for Shake Extraction of Solid Waste with Water* (ASTM D3987-06).

Geologic samples were collected at approximately 1.5 m (5 ft) depth intervals, and/or at discernible changes in lithology, from the ground surface to total depth. In addition to archive samples, the field geologist/hydrogeologist collected two samples by split-spoon for sieve analysis at depths representative of the top and the bottom of the planned well screen interval. In general, major stratigraphic units encountered during this project included backfill, holocene eolian deposits, cataclysmic flood deposits of the Hanford formation, and fluvially derived Ringold Formation deposits. Drilling was generally terminated just below the Ringold Formation lower mud unit contact.

The stratigraphy observed while drilling the 17 boreholes was consistent with previous geologic descriptions of the 300, 400, and 600 Areas, which are included in the following documents:

- *Geology and Hydrology of the 300 Area and Vicinity, Hanford Site, South-Central Washington* (WHC-EP-0500)
- *Borehole Summary Report for 300-FF-5 Operable Unit TCE Characterization Monitoring Wells C5575, C5706, C5707, and C5708* (SGW-36424)
- *Borehole Data Package for One CY 2005 CERCLA Well 699-S20-E10, 300-FF-5 Operable Unit, Hanford Site, Washington* (PNNL-15417)
- *Soil Gas Survey and Well Installations at the 618-10 Burial Ground, 300-FF-5 Operable Unit, Hanford Site, Washington* (PNNL-14320)
- *Geology and Groundwater Quality Beneath the 300 Area, Hanford Site, Washington* (PNL-2949)
- *Borehole Summary Report for the 618-11 Burial Ground Tritium Investigation* (BHI-01567)

Section 3.3 presents the results of the geologic investigations conducted for the 300 Area RI/FS.

Screen depths, generalized geology, and water level elevations are summarized in Table 2-9 (Section 2.1.11). Geologic data from the new wells were combined with data from older wells to create updated interpretations of the 300 Area geology, discussed in Chapter 3.

Geologic logging was performed in each borehole to determine the stratigraphic relationship better across the 300 Area. Geologic logs are documented in borehole summary reports (300 Area RI/FS Borehole Summary Report [SGW-50054]; Borehole Summary Report for Five 300-FF-5 OU Wells [SGW-50087]).

2.1.9.3 Geophysical Logging

To understand the geology of the area better, geophysical logging was conducted at each of the soil borings and groundwater monitoring wells installed under this RI. Each borehole was geophysically logged with the high-resolution, spectral gamma-ray logging system. Logging was conducted using the S.M. Stoller Corporation[2] Spectral Gamma Logging System and Neutron-Moisture Logging System to identify natural and synthetic gamma-emitting radionuclides present near the boreholes. Soil moisture was determined using a neutron logging tool. The starting point for logging, either the ground surface or top of the casing, was recorded for each well or borehole. Borehole logging was performed through the temporary casing to produce a geophysical log of the entire length of the borehole. Detailed information on the logging operations are provided in the Borehole Summary Reports (300 Area RI/FS Borehole Summary Report [SGW-50054]; Borehole Summary Report for Five 300-FF-5 OU Wells [SGW-50087]). The reports include summaries of the calibration requirements, processing data, log plots, and results. Borehole logs are presented in Chapter 4.

[2] S.M. Stoller Corporation, Broomfield, Colorado.

2.1.10 Soil and Vadose Zone Investigation

Samples were collected for determination of soil physical properties in 17 boreholes. Sampling was performed as guided by the 300 Area SAP (DOE/RL-2009-45). Soil properties of interest were grain size analysis, sediment moisture content, and bulk density. The samples were analyzed according to American Society for Testing and Materials (ASTM) Standards *Standard Test Method for Particle-Size Analysis of Soils* (ASTM D422-63) or an equivalent field procedure, *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass* (ASTM D2216-05), and *Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method* (ASTM D2937-04), respectively. Samples were collected in the vadose at major formation and lithology changes. In addition, batch leach analyses were performed on select samples (within 3 m [10 ft]) of the water table) to reveal exchange rates between dissolved and solid forms of uranium (primary isotopes and metal) under geochemical conditions expected for the 300 Area. Table 2-8 summarizes the soil samples collected and analyzed for soil physical properties and batch leaching.

2.1.11 Groundwater Investigations

The 300 Area groundwater investigations included the following activities:

- Installation, development, and initial sampling of 11 groundwater monitoring wells to address uncertainties with groundwater quality and the nature and extent of contamination within the 300 Area.
- Collection and analysis of depth-specific groundwater samples during drilling.
- Spatial and temporal groundwater sampling to address uncertainties associated with the groundwater risk assessment.
- Continuance of 300 Area groundwater monitoring in accordance with the 300-FF-5 O&M Plan (DOE/RL-95-73, Rev. 1); includes monitoring conducted between January 1, 2010 and December 31, 2010.

The following sections describe these activities.

2.1.11.1 Groundwater Monitoring Well Installation

Eleven groundwater monitoring wells were installed in the 300 Area between August 8, 2010 and March 10, 2011. General well construction for permanent groundwater monitoring wells is shown in Figure 2-8. In addition to the permanent wells, five soil borings were completed as temporary groundwater monitoring wells. Table 2-9 presents the well construction information and objective for each well. Figure 2-1 shows the well locations.

Table 2-9. Summary of Well Construction Information for New Wells at the 300 Area

Borehole ID	Well ID	Dates Drilled	Surface Elevation (m)	Depth Drilled (m [ft])	Elev. Top of Screen (m [ft])	Elev. Bottom of Screen (m [ft])	Elev. Water Level (m [ft])	Water level Date	Depth to Hanford/ Ringold Contact (m [ft]) bgs	Depth to Top of Ringold Lower Mud (m [ft]) bgs	Objective of Well
C7653	399-1-54	Sept. to Dec. 2010	114.65	36.12 [118.50]	107.31 [352.07]	102.74 [337.06]	105.44 [345.93]	11-Nov-10	19 [61]	35 [116]	Evaluate vadose zone and unconfined aquifer beneath the former 300-FF-1 liquid waste disposal site (North Process Pond).
C7654	399-1-55	Aug. to Sept. 2010	114.89	34.44 [113.00]	107.86 [353.88]	103.29 [338.87]	105.06 [344.67]	24-Aug-10	15 [49]	33 [109]	Evaluate vadose zone and unconfined aquifer beneath the former 300-FF-1 liquid waste disposal site (North Process Pond).
C7655	399-1-56	Sept. to Oct. 2010	114.68	37.64 [123.50]	108.58 [356.24]	104.01 [341.24]	105.17 [345.04]	8-Oct-10	12 [40]	37 [121]	Evaluate vadose zone and unconfined aquifer beneath the former 300-FF-1 liquid waste disposal site (300 Area Process Trenches).
C7656	399-1-57	Aug. to Sept. 2010	114.75	36.12 [118.50]	94.94 [311.47]	91.89 [301.47]	104.87 [344.07]	29-Sep-10	17 [56]	34 [110]	Evaluate water table zone and unconfined aquifer in high concentration portion of uranium plume, within zone of groundwater/river water interaction (Near River).
C7657	399-1-58	Aug. to Sept. 2010	119.85	38.40 [126.00]	109.02 [357.67]	104.44 [342.66]	105.04 [344.61]	8-Sep-10	20 [64]	37 [123]	Evaluate vadose zone and unconfined aquifer at northwest perimeter of uranium plume (Perimeter).
C7658	399-6-3	Dec. 2010 to Jan. 2011	118.80	39.20 [128.60]	107.71 [353.38]	103.14 [338.38]	104.88 [344.11]	29-Dec-10	19 [62]	37 [123]	Evaluate vadose zone and unconfined aquifer at west perimeter of uranium plume (Perimeter).
C7659	399-1-59	Dec. 2010	120.78	45.32 [148.70]	108.09 [354.63]	103.53 [339.67]	104.91 [344.18]	16-Dec-10	21 [68]	45 [147]	Evaluate vadose zone and unconfined aquifer at west perimeter of uranium plume, and downgradient of 618-1 and 618-2 Burial Grounds remedial action sites (Perimeter).
C7660	399-2-32	Sept. to Nov. 2010	114.85	36.88 [121.00]	107.90 [354.00]	103.33 [338.99]	104.93 [344.25]	3-Nov-10	16 [53]	33 [107]	Evaluate vadose zone and unconfined aquifer beneath the former 300-FF-1 liquid waste disposal site (South Process Pond).
C7661	399-6-4	Dec. 2010 to Jan. 2011	119.29	13.11 [43.00]	-- --	-- --	-- --	--	-- --	-- --	Evaluate vadose zone and unconfined aquifer at southwest perimeter of uranium plume (Perimeter). Replaced by C8245.
C8245 (replacement of C7661)	399-6-5	Jan. 2011	119.34	47.55 [156.00]	107.88 [353.93]	103.31 [338.93]	105.17 [345.04]	12-Jan-11	21 [70]	79 [152]	Evaluate vadose zone and unconfined aquifer at southwest perimeter of uranium plume (Perimeter).
C7662	399-4-15	Jan. to Feb. 2011	119.67	44.50 [146.00]	106.75 [350.22]	102.17 [335.20]	105.53 [346.22]	9-Feb-11	22 [72]	42 [138]	Evaluate vadose zone and unconfined aquifer at south perimeter of uranium plume. This location is south of the uranium plume between the western edge and the river (Near River).
C7663	399-3-33	Nov. to Dec. 2010	118.37	41.15 [135.00]	107.64 [353.15]	103.07 [338.15]	105.11 [344.85]	1-Dec-10	15 [49]	34 [111]	Evaluate water table zone and unconfined aquifer in high-concentration portion of uranium plume, within zone of groundwater/ river water interaction (Near River).
C8026	399-1-61	Feb. 2011	117.81	17.68 [58.00]	105.30 [345.47]	104.69 [343.47]	106.08 [348.02]	28-Feb-11	15 [49]	-- --	Develop contaminant information along transects away from waste site footprints and determine where uranium concentrations may be located in the lower vadose zone near waste sites.
C8027	399-1-62	Feb. to Mar. 2011	114.78	14.63 [48.00]	104.71 [343.55]	104.10 [341.55]	105.73 [346.87]	28-Feb-11	-- --	-- --	Develop contaminant information along transects away from waste site footprints and determine where uranium concentrations may be located in the lower vadose zone near waste sites.

Table 2-9. Summary of Well Construction Information for New Wells at the 300 Area

Borehole ID	Well ID	Dates Drilled	Surface Elevation (m)	Depth Drilled (m [ft])	Elev. Top of Screen (m [ft])	Elev. Bottom of Screen (m [ft])	Elev. Water Level (m [ft])	Water level Date	Depth to Hanford/ Ringold Contact (m [ft]) bgs	Depth to Top of Ringold Lower Mud (m [ft]) bgs	Objective of Well
C8028	399-1-63	Mar. 2011	117.42	16.92 [55.50]	106.51 [349.45]	105.90 [347.45]	105.93 [347.54]	1-Mar-11	-- --		Develop contaminant information along transects away from waste site footprints and determine where uranium concentrations may be located in the lower vadose zone near waste sites.
C8029	399-1-64	Mar. 2011	114.90	14.63 [48.00]	104.54 [343.00]	103.94 [341.00]	105.60 [346.46]	4-Mar-11	-- --		Develop contaminant information along transects away from waste site footprints and determine where uranium concentrations may be located in the lower vadose zone near waste sites.
C8030	399-3-38	Mar. 2011	118.46	17.31 [56.80]	104.70 [343.49]	104.09 [341.50]	105.72 [346.85]	8-Mar-11	-- --		Develop contaminant information along transects away from waste site footprints and determine where uranium concentrations may be located in the lower vadose zone near waste sites.

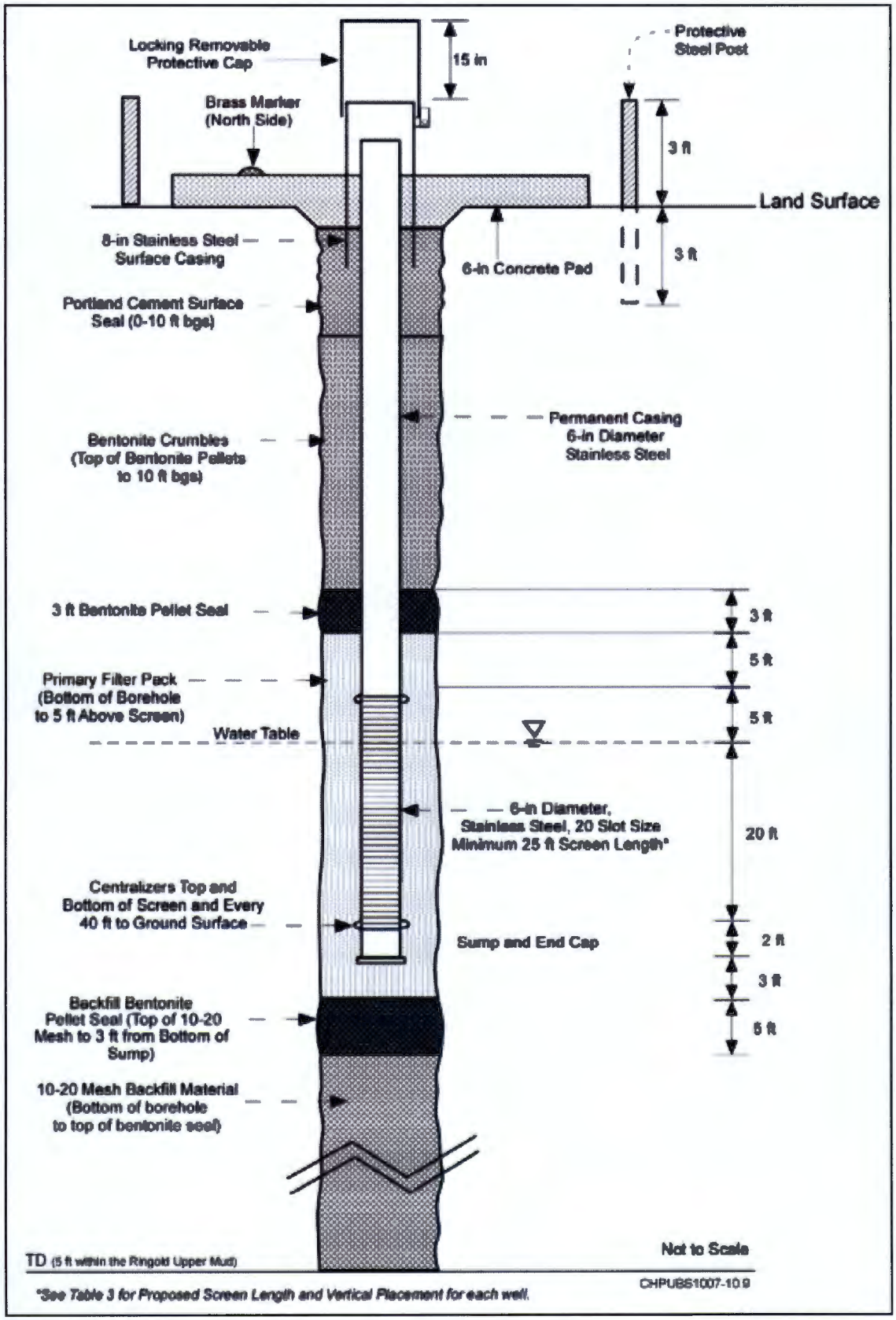


Figure 2-8. General Well Design

Unsaturated and saturated soil samples were collected for laboratory analysis from pre-defined depths within each borehole during drilling. Samples were also collected from zones of significant lithologic changes. In addition, one split-spoon sample was collected from the Ringold Formation lower mud unit from Well 399-1-57 (C7656) and 399-2-32 (C7660).

Groundwater samples were collected, in general, at depths near the top of the aquifer, the middle, and bottom of the aquifer. In addition, one groundwater sample was collected from Well 399-1-55 (C7654) from near the top of the aquifer where wood was identified during drilling.

The borehole for Well 399-6-4 (C7661) was drilled to a table depth of 13 m (43 ft) bgs. The borehole was drilled using 31.75 cm (12.5 in.) diameter temporary threaded casing from ground surface to 13 m (43 ft) bgs. Eight split-spoon samples were collected in the vadose zone before the borehole was abandoned. Grab samples for archive were collected at 1.5 m (5 ft) intervals or significant lithologic changes.

The split-spoon broke off the drill rod in the vadose zone at approximately 13 m (43 ft) bgs. After numerous unsuccessful fishing attempts and finally losing the overshot fishing tool downhole, a variance was obtained from Ecology and the borehole was abandoned in compliance with requirements. Borehole C7661 was abandoned and backfilled with bentonite chips on January 5, 2011. Borehole C8245 was drilled in close proximity as a replacement.

2.1.11.2 Spatial and Temporal Groundwater Sampling

Uncertainties associated with the groundwater risk assessment in the HHRA portion of the RCBRA 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 and CERCLA. 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, 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.

Monitoring well locations were identified to represent conditions at the 300 Area without regard to the location of surface facilities, waste sites, or known groundwater plumes. To provide the number of sampling points for a monitoring well network, the average groundwater yields are used to determine the number of residences supported on one supply well. Thus, the grid size specific to each area 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. Groundwater samples were collected so that they chemically, radiologically, spatially, and temporally represent the groundwater in the area.

These wells were then sampled to obtain temporal representation of groundwater conditions. This sampling was conducted at high, low, and transitional river stages. Three rounds of groundwater samples were collected for analysis of all COPCs to support the RI for each contaminant. A sampling round, or event, was conducted for each seasonal high, low, and transition river stages, totaling three samples per well. Each round of monitoring in the network of wells for this area was intended to be completed within 30 consecutive calendar days to minimize statistical variability in water levels. However, the actual sampling periods ranged from 33 to 48 days (Table 2-10). Groundwater samples were collected for COPCs to provide a data set that is representative of potential releases to the groundwater. Chapters 4, 6, and 7 discuss the results and subsequent evaluation of the analysis of the data.

Table 2-10. Dates of 300 Area Spatial/Temporal Groundwater Sampling (2010)

Sampling Round	Start	End	Elapsed Days
Round 1 (high river)	June 4, 2010	July 7, 2010	33
Round 2 (transitional river)	August 2, 2010	September 19, 2010	48
Round 3 (low river)	November 10, 2010	December 20, 2010	40

2.1.11.3 Groundwater Monitoring

The strategy for monitoring[3] groundwater conditions in the 300 Area RI/FS interest area is presented in the 300-FF-5 O&M Plan (DOE/RL-95-73, Rev. 1), which was prepared following the decision for interim action, which included groundwater monitoring and ICs on the use of groundwater (300-FF-1 and 300-FF-5 ROD [EPA/ROD/R10-96/143]). That strategy includes collecting periodic samples from groundwater monitoring wells, aquifer tubes beneath the Columbia River shoreline, riverbank springs, and the river.

Most wells provide groundwater samples from the uppermost hydrologic unit in the unconfined aquifer, i.e., saturated Hanford Site gravels, because that is where the preponderance of groundwater contamination from past disposal practices remains. Additional wells have deeper open intervals for obtaining samples, to monitor for potential downward migration of contamination, and several wells are completed in the uppermost confined aquifer, which resides in the more extensive aquitard at the base of the unconfined aquifer. Nearly all of the aquifer tubes emplaced beneath the river shore are positioned within the saturated Hanford Site gravels; riverbank springs, when they appear during low river stage conditions, also represent releases from that hydrologic unit. Near shore river water may include groundwater that has discharged from the unconfined aquifer through upwelling through riverbed sediment.

The lists of wells and analyses to be performed, along with sampling frequency, are described in *300-FF-5 Operable Unit Sampling and Analysis Plan* (DOE/RL-2002-11). For characterizing the uranium plume, a base frequency of twice per year was selected to represent the seasonal range in concentrations that typically appear, although more frequent sampling is conducted at locations where conditions might change more rapidly, or where waste site excavations and D4 activities are underway. Wells with screens below the uppermost hydrologic unit are sampled less frequently, depending on location. Aquifer tubes are sampled twice per year, while riverbank springs are sampled once during the Fall months, when aquifer discharge to the river is most pronounced.

Analytical results for groundwater samples are reviewed by a project hydrologist at approximately 2-week intervals, to evaluate how representative the result might be of aquifer conditions, and to identify potential errors in the HEIS record. The Tri-Parties are provided monthly briefings that highlight significant changes in groundwater conditions. An annual groundwater monitoring report provides an updated description of conditions in the 300-FF-5 OU, with the most recent report being *Hanford Site Groundwater Monitoring Report for 2010* (DOE/RL-2011-01).

[3] As used here, the term 'monitoring' includes planning field activities, conducting sampling, laboratory analyses of samples, evaluation of results, and interpretations regarding aquifer conditions.

2.1.11.4 Testing of the Infiltration of Phosphate – Polyphosphate Mixtures to Treat Uranium Contamination in the Vadose Zone and Periodically Rewetted Zone

The results of bench-scale testing have demonstrated that an effective method for treating uranium at the 300 Area is the application of phosphate-containing mixtures to form stable and insoluble uranium phosphate minerals. A treatability test was performed to evaluate the efficacy of using polyphosphate injections to treat uranium-contaminated groundwater in the saturated zone. The test had limited success due to high groundwater velocity in the 300 Area unconfined aquifer and unfavorable geochemical and hydrogeologic conditions. Therefore, a second treatability test was conducted to evaluate the efficacy of using polyphosphate infiltration from either ground surface or some depth of excavation to stabilize, in situ uranium within the deep vadose and the PRZ above the 300 Area aquifer.

In March 2010, a tracer test was initiated at the original infiltration test site located southeast of the 300 Area process trenches. After about an hour of water plus tracer application, it became evident that the ground was not accepting the water at the planned 10 cm (3.9 in.) per hour application rate. So, the original test was terminated after approximately 1 hour.

Assuming that the problem was a fine-grained and highly compacted layer at the top of the soil profile, the infiltration site was modified by excavating it to a depth of 122 cm (48 in.) below the ground surface. A pea-gravel cover was re-installed, and the drip system was reconstructed. A second test was then initiated. Again, ponding at the surface was observed, indicating that the surface/near surface sediments were still unable to accept the 10 cm (3.9 in.) per hour application rate. This test was also terminated after approximately 1 hour. Subsequent testing in small test plots within the infiltration gallery under various surface configurations indicates that infiltration rate limitations are likely associated with the relatively high silt content in the near-surface sediments and cannot be mitigated through operational changes. During these tests, the application rate was reduced to 5 cm (2 in.) per hour, but some ponding was still observed in parts of the infiltration gallery. Measurements using pressure transducers indicated that in locations where ponding was observed, the maximum infiltration rate was estimated at 2 to 4 cm (0.8 to 1.6 in.) per hour. At the south end of the infiltration gallery where ponding was not observed, the observed infiltration rates were estimated to be as high as 6 cm (2.4 in.) per hour.

The design target for infiltration rate is 10 cm (3.9 in.) of water per hour. This rate would allow the water to penetrate to the water table (approximately 10 m [32.8 ft]) in approximately 1.5 days. Laboratory studies have shown a retardation factor for phosphate to be about 4. Using this infiltration rate, the phosphate would reach the target zone in approximately 6 days. Accordingly, an infiltration rate of 3 cm (1.2 in.) per hour would require approximately three times longer. For this, and other reaction rate considerations, 3 cm (1.2 in.) per hour appears to be the minimum acceptable application rate.

Because of the difficulties in achieving the desired infiltration rate at the initial test site location, it was decided to try to find a new test location with more desirable infiltration characteristics. A series of studies were conducted to determine the areal extent of the high-silt content sediments in the 300 Area. These included a series of surface geophysical surveys and ring infiltrometer tests at a variety of locations. Three potential new test sites, two in the North Process Pond, and one in the south end of the Process Trenches were located. As of the time of this writing, no new infiltration field tests have been performed.

The original vadose zone treatability test concept relied on infiltration of the phosphate-containing reagent from the surface. Although the vadose zone at the 300 Area is only about 10 m (32.8 ft) thick, the tests described above show that there are potential difficulties with this approach. Therefore, several alternative methods by which the phosphate reagent could be injected into the deep vadose and PRZ were investigated. The technologies examined included the use of shear-thinning fluid delivery, foam-delivery,

and water mist delivery. Laboratory studies showed that injection of a liquid with a shear-thinning agent at the groundwater interface during periods of high groundwater elevation is the most promising of the prospective technologies. Properly deployed, lateral liquid injection is capable of contacting wetted vadose zone sediment at distances as great as 15 m (50 ft) from each injection well. Xanthan gum was found to be the most useful shear-thinning substance to facilitate penetration of the reagent and prolong contact time of the phosphate reagent after initial injection. No field tests using xanthan gum at the 300 Area have yet been completed.

2.1.12 Ecological Investigations

DOE monitors and surveys Hanford Site plant and animal resources to establish potential radiological exposures due to Site activities; assess the condition of endangered, threatened, or sensitive species; and evaluate breeding locations, habitat use, and distribution of key wildlife species. The following text describes the most recently published information regarding Hanford Site ecological monitoring activities (*Summary of the Hanford Site Environmental Report for Calendar Year 2008* [PNNL-18427-SUM]). No additional ecological investigations were conducted as part of this RI/FS effort.

2.1.12.1 Vegetation Monitoring

In 2008, vegetation samples were collected on or adjacent to former waste disposal sites, and from locations downwind and near or within the boundaries of operating facilities and remedial action sites to monitor for radioactive contaminants.

2.1.12.2 Fish and Wildlife Monitoring

Fish and wildlife on the Hanford Site are monitored for Hanford Site-produced contaminants. In 2008, sucker, common carp, smallmouth bass, and deer were collected at locations on and around the Hanford Site. Tissue samples were analyzed for strontium-90 and gamma emitters, including cesium-137. Since the 1990s, strontium-90 and cesium-137 have been the most frequently measured radionuclides in fish and wildlife samples. In addition, liver tissues from fish and deer were monitored for 17 trace metals (*Summary of the Hanford Site Environmental Report for Calendar Year 2008* [PNNL-18427-SUM]).

2.1.12.3 Plant Communities and Population Surveys

Plant populations monitored on the Hanford Site include species listed by Washington State as endangered, threatened, or sensitive, and species with insufficient data to evaluate. Monitoring data are used to develop baseline information and to monitor for changes resulting from Hanford Site operations. Surveys for rare annual species were conducted in 2008 as part of annual compliance review activities. More than 100 plants listed as endangered, threatened, sensitive or on their view or watch list are found on the Hanford Site.

2.1.12.4 Wildlife Populations Surveys

Four fish and wildlife species on the Hanford Site are surveyed annually: fall Chinook salmon, steelhead, bald eagle, and mule deer. The number of fall Chinook salmon spawning nests (redds) in the Hanford Reach is estimated by aerial surveys. Two aerial surveys were conducted to identify possible steelhead spawning areas.

Thirty-four eagles (18 adults and 16 juveniles) were observed during two surveys along the Hanford Reach from Vernita Bridge to the city of Richland in January and February 2009.

Roadside surveys were conducted for mule deer on the Hanford Site to assess age and sex ratios and the frequency of testicular atrophy in males. Testicular atrophy has been associated with an unusually large number of older deer residing on the Hanford Site. A combined total of 566 deer observations were made

over five repeated surveys during November 2008 to January 2009, which could include multiple observations of the same animals.

2.1.12.5 Habitat and Species Characterizations

Ecological monitoring on the Hanford Site includes characterizing breeding locations, habitat use, and distribution of key wildlife species. In 2008, characterization studies focused on the Woodhouse's toad and the burrowing owl, a Washington State candidate species and federal species of concern in this region. Toads were monitored using radio telemetry and found predominantly within 200 m (656 ft) of the Columbia River or the high water channel of the 100-F Slough. Burrowing owl distributions and nesting habitats were evaluated; 53 nests have been documented on the Hanford Site.

2.1.12.6 Contaminated Biota

Animals (including insects) must be controlled when they are contaminated with radioactivity. There were 33 contaminated animals or animal-related materials discovered in 2008 on the Hanford Site (*Summary of the Hanford Site Environmental Report for Calendar Year 2008* [PNNL-18427-SUM]).

2.2 Field Activity Documentation

As discussed in previous sections, field investigations have been conducted in the 300 Area to supplement information received from the LFIs and in response to results from ongoing remedial actions (e.g., CERCLA 5-year reviews). The results of these field investigations are summarized in a variety of documents as indicated in Table 2-11. Appendix C contains the geophysical logs. Additional well drilling details are provided in the Summary Borehole Reports (300 Area RI/FS Borehole Summary Report [SGW-50054]; Borehole Summary Report for Five 300-FF-5 OU Wells [SGW-50087]), and the documentation listed in Table 2-11.

Table 2-11. Summary of Field Activity Documentation

Field Activity		Document Name (Number)	Document Date
300 Area RI/FS Work Plan 1-11 Wells		*Borehole Summary Report for the Installation of 11 Wells to Support RI/FS in the 300-FF-5 Operable Unit* (SGW-50054) Well database: http://environet.rl.gov/EDA	July 2011
300 Area RI/FS Work Plan Boreholes		*Borehole Summary Report For The Installation Of Five Wells In The 300-FF-5 Operable Unit To Support RI/FS In FY 2011* (SGW-50087) Well database: http://environet.rl.gov/EDA	August 2011
Orphan Site Evaluations	300 Area	*300 Area Orphan Sites Evaluation Report* (OSR-2010-0002)	September 2010
	400 Area	*400 Area Orphan Sites Evaluation Report* (OSR-2010-0003)	November 2010
Air Investigations		*Hanford Site Environmental Report for Calendar Year 2009* (PNNL-19455)	

Table 2-11. Summary of Field Activity Documentation

Field Activity	Document Name (Number)	Document Date
Groundwater Upwelling	*Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington* (WCH-398)	September 2008
Porewater Sampling	*Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington* (WCH-398)	September 2008
Surface Water Sampling	*Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington* (WCH-398)	September 2008
Sediment Sampling	*Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington* (WCH-398)	September 2008
Groundwater Monitoring	*Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2* (DOE/RL-2010-11)	2010
Groundwater sampling of spatial and temporal monitoring network	Groundwater sample records in IDMS; groundwater data in HEIS (http://environet.rl.gov/EDA)	2010
Ecological Investigations	*Summary of the Hanford Site Environmental Report for Calendar Year 2008* (PNNL-18427-SUM)	September 2009

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3 Physical Characteristics of the Study Area

This chapter describes the 300 Area's physical characteristics, which form the basis of the conceptual model framework for later discussions regarding the nature and extent of contamination (Chapter 4) and contaminant fate and transport (Chapter 5). The following 300 Area characteristics are discussed in this chapter: surface features, meteorology, surface water hydrology, geology, hydrogeology, artificial water systems, ecology, and cultural resources. This chapter also includes a discussion of current and reasonably anticipated future land use, and demography that support risk characterization (Chapters 6 and 7).

Highlights

- The Columbia River is a gaining stream as it crosses the Hanford Site. The flow volume and river stage within the 300 Area are controlled by releases from Priest Rapids Dam, which have typical flows between 1,132 and 7,079 m^3/s (40,000 and 250,000 ft^3/s).
- The uppermost aquifer is unconfined, is comprised of the gravel-dominated Hanford formation and the sands and gravels of Ringold unit E. A low-permeability aquitard, the Ringold Formation lower mud unit, forms the base of the unconfined aquifer.
- Very high groundwater flow velocities (e.g., 18 m/d [59 ft/day]) have been observed within the 300 Area. Hydraulic gradients in the aquifer change rapidly in steepness and orientation as the river stage fluctuates on daily, weekly, seasonal, and multiyear cycles.
- In general, regional groundwater flow converges into the 300 Area from the northwest, west, and southwest, causing a generally southeasterly or easterly flow direction beneath the 300 Area. During the period of high Columbia River flow, movement beneath the 300 Area is more southerly, and during the period of low Columbia River flow, movement becomes more easterly.
- Changes in geochemical environment in saturated Hanford formation sediment are most pronounced near the Columbia River, where river water intrudes into the aquifer. River water is lower in bicarbonate content than groundwater, resulting in lower ionic strength, which can influence the transport of certain contaminants. Lower bicarbonate content enhances the tendency for certain contaminants, such as uranium, to adsorb onto sediment.

3.1 Surface Features

The surface topography of the Site has been modified by natural and manmade forces. These forces include the Columbia River, Pleistocene catastrophic flooding, Holocene eolian forces, interim source remedial action, and the construction of roads and buildings to support DOE's missions (*200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program*, hereinafter called 200 Areas RI/FS Implementation Plan–ERP [DOE/RL-98-28]). Basalt ridges and low-relief plains dominate the land surface on the Site (200 Areas RI/FS Implementation Plan–ERP [DOE/RL-98-28]). The low relief plains encompass the 300 Area boundary. East-west trending anticlinal ridges are present west of the plains.

The surface topography of the 300 Area was mapped in FY 2008. Maps were generated using LIDAR. Figures 3-1, 3-2, and 3-3 show the 300 Decision Area, 300 Area Industrial Complex, and 400 Area topography, respectively.

The topography in the 300 Decision Area is relatively flat inland from the Columbia River. Topography changes are greatest near the Columbia River where the riverbank slopes steeply. Surface elevations range from between 135 and 137 m (443 and 449 ft) above mean sea level (AMSL) at the 618-11 Burial Ground subregion and Energy Northwest Complex to between 115 and 118 m (377 and 387 ft) AMSL at the 300 Area.

3.2 Meteorology

The Site is characterized by a semi-arid climate, and is the driest, lowest, 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 (*Hanford Site National Environmental Policy Act [NEPA] Characterization*, hereinafter called NEPA Characterization Report [PNNL-6415]). The Cascade Range to the west creates a rain shadow effect over the Site's climate, while the Rocky Mountains and ranges in southern British Columbia protect it from the more severe polar air masses from Canada (*Hanford Site Climatological Summary 2004 with Historical Data*, hereinafter called 2004 Hanford Climatological Summary [PNNL-15160]).

Climatologic data are monitored at the HMS located in the 200 Area and 30 monitoring locations throughout the Site. From 1945 through 2009, 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. The annual average relative humidity is 54 percent.

Annual precipitation historically recorded at the Site has varied from approximately 7.6 to 31.3 cm/year (3.0 to 12.3 in./year) since 1947, with an average of 17.2 cm/year (6.8 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. Winter monthly average snowfall ranges from 05.6 cm (2.2 in.) in February to 13.2 cm (5.2 in.) in January. Surface winds blow predominantly from the northwest during winter and summer and from the southwest during spring and fall. In the southeastern portion of the Site, prevailing wind direction near the surface is from the southwest during most months; wind from the northwest are much less common. Figure 3-4 contains composite wind roses and joint frequency distributions for the Hanford meteorological monitoring network for the period 1982 through 2004.[1] The prevailing wind direction at the Site is from the west-northwest or northwest, and the peak gusts are from the south-southwest, southwest, or west-southwest. The highest monthly average wind speeds occur in June, and the lowest are in December. The variability in monthly average wind speeds is much greater in the winter months than during the remainder of the year.

Winds are typically between 6 and 11 km (4 and 7 mi)/hour, which occurs 37 percent of the time. Winds between 13 and 19 km (8 and 12 mi)/hour occur 25 percent of the time, with winds over 40 km (25 mi)/hour only occurring 1 percent of the time annually, with the highest frequency in March (1.6 percent). High-speed surface winds in the summer from the southwest can generate regional dust storms that can limit the progress of work, and at times, make it necessary to stop work. Figure 3-5 shows the Hanford Construction Camp during one such dust storm, taken around 1944.

[1] Wind speed averages have not been published for years 2005 to present. However, speeds are not expected to have varied considerably during that time range.

Figure 3-1. Topographic Map—300 Decision Area

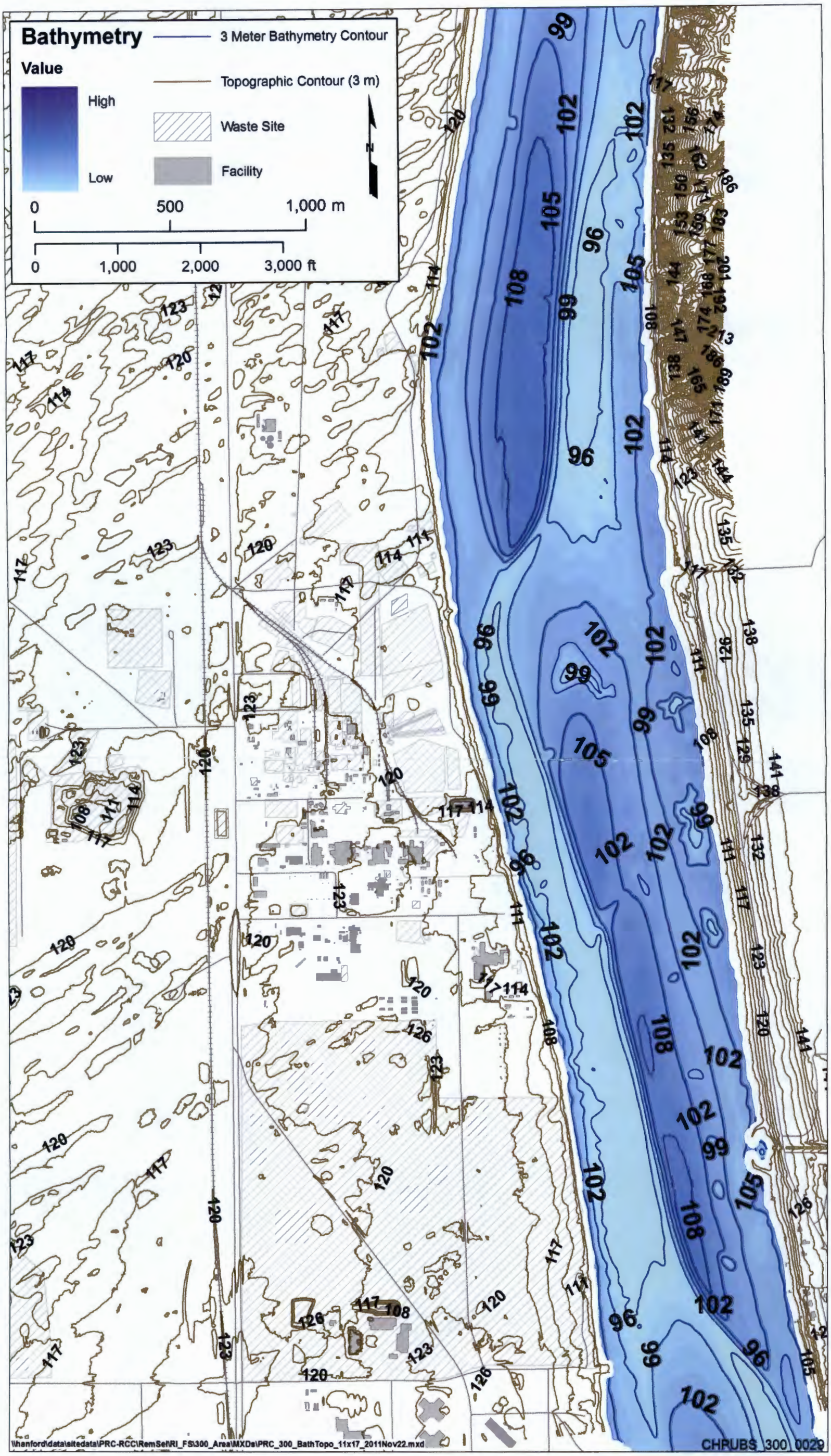

Figure 3-2. Topographic Map—300 Area

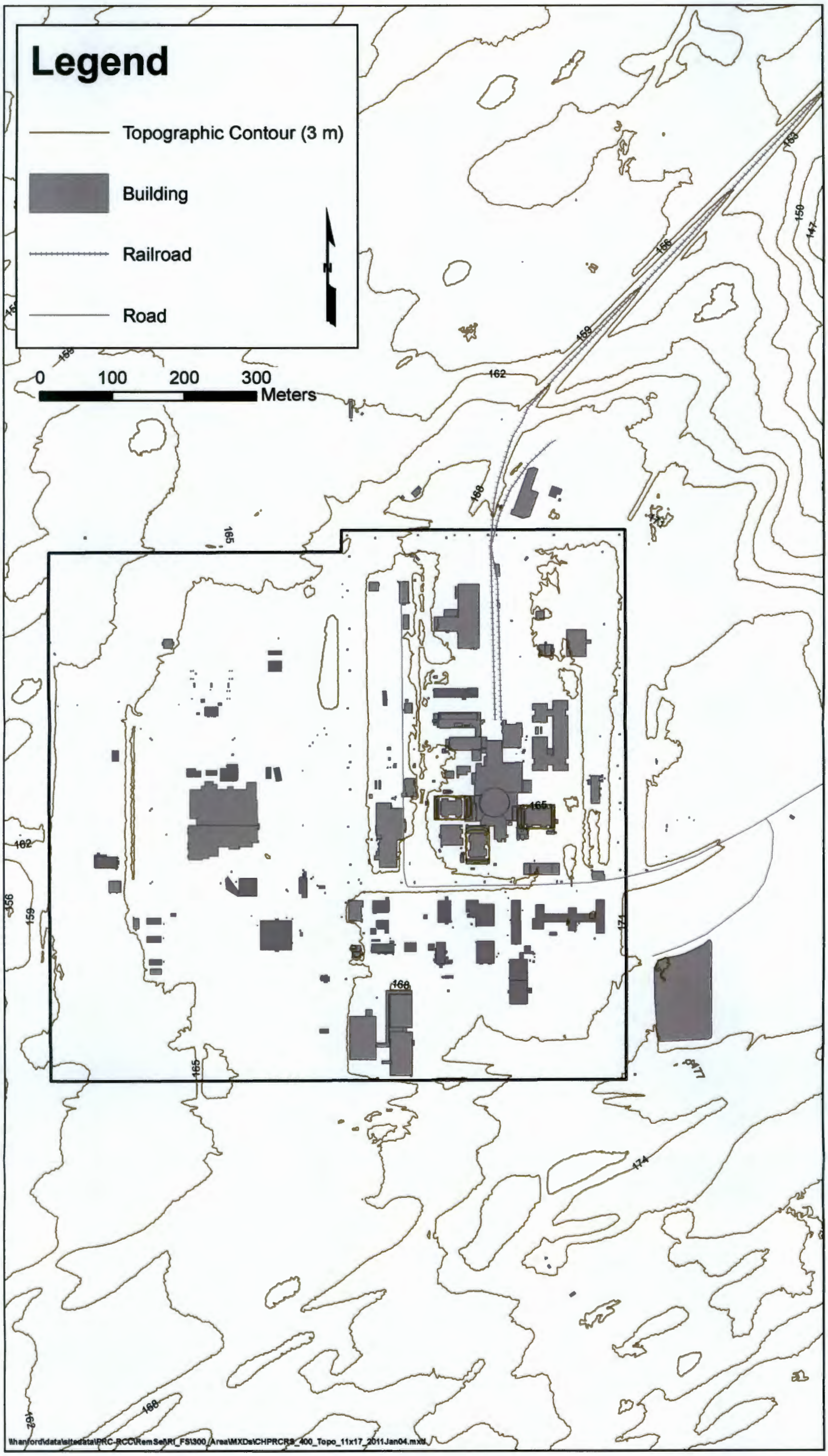

Figure 3-3. Topographic Map—400 Area

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Source: PNNL-15160, *Hanford Site Climatological Summary 2004 with Historical Data.*

Figure 3-4. Hanford Meteorological Monitoring Network Wind Roses at 30 ft, 1982 through 2004

Figure 3-5. Dust Storm at Hanford Site Construction Camp, ca. 1944

3.3 Surface Water Hydrology

The principal surface water feature associated with the 300 Decision Area is the Columbia River. No other streams, lakes, or natural ponds are present within the 300 Area. The following sections describe the key features of the Columbia River as it passes through the Pasco Basin physiographic province, with emphasis on that portion adjacent to the 300 Decision Area.

3.3.1 Columbia River, Hanford Reach

The Hanford Reach is defined as the segment of the Columbia River that crosses the Site. The Reach extends from approximately Vernita Bridge on Highway 240 downstream to Lake Wallula. Two USGS 7.5-minute quadrangle maps include that portion of the Reach that is adjacent to the 300 Decision Area: Wooded Island and Richland. The northernmost portion of the Reach, where the channel changes direction from northeasterly to southeasterly, is referred to as the horn area.

3.3.1.1 Hanford Reach Flow Characteristics

The Columbia River is considered "free-flowing" as it passes through the Hanford Reach in the sense that flow is not constrained by pools upstream of dams. The volume of flow through the Reach is controlled by release of water from Priest Rapids Dam. The dam determines release rates in response to a variety of factors, with the most significant being electric power generation needs. Other factors include responding

to upstream flow from the Columbia River drainage basin, reservoir and dam maintenance needs, and salmon spawning considerations. Priest Rapids Dam has a relatively limited range in reservoir capacity, and must release water during periods of high Columbia River flows regardless of power generation needs.

Discharge from Priest Rapids Dam varies seasonally, with typical flows between a low of 1,132 m^3 (40,000 ft^3)/s to a high of 7,079 m^3 (250,000 ft^3)/s, although extremes beyond this range are not uncommon. Detailed information on Columbia River flow characteristics is available from a database (Columbia River DART; Data Access in Real Time) maintained by the University of Washington. Stream flow data are also available from the USGS (*USGS Water Data for the Nation* [USGS, 2007]) for a gauging station immediately downstream from Priest Rapids Dam ("Columbia River Below Priest Rapids Dam, WA" [USGS 12472800]). Figure 3-6 is a graph of Priest Rapids Dam discharge for the period October 2005 to June 2011; also shown on the figure is a plot of river stage at the 300 Area gauging station SWS-1. Note that the river stage at the 300 Area directly mimics the release from Priest Rapids Dam, even though river stage at the 300 Area is also influenced by the elevation of Lake Wallula. The upstream limit of Lake Wallula is approximately 4.5 m (14.7 ft) upstream of the 300 Area, at the downstream end of Wooded Island (Hanford River Marker 39.5; USGS River Mile 348.2). The travel time for a release at Priest Rapids Dam to reach the 300 Area is approximately 8 hours.

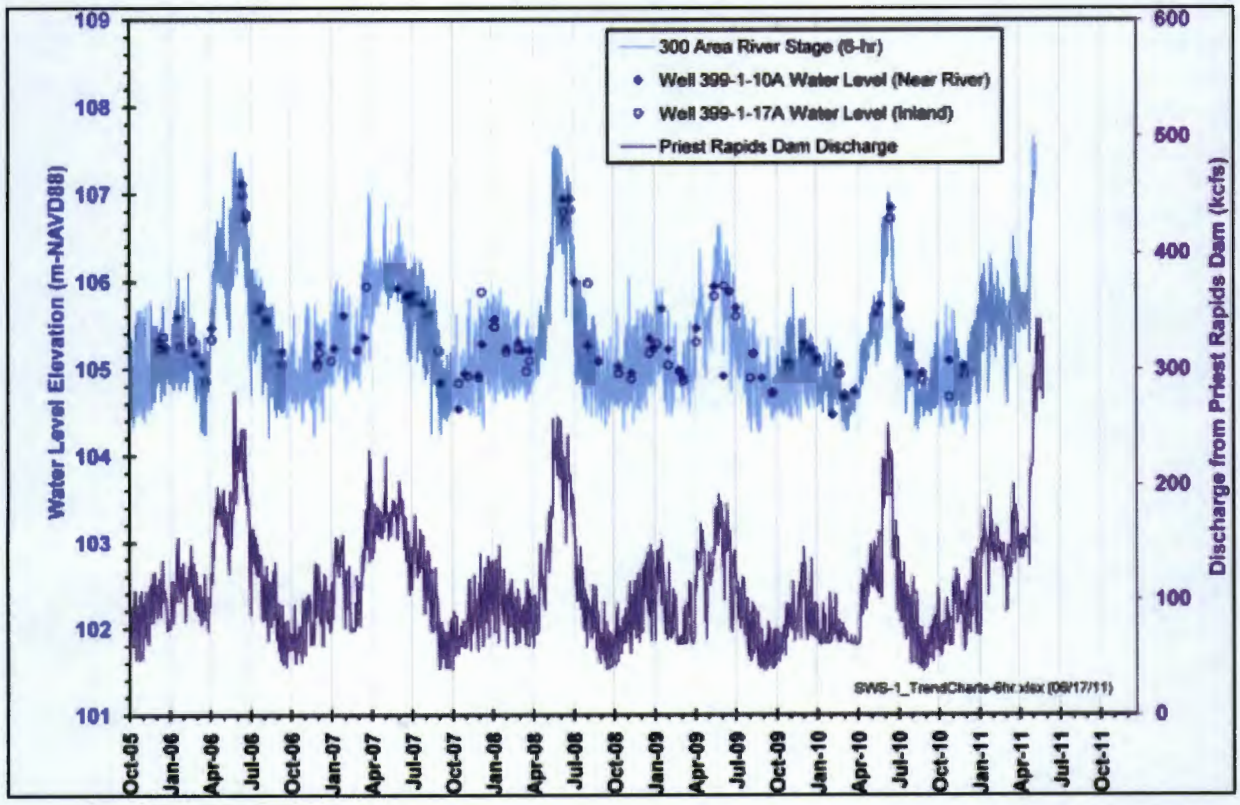


Figure 3-6. River Water Discharge from Priest Rapids Dam and River Stage at the 300 Area

3.3.1.2 Input along Hanford Reach: Regional Aquifer Discharge and Irrigation Returns

The Columbia River is a gaining stream as it crosses the Site. Various estimates have been made for the rate of groundwater discharge from the Site unconfined aquifer (i.e., water table aquifer) to the river, with values typically falling in the range 0.85 to 1.4 m^3 (30 to 50 ft^3)/s. Similar estimates for the rate of discharge from the unconfined aquifer on the opposite side of the river are not known but may be

comparable in magnitude or larger. The total input from aquifers on either side of the river is small relative to the flow of the river. Assuming representative values for total aquifer discharge from both sides of the channel (2.8 m^3 [100 ft^3]/s) and for a typical river discharge (3,400 m^3 [120,000 ft^3]/s), the aquifer discharge is approximately 0.08 percent of the river flow.

The rate of discharge from the Hanford aquifer varies along the shoreline depending on local geologic characteristics. In general, rates are highest where the channel incises highly permeable Hanford formation sediment, which occurs on the shoreline east of the horn area. The rate is probably lower on the shoreline west of the horn area, where the river channel incises Ringold unit E sediment, which is less permeable than Hanford formation sediment. However, variable hydraulic gradients also influence the rate of discharge, along with the permeability of the sediment. Finally, fabricated features such as reactor outfall pipes may provide a preferential pathway for groundwater to discharge through the riverbed.

The Hanford Reach also gains water via irrigation wastewater returns from the Franklin Country side of the river, of which there are four opposite the 300 Decision Area. From north to south, they are PE 16.4 Waterway, Ringold Waterway, Potholes East Canal, and Esquatzel Diversion Canal (Figure 3-7). A typical discharge from these returns to the Hanford Reach is approximately 6.3 m^3 (221 ft^3)/s, which represents approximately 0.18 percent of the river flow at 3,400 m^3 (120,000 ft^3)/s.

Dissolved uranium is present in irrigation return water discharging to the Columbia River via irrigation waste ways. The dissolved uranium occurs by leaching of natural deposits, and from uranium-containing minerals used in fertilizers. An updated evaluation of uranium discharge to the Columbia River from irrigation return water was started in November 2010 as part of this RI. Initially, 15 irrigation waste ways were identified that return irrigation water back to the Columbia River; these were located between the Interstate-90 bridge at Vantage, Washington, and the Oregon state line (Figure 3-7). The Bureau of Reclamation provided 14 years of recent flow data for these waste ways from 1995 through 2008 (Table 3-1). Of these 15 waste ways, seven contributed 95 percent of the irrigation water returned to the river in the lower Columbia Basin.

Table 3-1. Acre Feet of Water Returned to the Columbia River Annually in the Lower Columbia Basin between Vantage and the Oregon Border

Waste Way Location	Water Returned to the Columbia River Annually (ac ft; 14-Year Average)[a]	Percent of Total
WB10WW1	12,627	2.9
Pasco WW	21,444	4.9
WB5WW1	28,019	6.4
Priest Rapids	34,836	7.9
Esquatzel Diversion Canal[b]	55,296	12.6
PE16.4WW[b]	103,814	23.6
Crab Creek at Beverly	161,492	36.7
Total, 15 waste ways	440,107	~95

a. One acre-foot equals 43,560 ft^3.

b. Waste way opposite the 300 Decision Area.

The water in these canals was originally taken from the Columbia River, which is then diverted across Eastern Washington in a vast system of irrigation canals. After application to fields using a variety of methods, water returns to the Columbia River through the waste ways. Water in the waste ways is a combination of unused irrigation water, surface runoff (irrigation and precipitation), and water that percolates through the vadose zone to the water table and then eventually re-emerges in the waste ways.

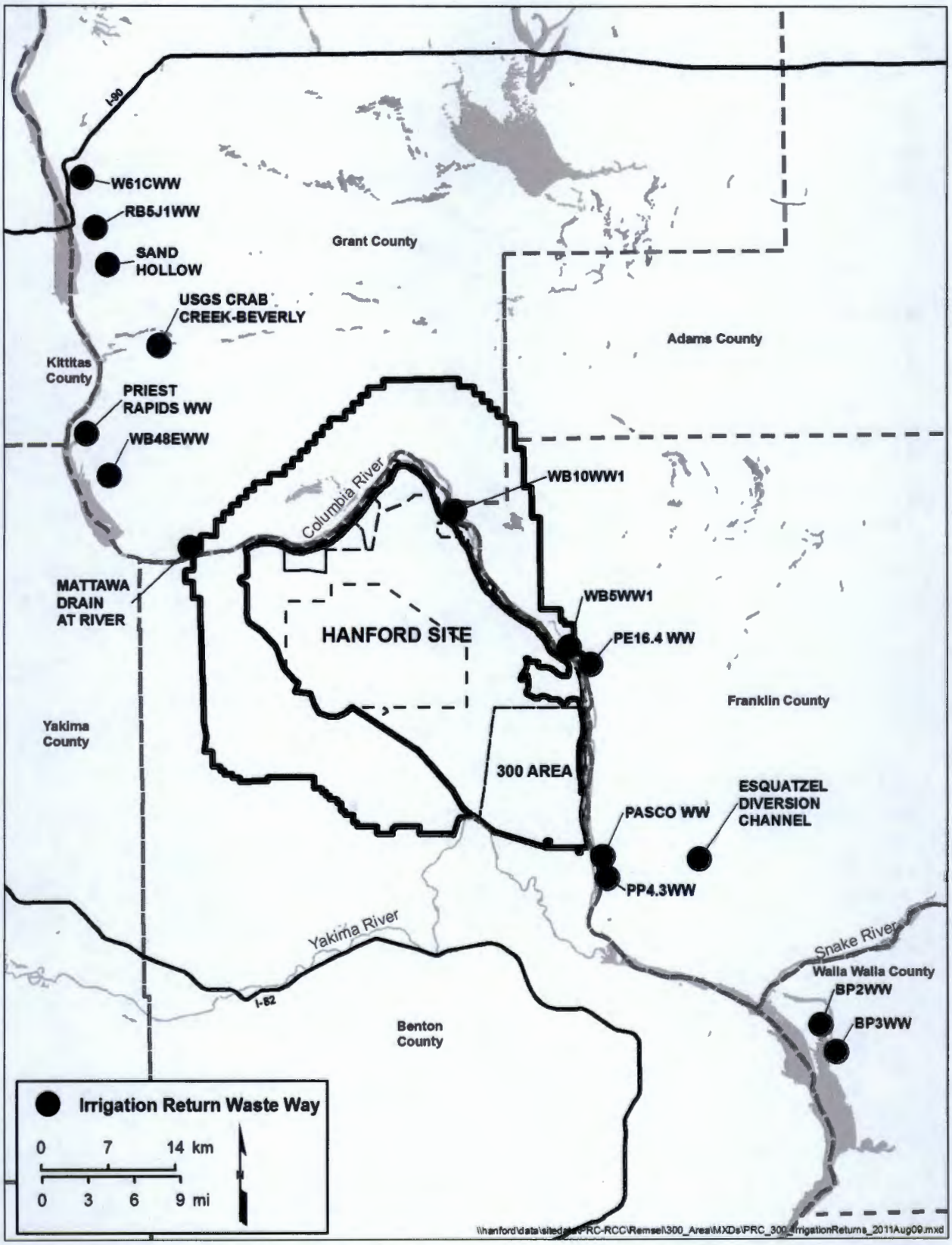


Figure 3-7. Irrigation Return Waste Ways Located between the I-90 Bridge at Vantage and the Oregon Border (i.e., Lower Columbia Basin)

To put the irrigation return flow in perspective with the flow of the river through the Hanford Reach, the monthly discharge of irrigation return PE16.4WW for 2005 was compared to total monthly water discharged from Priest Rapids Dam for the same year (Figure 3-8). The separate scales for each flow illustrate the large degree of dilution that occurs within the Columbia River, and highlights the seasonal variability of both river and irrigation return flows. While the August through October time period has the highest irrigation return flow, it has some of the lowest Columbia River flows throughout the year; thus, it is the season when the percentage of irrigation return flow is highest in the river.

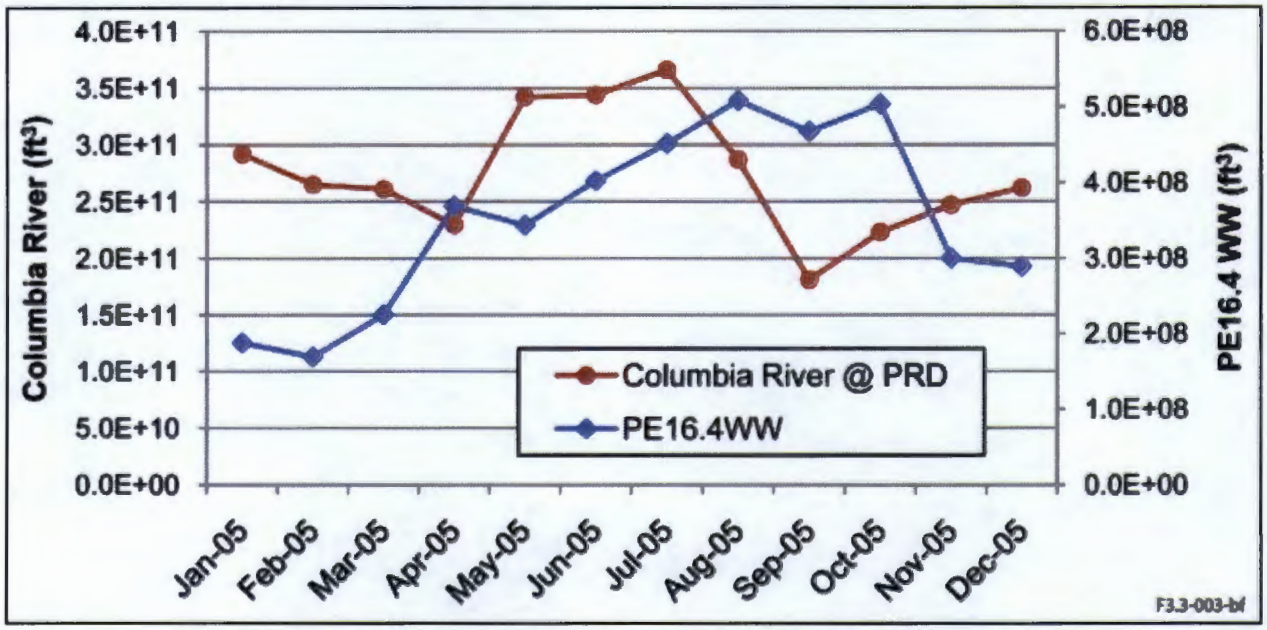


Figure 3-8. Monthly Total Water Discharges from Irrigation Return PE16.4WW and Priest Rapids Dam during 2005

3.3.1.3 Water Quality/Water Use

USGS monitors the chemical characteristics of the Columbia River at the Site at two stations: Vernita Bridge and at Richland. Results of this monitoring are described in the annual Environmental Report for the Hanford Site (e.g., 2009 Sitewide Environmental Report [PNNL-19455], Appendix C). The bicarbonate content of the river is relatively low, compared to that of groundwater, a factor that potentially influences the mobility of uranium contamination in near-river groundwater. River water has very low turbidity and very low amounts of dissolved organic matter. The temperature of the free-flowing stream varies seasonally within the approximate range 4 to 20 degrees Centigrade 4°C to 20°C 39 (39°Fto 68 F). Occasionally, freezing will occur in sheltered areas during cold spells, but the main stream does not freeze up during winter. Much higher temperatures occur in shallow areas during the summer months, which is of concern for the survival of juvenile salmon.

Contaminants in the river are typically at concentrations lower than relevant regulatory standards. Sources for these contaminants are spread throughout the drainage basin, which covers approximately 670,000 km^2 (260,000 mi^2). Chemical contaminants result from mining activities, drainage over geologic terrains containing leachable constituents, and from agricultural activities. Radiological contamination results from atmospheric fallout of bomb test debris, leaching of natural deposits, and discharge via Site groundwater.

Limited characterization of uranium in irrigation water returned to the Columbia River through waste ways has been done to date. Available results indicate a narrow range of uranium concentrations (i.e., 3 to 9 µg/L), which is within the range of natural background for groundwater in the saturated Hanford formation sediment at the 300 Area (*Uranium and Other Chemical Contaminants Entering the Columbia River from the South Columbia Basin Irrigation Outfalls* [Ecology Publication 10-05-019]). To calculate an estimate of the total mass of uranium that might be returned to the Columbia River annually from these irrigation canals, an assumption was made that the annual average uranium concentration in all of the irrigation return water is 5 µg/L. This value was multiplied by the total amount of water returned to the Columbia in the lower Columbia Basin annually between 2000 and 2008 (Figure 3-9), to provide an estimate of the annual uranium contribution to the Columbia River from irrigation return water in the lower Columbia Basin. While the estimate contains uncertainty related to the assumed concentration of uranium in irrigation return water, it is apparent that several thousand kilograms of uranium could be added annually to the Columbia River near the Hanford Reach from irrigation return water.

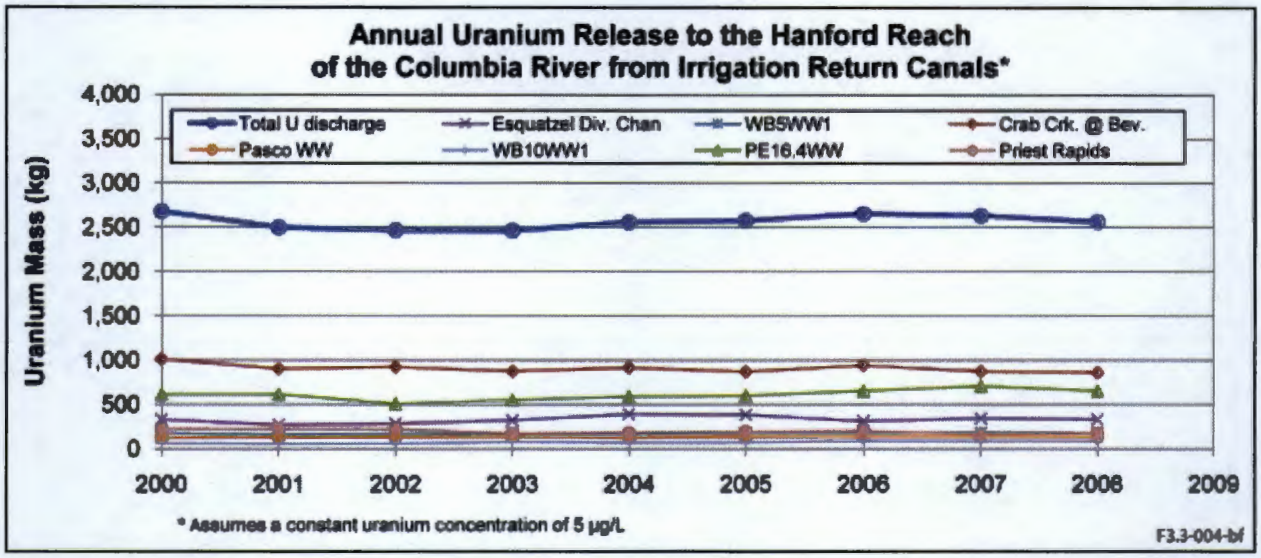


Figure 3-9. Potential Total Uranium Discharge to the Columbia River from 15 Irrigation Waste Ways in the Lower Columbia Basin, Also Showing Discharge from the Top Seven Contributors

Water quality of the Hanford Reach is ranked high by most measures. There are no restrictions on its use for water supply and miscellaneous uses per Washington State requirements. The State's recently revised classification for surface waters describes the Columbia River downstream of Grand Coulee Dam as providing for "…protection of spawning, rearing, and migration of salmon and trout as well as other associated aquatic life," and suitable for recreational activities that may involve complete submersion of the participant (2009 Sitewide Environmental Report [PNNL-19455]).

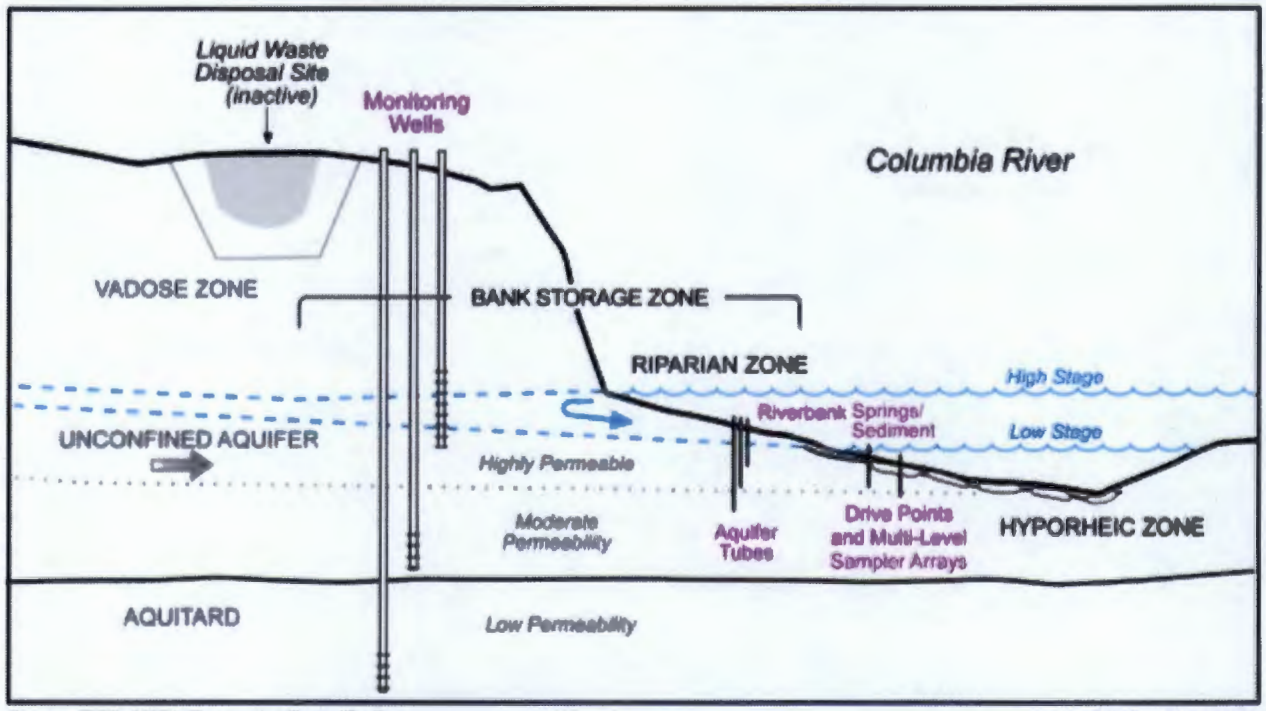
River water is withdrawn at several points along the Reach, with withdrawal just downstream of the 300 Area to supply the city of Richland with drinking water. Other withdrawals include 100-BC and 100-D/H where water is withdrawn to supply Site industrial needs; withdrawal by Energy Northwest for its industrial needs; and near the 300 Area where withdrawal supplies irrigation water for agriculture just south of the Site boundary. A small amount of river water is also withdrawn for use in aquariums in PNNL's Life Sciences Building (331 Building); river water supplements groundwater withdrawn from water supply Well 399-4-12 (see Section 3.7.1 for more information on this well).

3.3.1.4 Hanford Reach Natural Resources

Natural resources within the Hanford Reach near the 300 Decision Area include drinking water for the city of Richland; natural habitat for a variety of aquatic, riparian, and terrestrial plants and animals; recreational opportunities for humans, including water sports and hunting; and aesthetic qualities of the landscape. In the late 19th and early 20th centuries, gold was extracted from sediment along the river's edge, but that activity ceased in approximately 1930 (*Chinese Gold Miners of the Mid-Columbia Region* [BHI-01316]). All of these natural resources are acknowledged by the formation of the HRNM (Hanford Reach National Monument website [USFWS, 2011]). Additional descriptions of the natural resources associated with the Hanford Reach are presented in the NEPA Characterization Report (PNNL-6415) and in the most recent annual (CY 2009) environmental report for the Site (2009 Sitewide Environmental Report [PNNL-19455]).

3.3.2 Hyporheic Zone and Bank Storage (Regional Characteristics)

A zone of interaction is formed at the juncture of the river and aquifer systems near the river channel. This zone is referred to as the hyporheic zone, which has various definitions depending on the discipline using the term. For purposes of the RI, the hyporheic zone will refer to the subsurface region influenced by hydrologic aspects of the river, such as water quality characteristics and hydraulic parameters. An understanding of the features and processes in the zone on the Hanford Site side of the channel is useful for predicting the fate and transport of contaminants, for selecting a remedial action alternative, and for developing ways to monitor the performance of remedial actions. Figure 3-10 is a schematic that illustrates the principal features of the zone of interaction between the river and groundwater hydrologic systems.



Source: PNNL-13874, Figure 1.1, with modifications

ZOI-terms-042709.ai

Figure 3-10. Schematic Showing the Principal Features Associated with the Zone of Groundwater/River Interaction

The term "bank storage" is also associated with stream channels. Bank storage has been defined as stream water that intrudes into the banks when the pressure gradient is directed inland, and for gaining streams such as the Hanford Reach, also includes groundwater that is effectively dammed as it approaches the river during high stream conditions (*Evaluation of Bank Storage Along the Columbia River Between Richland and China Bar, Washington* [Newcomb and Brown, 1961]). Intruding river water within the River Corridor influences the transport of contaminant plumes to the river. The intruding water may flow along the top of the unconfined aquifer, or it may rapidly mix with the approaching groundwater, depending on local conditions. At the 300 Area, there is evidence for layering and mixing (see Section 3.6.4).

3.4 Geology

This section presents the regional and 300 Area geologic setting.

3.4.1 Regional Geologic Setting

The Hanford Site and the 300 Decision Area are located in the Columbia Basin of the Pacific Northwest. The Columbia Basin forms the northern part of the Columbia Plateau physiographic province and the Columbia River flood basalt province. Most of the geologic features visible in the Basin occurred during the last 17 million years of the Cenozoic Era.

The Columbia Basin has four structural subdivisions or subprovinces, two of which are important to the Pasco Basin and the Site the Yakima Fold Belt and the Palouse Slope (*Site Characterization Plan: Reference Repository Location, Hanford Site, Washington* [DOE/RW-0164]). The Yakima Fold Belt is a series of anticlinal ridges and synclinal valleys in the western part of the Columbia Basin that has predominantly an east-west structural trend (Figure 3-11). The Palouse Slope is the eastern part of the Columbia Basin and shows little deformation with only a few faults and low-amplitude, long wavelength folds on an otherwise gentle southwestward-dipping paleoslope. The Site lies within the Pasco Basin, a geologic structural basin situated between the Yakima Fold Belt and Palouse Slope geologic subprovinces. The Saddle Mountains form the northern boundary of the Pasco Basin while Rattlesnake Mountain forms part of the southern boundary. Ridges and valleys of the Yakima Fold Belt are to the west of the Basin and more gentle features of the Palouse Slope to the east.

The Pasco Basin's origins go back to the Miocene Epoch when lava flows of Columbia River basalt blanketed the area ("Volcanism and Tectonism in the Columbia River Flood-Basalt Province" [Reidel and Hooper, 1989]; "An Introduction to the Stratigraphy, Structural Geology, and Hydrogeology of the Columbia River Flood-Basalt Province: A Primer for the GSA Columbia River Basalt Group Field Trips" [Tolan et al., 2009]). Simultaneous with emplacement of the lava flows was north-south tectonic compression, which created a series of east-west structures called the Yakima Folds. Indications are that these folds are still deforming today, albeit at a slower rate than in the geologic past ("The Saddle Mountains: The Evolution of an Anticline in the Yakima Fold Belt" [Reidel, 1984]). Downwarping of the basins of the Yakima Fold Belt led to the accumulation of epiclastic sediments of the Ellensburg and Ringold formations within the Pasco Basin ("Paleodrainage of the Columbia River System on the Columbia Plateau of Washington State: A Summary" [Fecht et al., 1987]; DOE/RW-0164; *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington* [BHI-00184]). The accumulation of the Ringold Formation continued into post-basalt times for another six to seven million years until about 3.4 million years ago, when accumulations of the fluvial-lacustrine Ringold suddenly ended with a regional drop in base level. The cause for the base level drop is associated with regional tectonic uplift and Cascade volcanism associated with the ancestral Cascade Range, or perhaps the downstream breaching of a volcanic dam in the Columbia River Gorge ("Paleodrainage of the Columbia River System on the Columbia Plateau of Washington State: A Summary" [Fecht et al., 1987]).

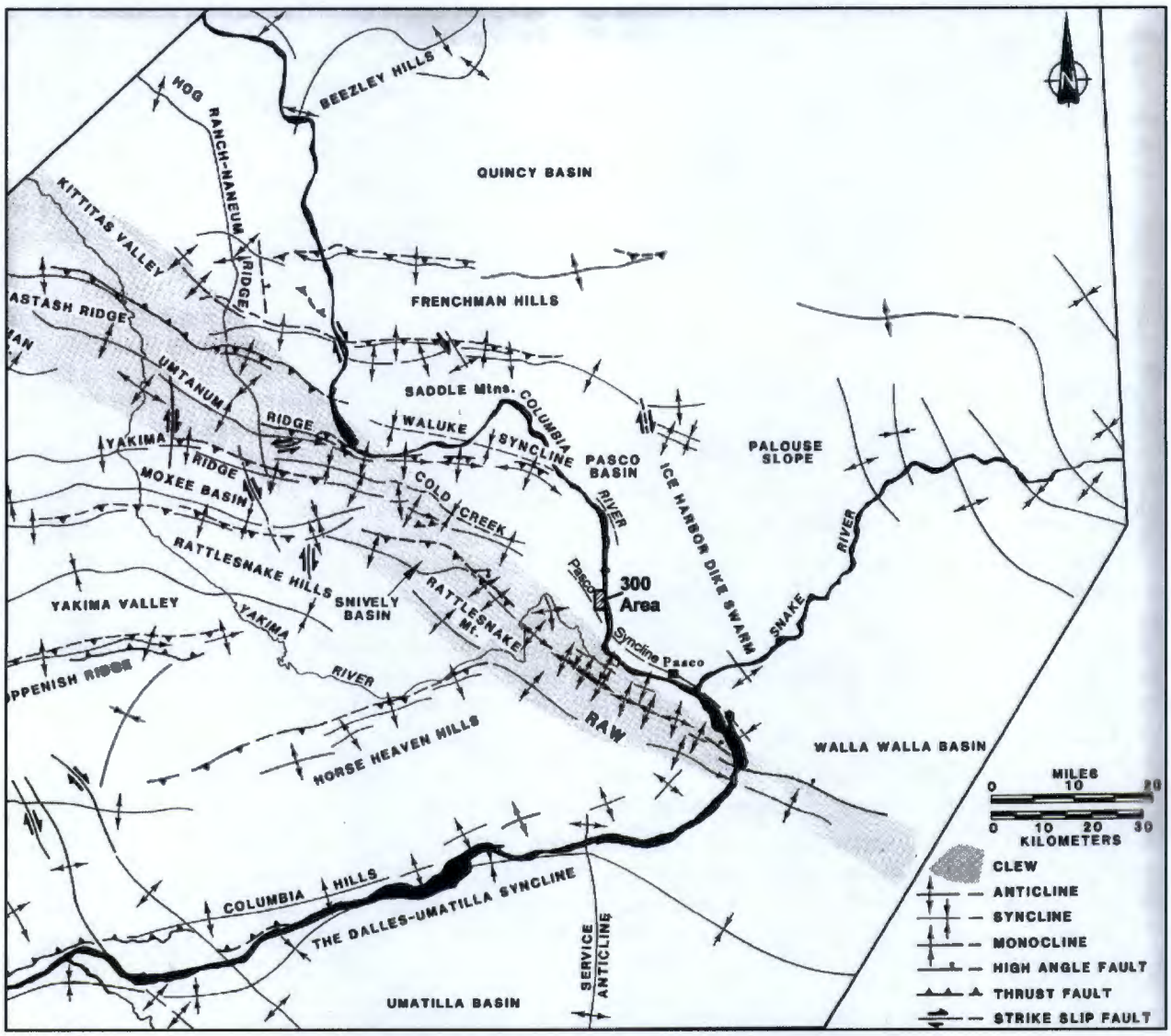


Figure 3-11. Structural Elements of the Columbia Basin

Due to the drop in base level, the Ringold Formation was deeply incised and much of it moved from the center of the Pasco Basin, including the Site. (The White Bluffs escarpment along the eastern boundary of the Site is a more protected erosional remnant of the Ringold Formation, still in the process of the being eroded and removed from the basin.) Within a relatively short time, the Columbia River found a new base level that was 150 m (500 ft) lower than at the close of Ringold deposition. Following the drop in base level, a long period (one to two million years) ensued where there was little or no deposition. An exception was the development of localized post-Ringold-age calcic paleosols, eolian deposits, and river-channel deposits of the Cold Creek unit, mostly restricted to the western Pasco Basin (*Standardized Stratigraphic Nomenclature for Post-Ringold-Formation Sediments Within the Central Pasco Basin*, hereinafter called Standardized Nomenclature for Post-Ringold Sediments [DOE/RL-2002-39]).

Widespread sediment accumulations in the Pasco Basin began again, probably in the early Pleistocene, with glacio-fluvial deposits from repeated Ice Age (Missoula) floods ("Long History of Pre-Wisconsin, Ice Age Cataclysmic Floods: Evidence from Southeastern Washington State" [Bjornstad et al., 2001]; "Magnetostratigraphic Evidence from the Cold Creek Bar for Onset of Ice-Age Cataclysmic Floods in

Eastern Washington During the Early Pleistocene" [Pluhar et al., 2006]; and *On the Trail of the Ice Age Floods: A Geological Field Guide to the Mid-Columbia Basin*, hereinafter called A Geological Field Guide to the Mid-Columbia Basin [Bjornstad, 2006]). The exact age of the earliest Ice Age floods is unknown. The oldest documented floods were at least 780,000 years ago although the first floods may have occurred closer to the beginning of the Ice Age around 2.6 million years ago. Evidence for the earliest floods has since been destroyed either by multiple younger floods, or by lies buried beneath the cover of the younger flood deposits.

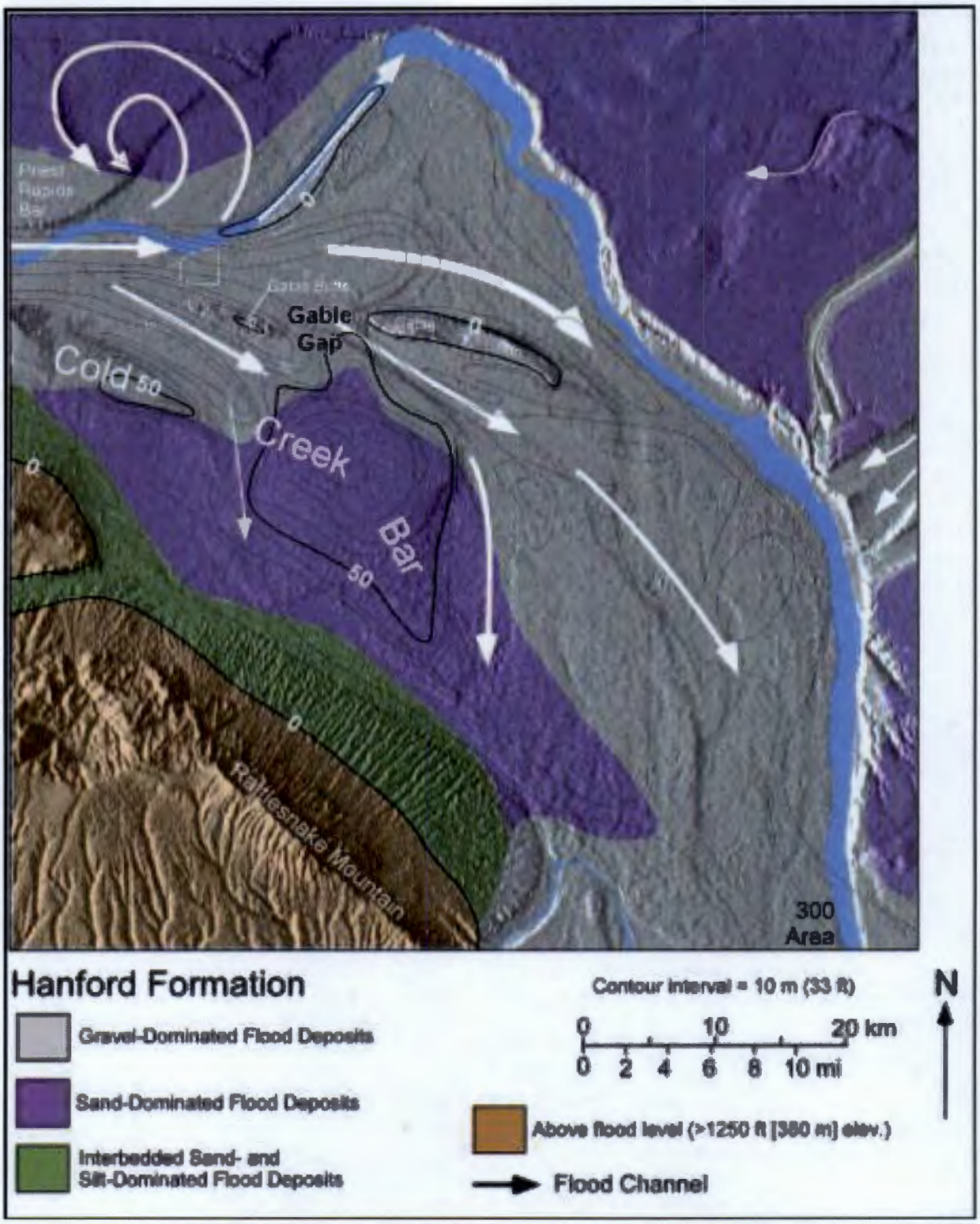
The Ice Age was not a single climatic event; instead, glacial periods were cyclic, occurring about every 100,000 years over at least the last million years. Ice Age floods may be associated with each cycle of glaciation. In between glacial cycles were several tens of thousands of years of interglacial conditions similar to those of today.

Three facies exist for the Hanford formation in the Pasco Basin: (1) gravel-dominated, (2) sand-dominated, and (3) interbedded sand- and silt-dominated (Standardized Nomenclature for Post-Ringold Sediments [DOE/RL-2002-39]). The gravel-dominated facies were deposited in the central portion of the basin adjacent to the present Columbia River. This was at lower elevations and where the energy was the greatest during flooding. The interbedded sand- and silt-dominated facies lie around the margins of the basin and in slackwater areas. The sand-dominated facies, which is the most voluminous facies at the Site, was deposited in the large area between the other two. The 300 Area, which lies at a low elevation adjacent to the Columbia River, received the full brunt of high-energy floodwaters; therefore, the area is composed exclusively of gravel-dominated facies of the Hanford formation. High-energy flood flows are indicated where a train of braided, anastamosing flood channels developed along the center of the basin (Figures 3-12 and 3-13).

In the western Pasco Basin, several huge flood bars buried the older deposits of the Ringold Formation and Cold Creek unit beneath the Cold Creek, Priest Rapids, and Gable Mountain flood bars. These bars prograded eastward with each subsequent flood that entered the basin from the northwest via Sentinel Gap. Repeated cataclysmic flood events deposited up 300 ft (100 m) of coarse sand and gravel toward the center of the basin (Figure 3-12). In contrast, the flood sediments thin and become finer-grained around the margins of the basin. The Pasco Basin was the depocenter for much of the sediment carried by the floods for two reasons:

1. After being constrained through the Channeled Scabland, floodwater flow was allowed to suddenly expand into the broad Pasco Basin, promoting sediment deposition.
2. Hydraulic gradient for the floods flattened considerably due to the hydraulic damming at the extremely narrow Wallula Gap—the only outlet for floodwaters out of the Pasco Basin.

During the largest floods, water backed up into the Pasco Basin to 1,250 ft elevation, creating temporary Lake Lewis that was up to 900 ft deep over the Pasco Basin (A Geological Field Guide to the Mid-Columbia Basin [Bjornstad, 2006]). After each outburst flood, the lake existed for only a few weeks before all the water drained through Wallula Gap on its way to the Pacific Ocean. Within the eastern Pasco Basin, beyond the edges of the prograding flood bars, the Ice Age floods carved an anastomosed network of interconnected, low-relief channels as the floodwaters made their way to Wallula Gap (Figures 3-12 and 3-13).



Source: DOE/RL-2002-39, *Standardized Stratigraphic Nomenclature for Post-Ringold-Formation Sediments Within the Central Pasco Basin.*

Note: Anastomosing network of flood channels through the center of the basin.

Figure 3-12. Ice Age Flood Features within the Central Pasco Basin

Source: PNNL-18340, *Borehole Completion and Conceptual Hydrogeologic Model for the IFRC Well Field, 300 Area, Hanford Site.*

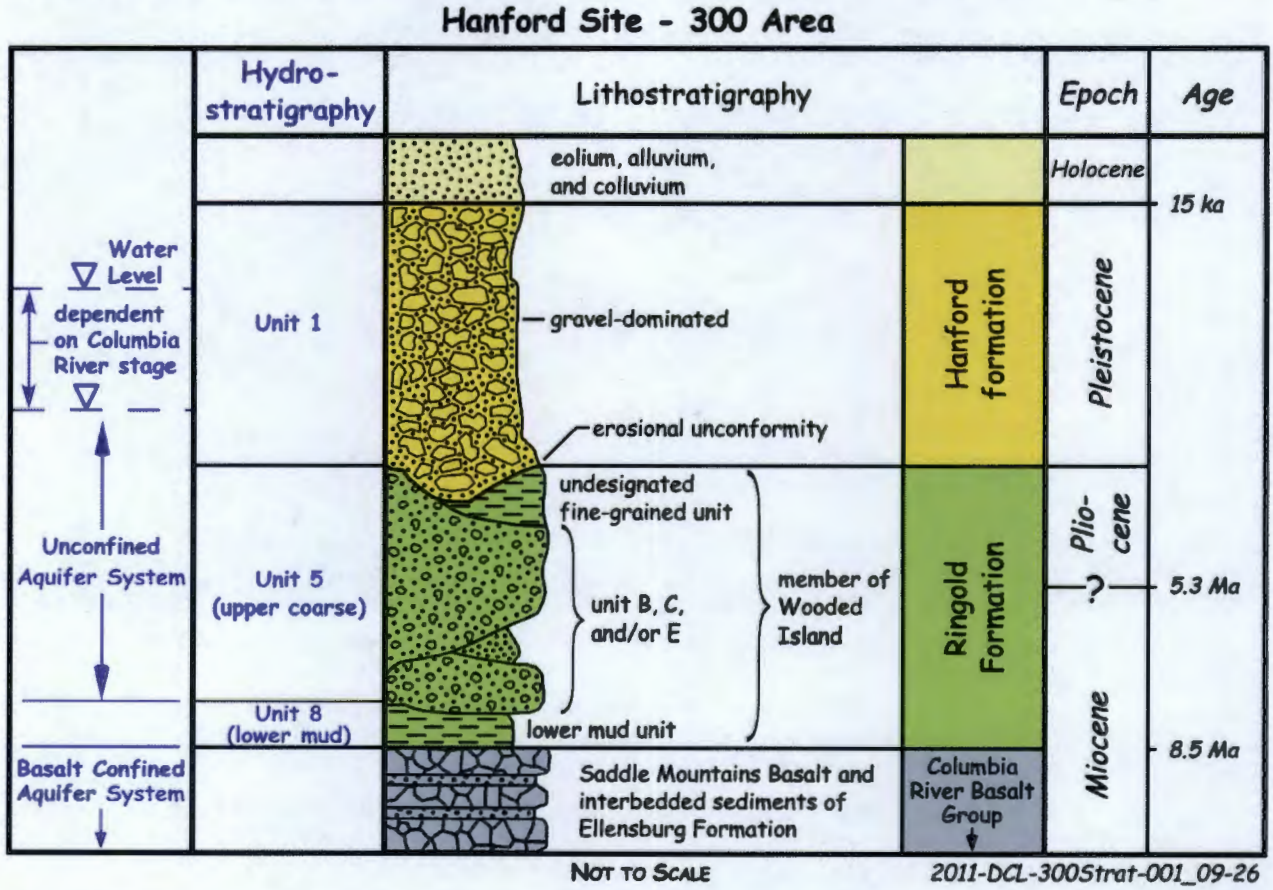
Note: (arrows). During flooding, up to 900 ft of water submerged this area with the exception of the higher ridges like Rattlesnake Mountain. Channels were partially to totally backfilled with sand and/or gravel-dominated sediments of the Hanford formation during flooding.

Figure 3-13. Network of Interconnected Braided Channels Created by the Last Cataclysmic Ice Age Floods

3.4.2 Stratigraphy and Lithology: 300 Area

Sediments overlying basalt bedrock within the 300 Area belong to three geologic units: backfill materials, the Hanford formation, and the Ringold Formation (Figure 3-14). The Cold Creek unit, present elsewhere within the Pasco Basin, is absent in 300 Area. If present, this unit was later completely removed through erosion by Ice Age floods. The water table lies within the Hanford formation everywhere within the 300 Decision Area. Figure 3-15 shows an example of the stratigraphy and lithology in Well 399-2-25, a continuously cored characterization well drilled within the central 300 Area. Figure 3-16 is a 3-D cross section showing the geology in the 300 Area. Figure 3-17 is an index map showing the locations of six hydrogeologic cross sections that cut through the 300 Area. Cross section A-A' (Figure 3-18) is oriented north-to-south along the 300 Area shoreline of the Columbia River. The thickness of the unconfined aquifer is relatively constant along this section, although the thickness and continuity of individual lithofacies vary. Cross section B-B' (Figure 3-19) extends from the northwest corner of the 300 Area

south-southeastward across locations suspected of having been sources for groundwater contamination (i.e., the former 300 Area Process Trenches, North Process Pond, and South Process Pond). Most monitoring wells have open intervals in the saturated Hanford formation sediment, although several wells have been completed to monitor the lower portion of the unconfined aquifer and a confined, permeable interval beneath the Ringold formation lower mud unit. Cross sections C-C' (Figure 3-20) and D-D' (Figure 3-21) provide information on stratigraphy beneath the central portion of the 300 Area, with their eastern ends extending into the Columbia River channel. Cross section E-E' (Figure 3-22) extends from the southwest corner of the 300 Area eastward and into the river channel. This cross section extends across a major paleochannel that is filled with permeable Hanford formation sediment; the section also crosses locations that are suspected sources for groundwater contaminants (i.e., 307 Process Trenches; South Process Pond). Finally, cross section F-F' (Figure 3-23) extends from the southwest portion of the 300 Area to the northeast portion, crossing the industrial complex and former North Process Pond.



Modified for 300 Area after Reidel et. al. (1992), Thorne et al. (1993), Lindsey (1995), Williams et. al. (2000), DOE (2002)

Figure 3-14. Suprabasalt Stratigraphy of the 300 Area

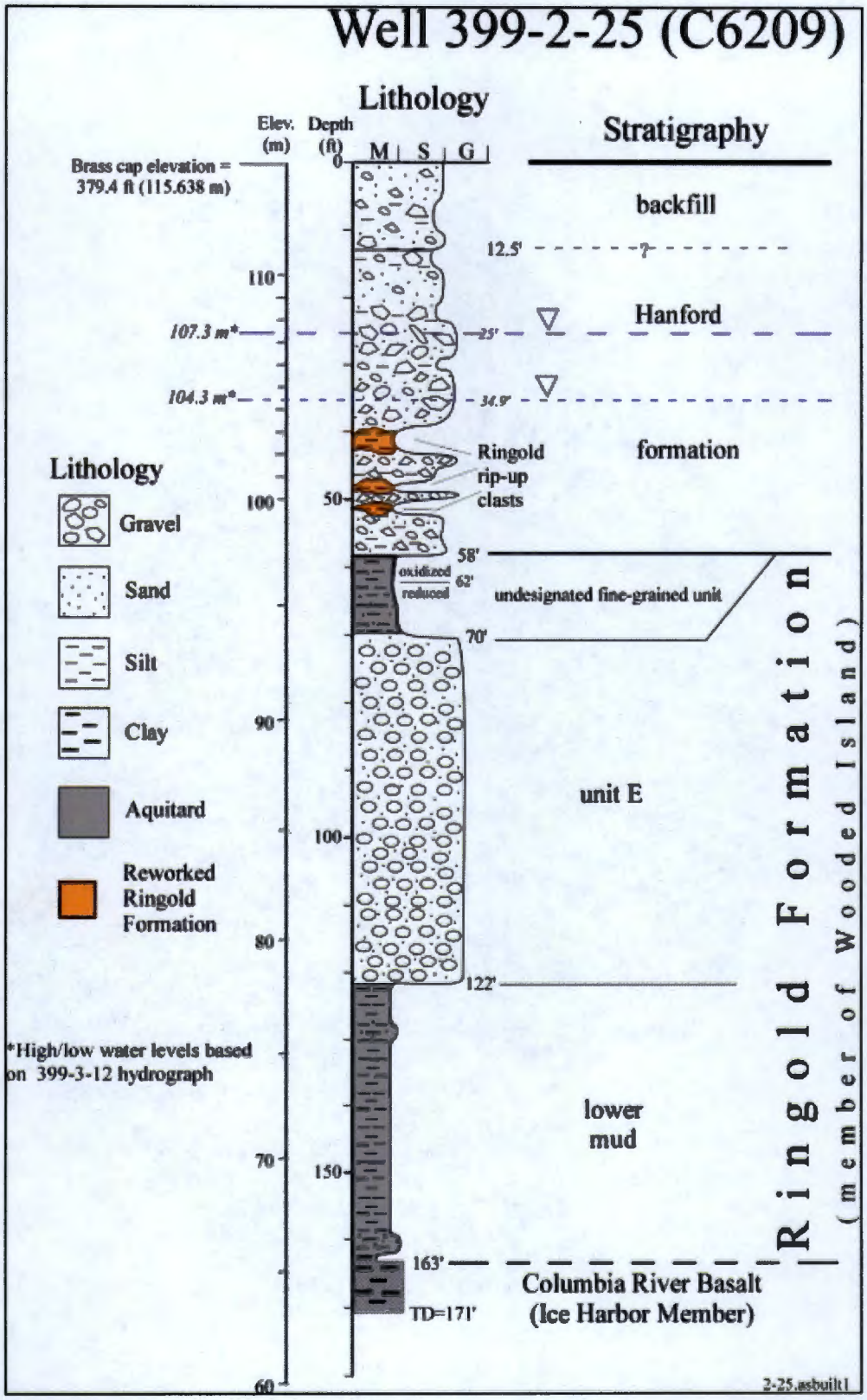
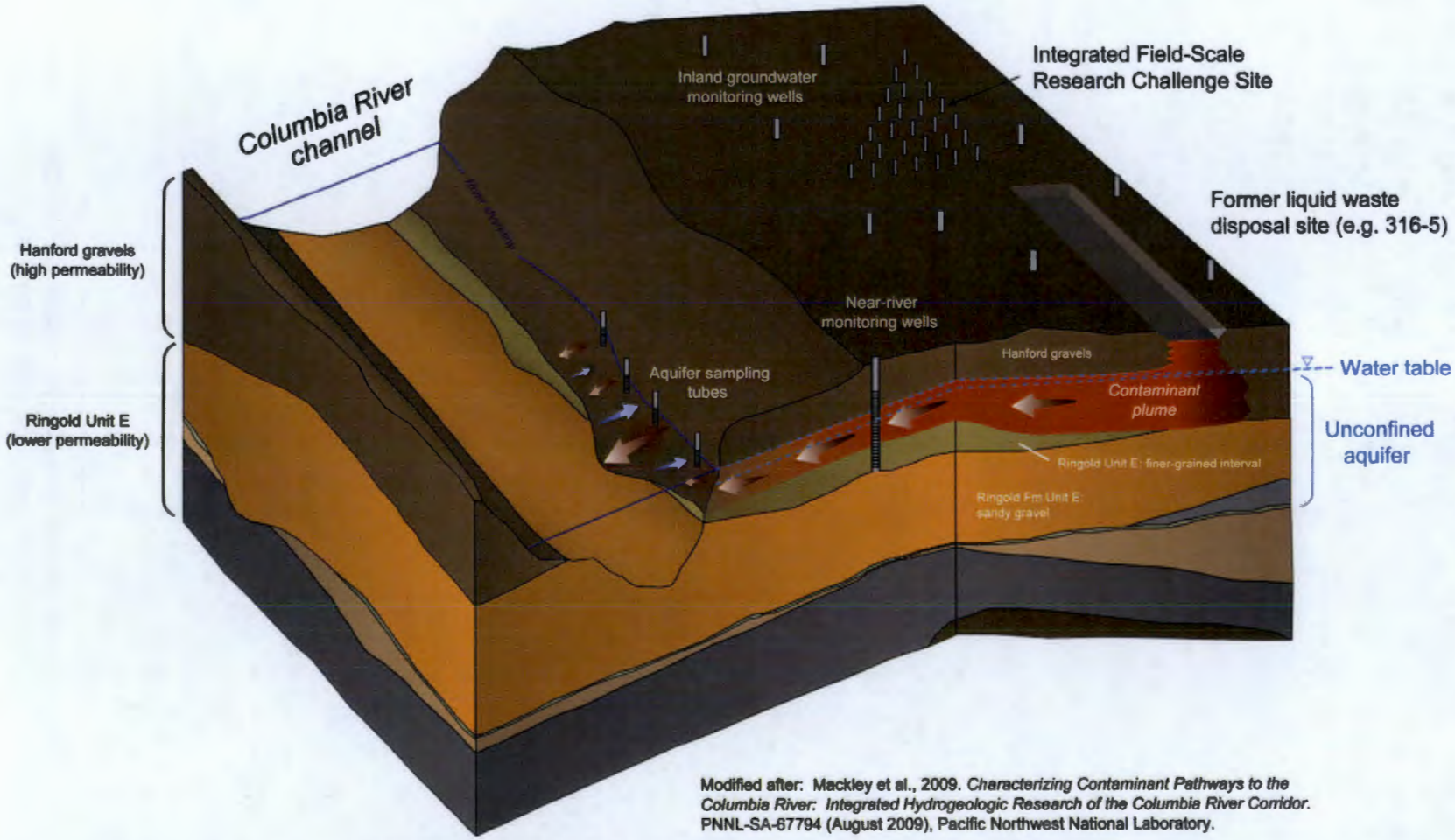


Figure 3-15. Stratigraphy and Lithology Represented in Microbiological Characterization Borehole 399-2-25 at the IFRC Site, Located within the East-Central Portion of the 300 Area



Modified after: Mackley et al., 2009. *Characterizing Contaminant Pathways to the Columbia River: Integrated Hydrogeologic Research of the Columbia River Corridor.* PNNL-SA-67794 (August 2009), Pacific Northwest National Laboratory.

Figure 3-16. Three-Dimensional Cross-Sectional View of 300 Area Geology

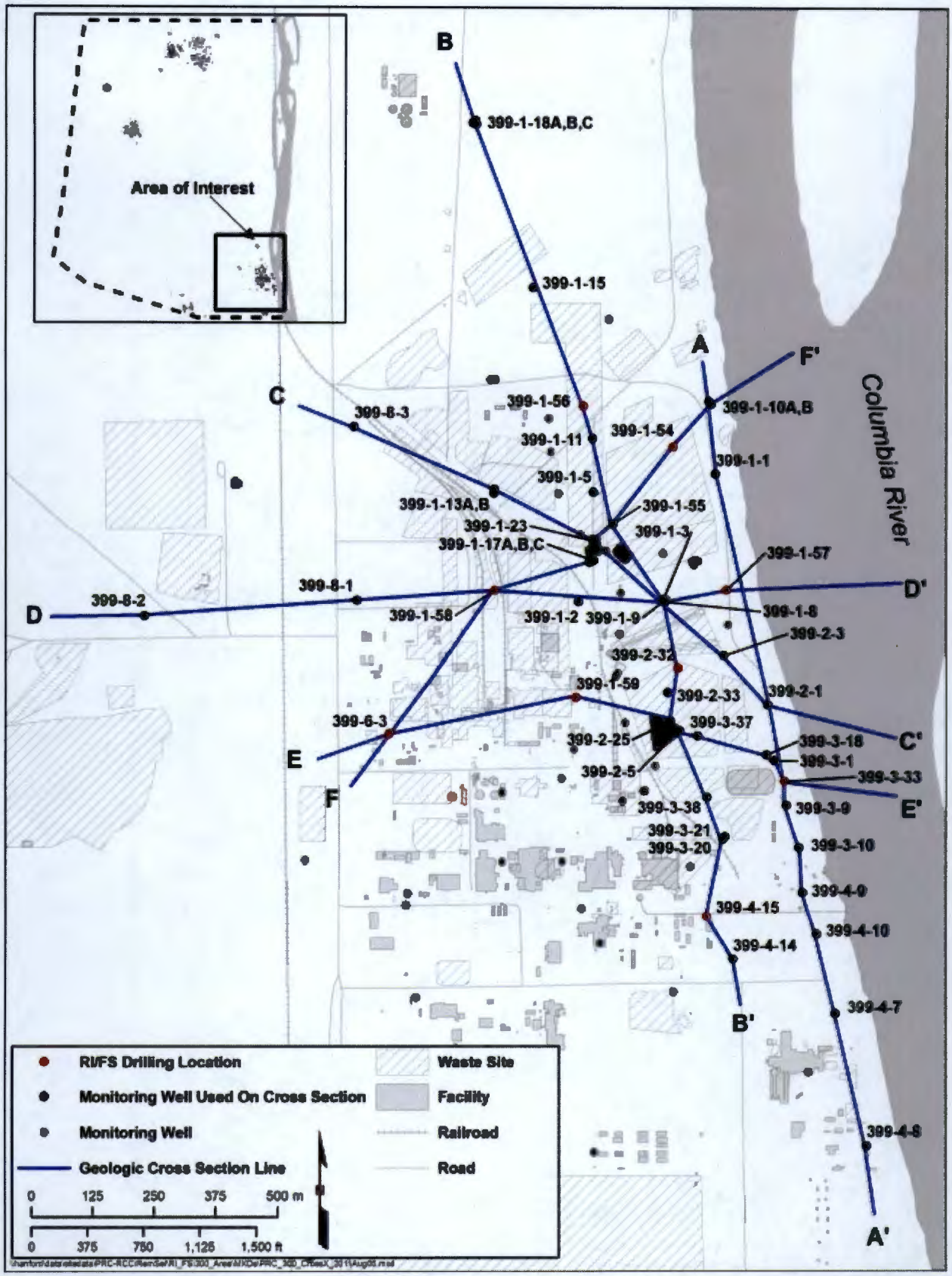


Figure 3-17. Index Map for Cross Sections Drawn to Illustrate Hydrogeologic Features beneath the 300 Area

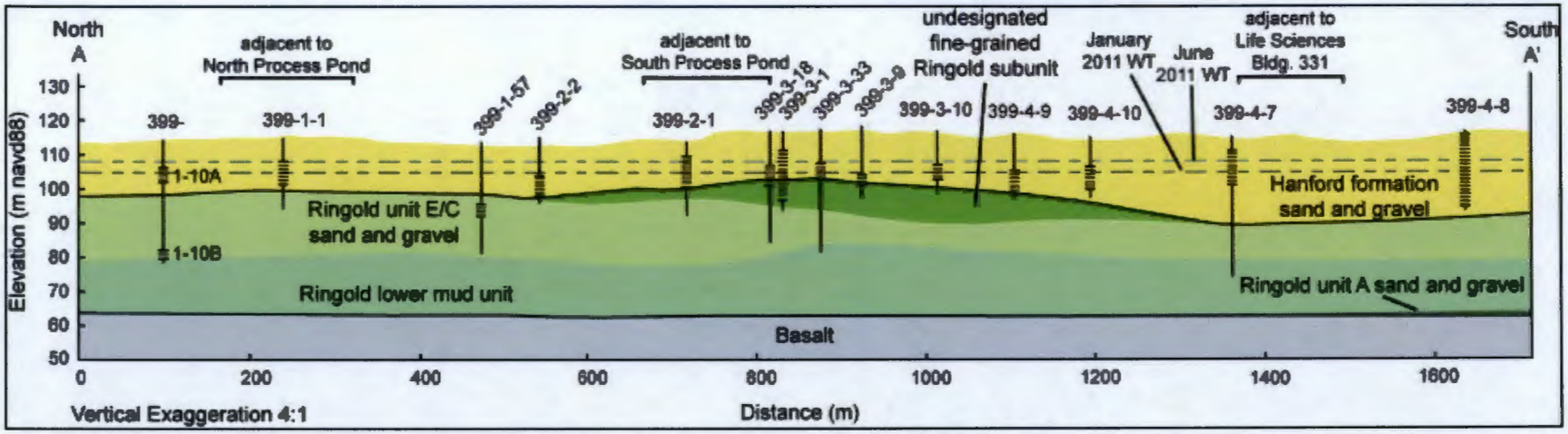


Figure 3-18. Cross Section A-A' Showing Stratigraphic Units and Wells at the 300 Area

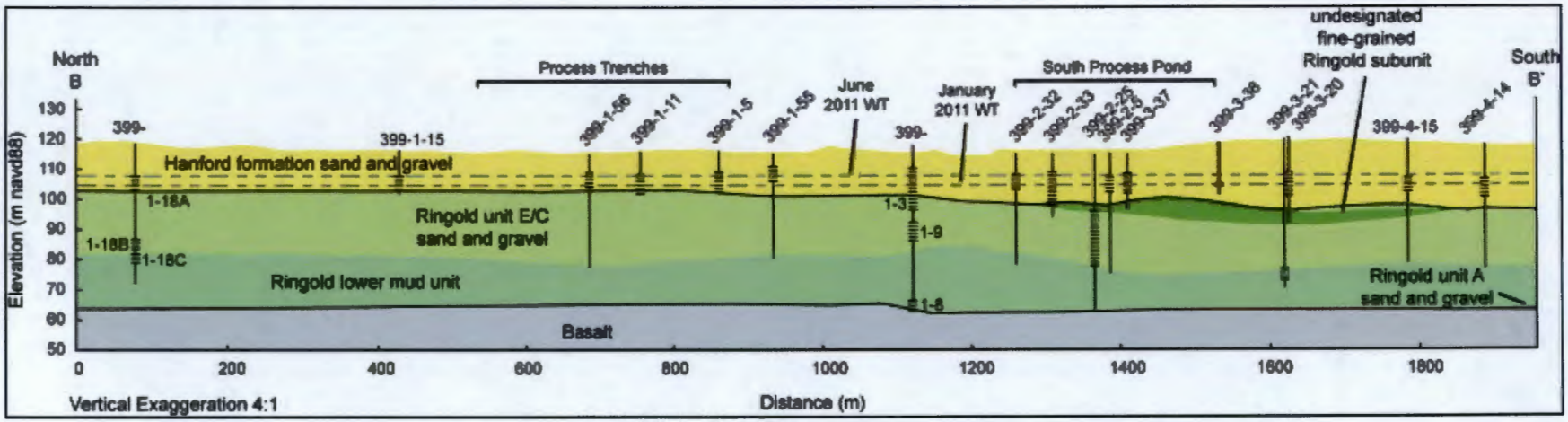


Figure 3-19. Cross Section B-B' Showing Stratigraphic Units and Wells at the 300 Area

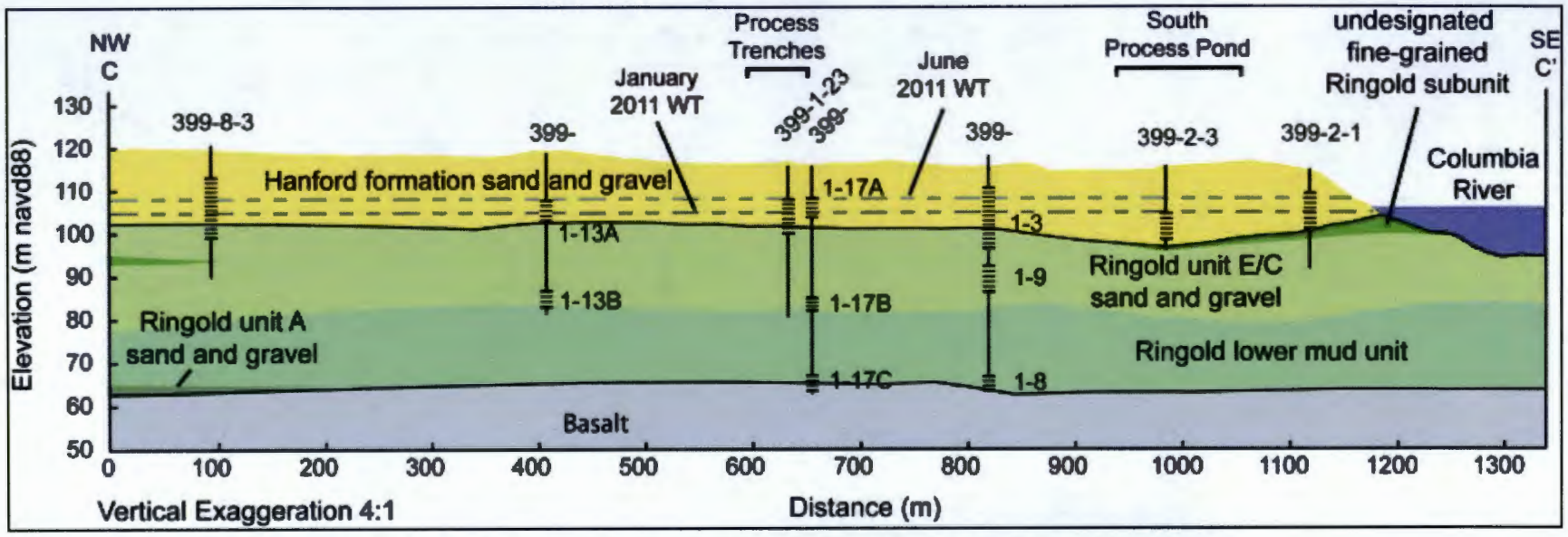


Figure 3-20. Cross Section C-C' Showing Stratigraphic Units and Wells at the 300 Area

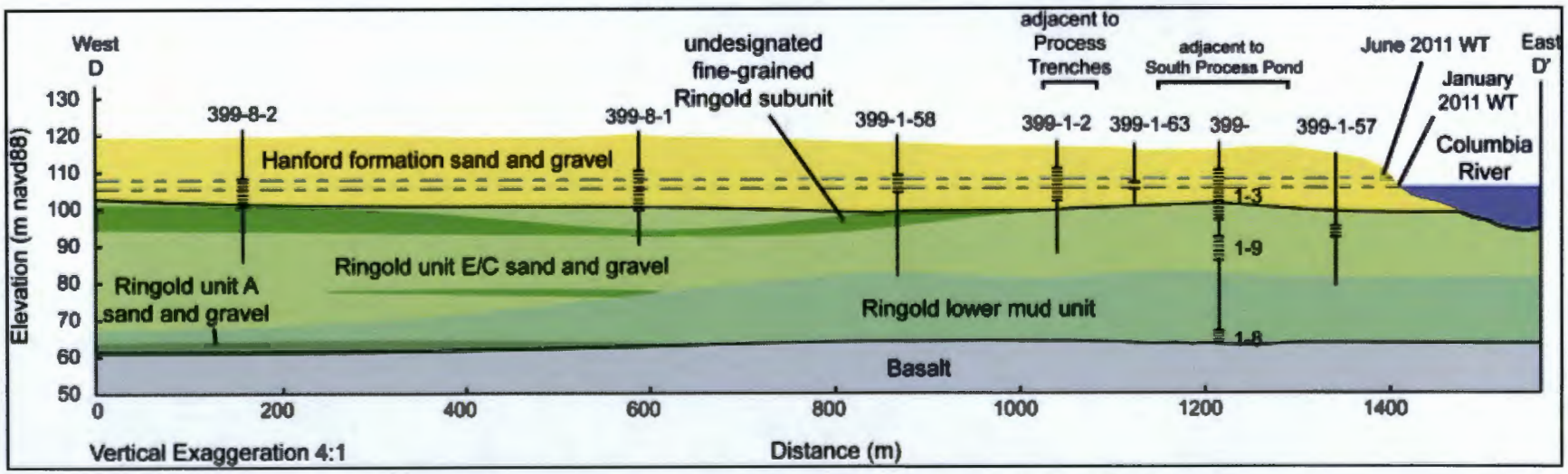


Figure 3-21. Cross Section D-D' Showing Stratigraphic Units and Wells at the 300 Area

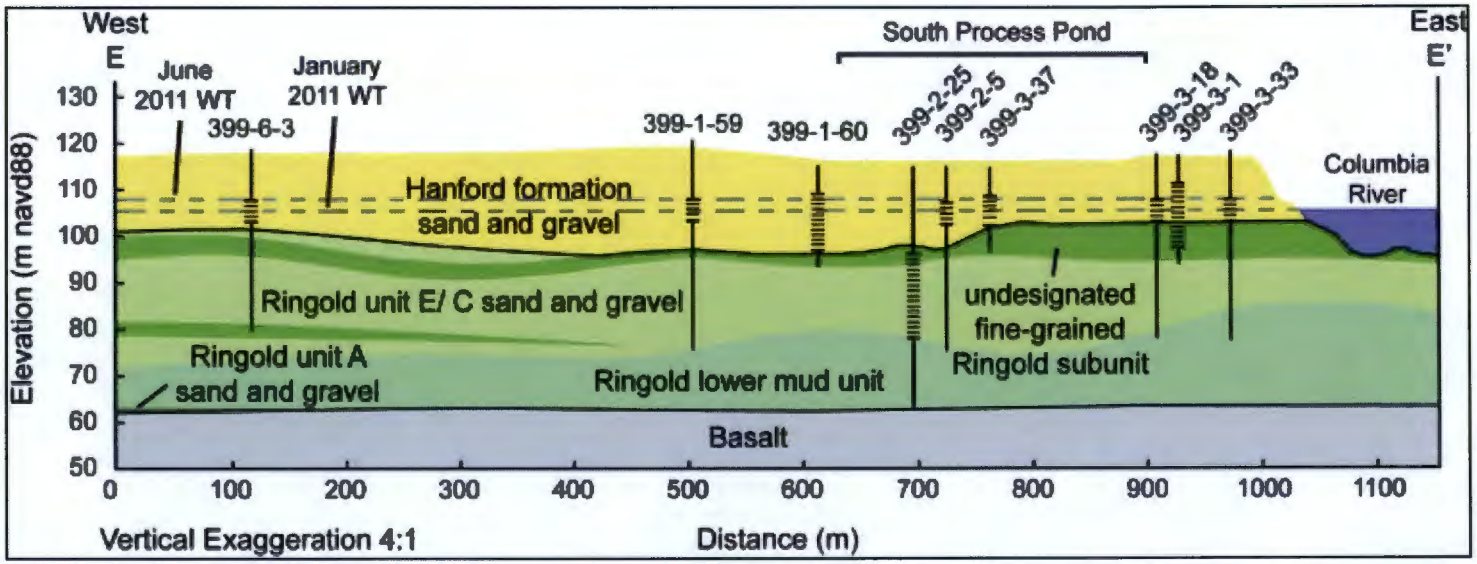


Figure 3-22. Cross Section E-E' Showing Stratigraphic Units and Wells at the 300 Area

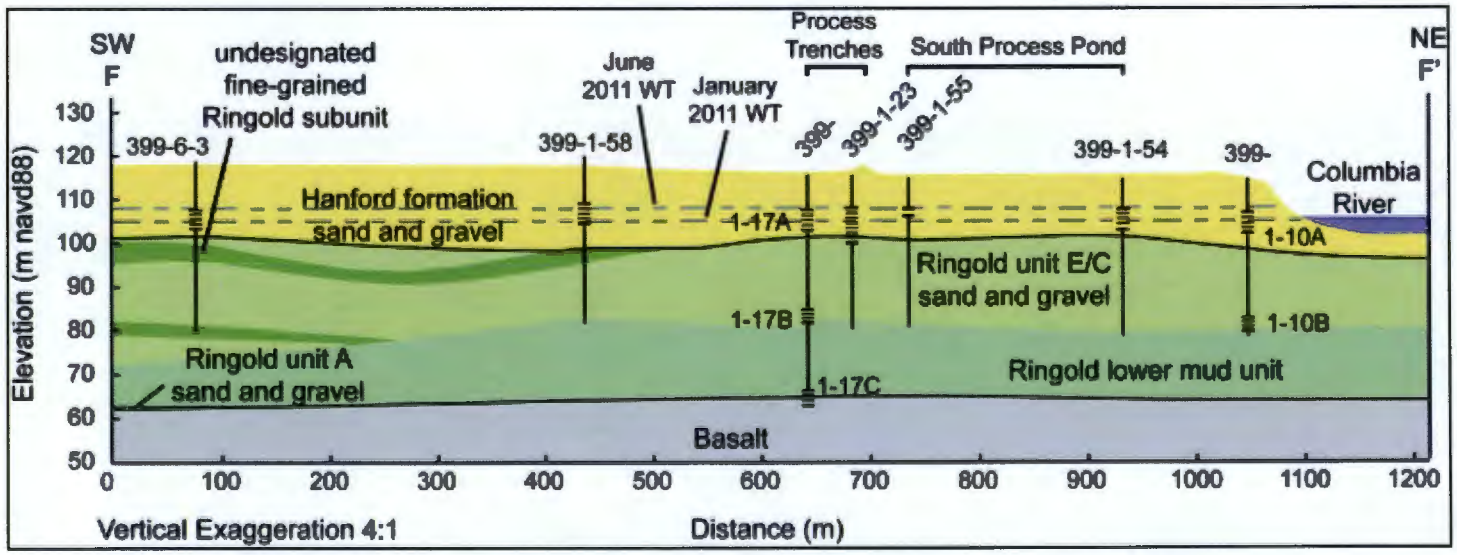
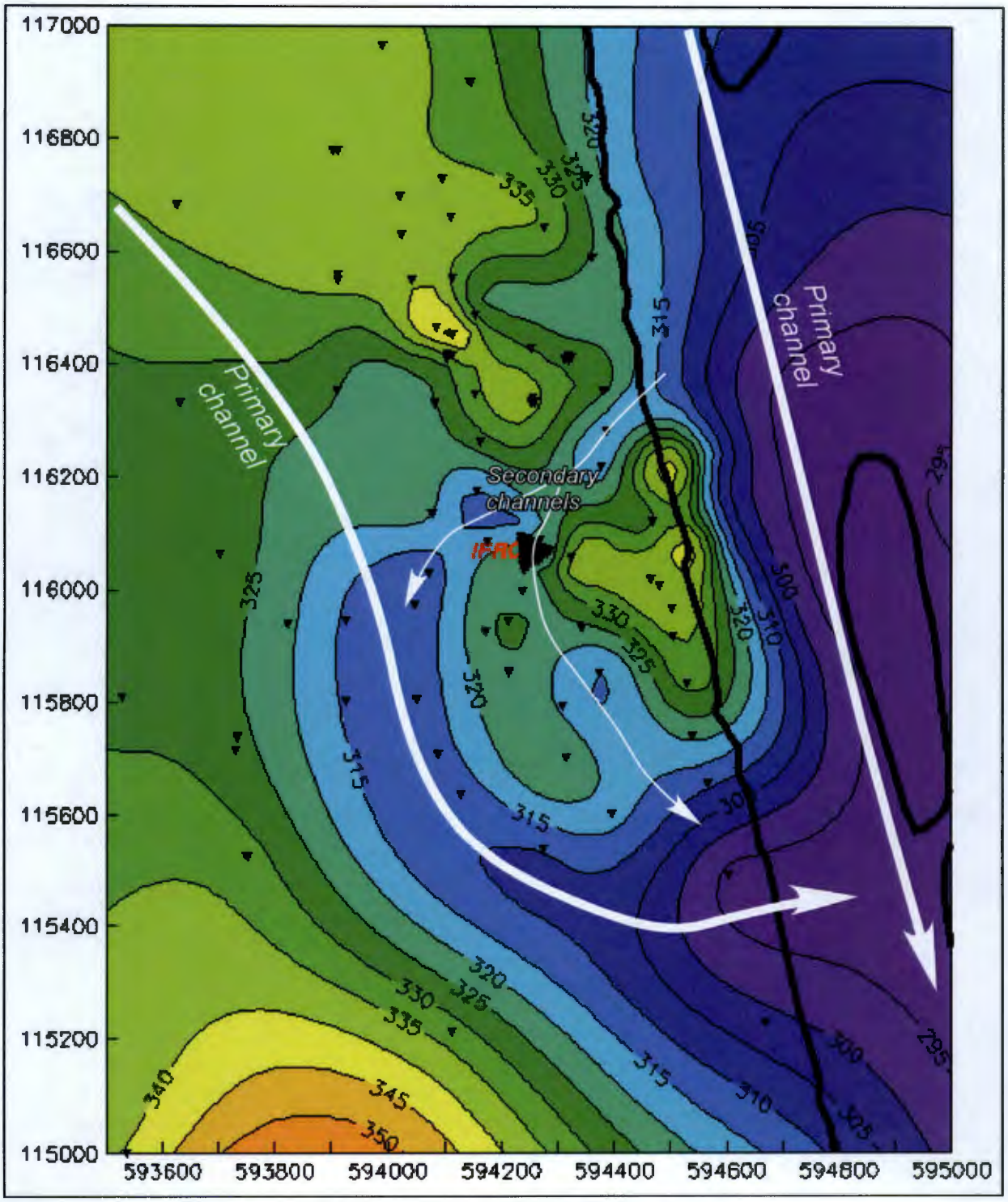


Figure 3-23. Cross Section F-F' Showing Stratigraphic Units and Wells at the 300 Area

Figure 3-24 is a map that also illustrates the paleochannels that have been eroded into the top of the Ringold Formation during Ice Age flooding. This map shows the elevation (in feet AMSL, *North American Vertical Datum of 1988* [NAVD88]) at the top of the Ringold Formation, along with white arrows to indicate the paleochannels filled with highly transmissive Hanford formation sediment.



Note: White arrows indicate primary and secondary, erosional Ice Age flood channels.

Figure 3-24. Top of the Ringold Formation Structure-Contour Map

3.4.2.1 Columbia River Basalt

Volcanic Columbia River basalt comprises the basement rock beneath the 300 Area. The basalt originated from long, linear, volcanic vents in southeast Washington, northeast Oregon, and western Idaho that flowed westward into the Pasco Basin between 17 and 6.5 million years ago ("Volcanism and Tectonism in the Columbia River Flood-Basalt Province" [Reidel and Hooper, 1989]; *Site Characterization Plan: Reference Repository Location, Hanford Site, Washington* [DOE/RW-0164]; "An Introduction to the Stratigraphy, Structural Geology, and Hydrogeology of the Columbia River Flood-Basalt Province: A Primer for the GSA Columbia River Basalt Group Field Trips" [Tolan et al., 2009]). The uppermost basalt in the 300 Area is the Ice Harbor Member, dated at 8.5 million years. A photo of a core segment of the weathered top of basalt in the 300 Area is shown in Figure 3-25.

Note: The 1 ft long Lexan-lined, split-spoon core is filled with irregular fragments of black vesicular basalt in a highly weathered and green-gray, mottled, alteration-clay matrix. The clay is an alteration product derived from an extended period of weathering of the basalt flow top prior to burial by the Ringold Formation.

Figure 3-25. Weathered Basalt of the Ice Harbor Member from the Bottom of Well 399-2-25, 169 to 170 ft Depth (bgs)

The 300 Area lies just east of the axis of the Pasco syncline, a downwarped northwest-to-southeast trending trough of the Yakima Fold Belt (*Site Characterization Plan: Reference Repository Location, Hanford Site, Washington* [DOE/RW-0164]). The surface of the basalt dips slightly west-southwest beneath the 300 Area.

3.4.2.2 Ringold Formation

Above Columbia River basalt lies the Ringold Formation, which displays a wide range of fluvial-lacustrine sedimentary deposits clay, silt, sand and pebble-cobble gravel of Miocene to Pliocene-age (*Site Characterization Plan: Reference Repository Location, Hanford Site, Washington* [DOE/RW-0164]; *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington* [BHI-00184]). The Ringold Formation ranges in age from late Miocene to Pliocene (8.5 to 3.4 million years) and consists of mostly fluvial-lacustrine sediments laid down during tectonic downwarping and infilling of the Pasco Basin, one of many synclinal basins of the Yakima Fold Belt (*Site Characterization Plan: Reference Repository Location, Hanford Site, Washington* [DOE/RW-0164]). Ringold Formation sedimentary deposits were laid down by the ancestral Columbia and Snake (formerly the Salmon-Clearwater) Rivers, which were temporarily blocked downstream, occasionally forming lakes within the Pasco Basin. Within the 300 Area, the Ringold Formation lower mud unit makes up the lower half of the Ringold Formation, while unit E comprises the upper half of the formation. Both of these units lie within the Ringold Formation member of Wooded Island (*Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington* [BHI-00184]).

Dark, fibrous fragments of decomposed wood are preserved and frequently observed in sediment cores collected during drilling at the 300 Area and reported in drill logs. The colors of the Ringold Formation range from an oxidized reddish-brown to reduced, gleyed shades of blue, green, olive, and gray. The later appear to be associated with long-term chemical reduction beneath the water table, especially within organic-rich, lower-permeability silts and clays.

Ringold Formation Lower Mud Unit. Immediately overlying the weathered basalt surface are up to 24 m (80 ft) of dark-colored, fine-grained sediments of the Ringold Formation lower mud unit (Figure 3-26). These sediments are predominantly compact and cohesive, low-permeability massive to weakly laminated, gray to gleyed-green and blue deposits that vary in grain size among clay, silt, and fine sand.

Note: These laminated deposits represent deposition within a fluvial overbank and/or lacustrine (lake) environment. The gray to olive green color displayed in this core is typical of chemically reducing conditions that prevailed since deposition of this unit since about 7 to 8.5 million years ago. Well 399-3-18.

Figure 3-26. Fine-Grained Sand, Silt, and Clay of the Ringold Formation Lower Mud Unit

The Ringold Formation lower mud unit was deposited in a fluvial-overbank to lacustrine (lake) environment. This unit forms an aquitard beneath the unconfined aquifer system. This aquitard separates the unconfined aquifer from deeper confined aquifers in the underlying Columbia River Basalt Group.

Ringold Unit E. Overlying the Ringold Formation lower mud unit is coarser, gravel-dominated sediment, up to 24 m (80 ft) thick, belonging to the Ringold unit E. Some of unit E within the 300 Area may be equivalent to Ringold Formation units B, C, and D as described in (*Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington* [BHI-00184]). However, without fine-grained Ringold strata separating these gravel-dominated units, it is not possible to distinguish between units B, C, D, and E in the 300 Area. Therefore, in this report, we combine all the Ringold Formation above the lower mud unit into unit E. One exception is the Ringold Formation undesignated fine-grained unit that lies at or near the top of unit E over parts of the 300 Area. This hydrologically significant unit of fine sand and silt, considered a localized facies within Ringold unit E, is discussed in more detail below.

Ringold unit E is a conglomeratic unit, approximately 4.8 to 6.7 million years old (*Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington* [BHI-00184]), consisting of a bimodal mixture of well-rounded and polished, clast-supported pebbles and cobbles compacted within a matrix of fine- to medium-grained sand (Figures 3-27 to 3-30). Variable amounts of silt or clay may occur within the matrix and as weathering skins around gravel clasts. Within each of the two modes, sediment sorting is moderate to good, with relatively few particles between medium-grained sand to fine-pebble size. Sand grains within the matrix are predominantly felsic (i.e., composed principally of the minerals quartz, feldspar, and mica).

Note: Shown here are semiconsolidated sandy pebble-cobble gravel typical of the Ringold Formation along the White Bluffs across the Columbia River northeast of the 300 Area. In outcrop, these clast-supported, bimodal deposits may be crudely stratified and weakly imbricated, with occasional lenses of well-sorted, fine- to medium-grained sand. Note that clasts larger than cobble size are rarely, if ever, observed. These exposures conveniently reveal the 2-D stratigraphic and structural characteristics of the sediments that cannot be observed in 1-D boreholes.

Figure 3-27. Erosional Remnants of Gravel-Dominated Facies within the Ringold Formation Member of Wooded Island

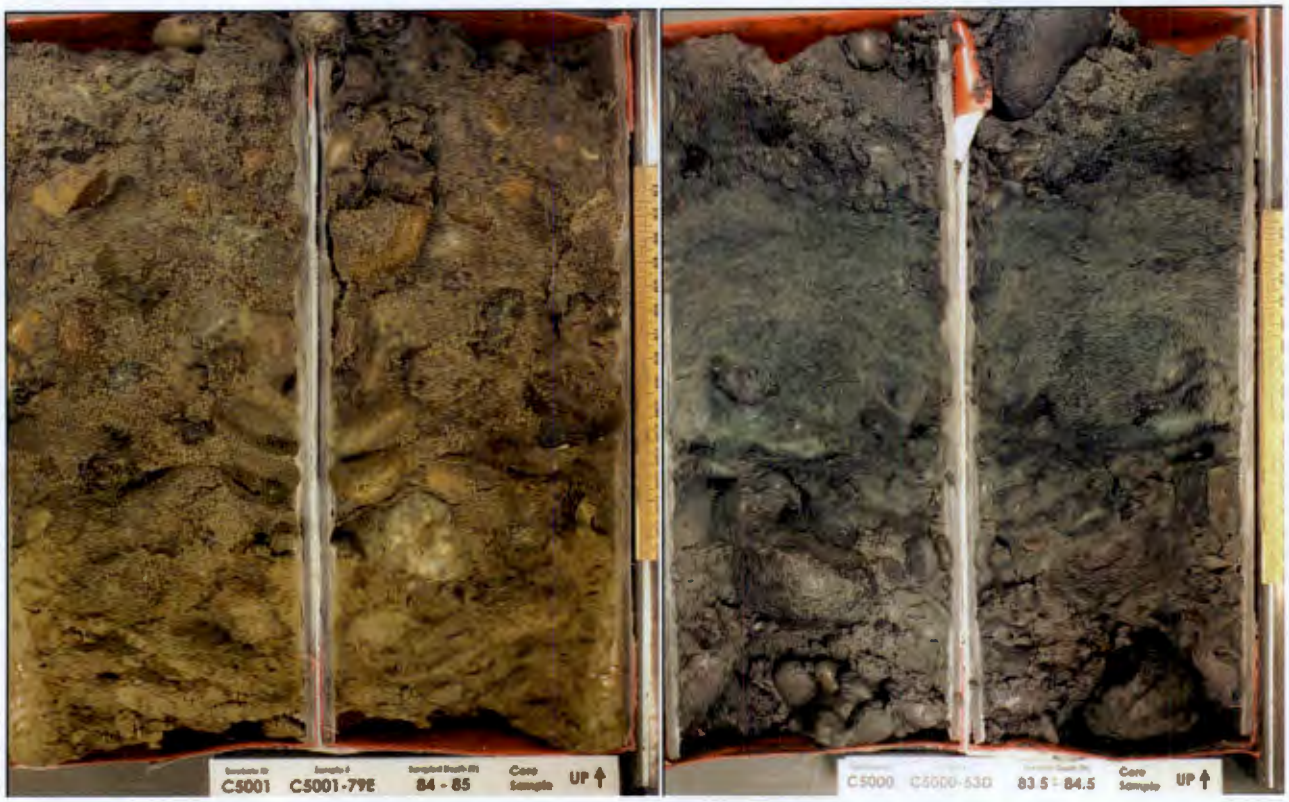
In contrast to the well-rounded, pebble- to cobble-sized clasts, sand-sized grains are generally angular to subangular. Individual pebble and cobble-size clasts, especially those composed of basalt, often display clay skins and weathering (alteration) rinds. Colors within this unit are mostly reduced gleyed shades of gray, green, and blue below the water table (Figure 3-29, right) but may be oxidized in proximity to the overlying high-hydraulic-conductivity Hanford formation (Figure 3-29, left). This sedimentary facies represents deposition within a high-energy, shallow, braided-stream (fluvial) environment (*Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington* [BHI-00184]).

Note: These represent channel-fill deposits of the ancestral Columbia and/or Snake (formerly the Salmon-Clearwater) Rivers. Left image includes lenses of clean felsic sand within these ancient fluvial deposits. Above the water table, coarse-grained Ringold deposits are generally oxidized displaying a pervasive rusty, red-brown color. The pebble- to cobble-size clasts are dominantly quartzite, granite, and gneiss with a lesser number of dark basalt, andesite, and volcanic porphyry clasts ("Correlation of Late Cenozoic Gravel Deposits Along the Yakima River Drainage from Ellensburg to Richland, Washington" [Campbell, 1983]).

Figure 3-28. Compacted, Semi-Consolidated, Gravel-Dominated Facies of the Ringold Formation (Unit E Equivalent), Exposed in the White Bluffs

Note: Left: Bimodal sandy gravel in Well 399-3-18. One mode consists of well-rounded and polished, clast-supported pebbles and cobbles; the other mode consists of well-sorted, fine-to-medium-grained, arkosic sand that fills the matrices between gravel clasts. Right: Several dark wood fragments lie within well-sorted, arkosic sand in upper half of core in Well 399-1-23. The lower half of the core consists of mostly matrix-supported pebbly sand. Upward arching in stratification is drag folding—an artifact of the drilling process.

Figure 3-29. Sediment Cores of Ringold Unit E beneath the 300 Area



Note: The left core (from well 399-3-19) is strongly oxidized, recovered only a few feet below the contact with the high-K Hanford formation. In contrast, the right core (Well 399-1-23) was recovered from 10 m (30 ft) below the Hanford-Ringold contact, far below the oxidation front associated with the overlying Hanford formation. Chemical reduction in this core is indicated by darker shades of gray, blue, and green. In particular, note the gleyed, blue-green sand lens that is more typical of Ringold Formation in the saturated zone beneath the 300 Area.

Figure 3-30. Sediment Cores of Ringold Formation Member Unit E Showing Variable Reduction-Oxidation States within the Saturated Zone beneath the 300 Area

A sharp, well-defined contact boundary exists between the Ringold Formation lower mud unit and gravel-dominated unit E. Boulder-sized clasts are rarely, if ever, present in the Ringold Formation. Gravel clasts generally show a high degree of rounding and polishing—characteristic of mature river gravels in a fluvial environment. Massive beds of gravel-dominated facies are sometimes separated by beds or lenses of sand, silt, and/or clay. The Ringold Formation is typically semi-consolidated due to diagenetic compaction and secondary mineralization that has occurred over the millions of years since deposition. Thick weathering rinds developed around the more mafic gravel clasts are another indication of old age.

The top of Ringold unit E represents an erosional unconformity created during scouring by repeated Ice Age floods that backfilled the eroded surface with coarse-grained deposits of the Hanford formation. Several paleochannels (see Figure 3-24), eroded into the top of the Ringold unit E, are discussed below for the Hanford formation.

Ringold Formation Undesignated Finer-Grained Unit. A distinct relatively finer-grained interval of silt and fine sand lies at or near the top of Ringold unit E over portions of the 300 Area. This is also known as the "finer-grained Ringold subunit" identified in previous reports (*Three-Dimensional Groundwater Models of the 300 Area at the Hanford Site, Washington State*, hereinafter called 300 Area 3-D Groundwater Models [PNNL-17708]; *Uranium Contamination in the Subsurface Beneath the 300 Area, Hanford Site, Washington* [PNNL-17034]). The finer-grained interval is specified here, however, because it locally

creates an aquitard that influences the flow of groundwater within key, critical areas of the 300 Area. Where present, the fine-grained interval often lies at the top of the Ringold Formation in contact with the overlying coarse-grained Hanford formation. However, in some boreholes (e.g., Well 399-3-19 in Figure 3-30, left) gravel facies of Ringold unit E lie both above and below the undesignated fine-grained subunit, suggesting the fine-grained interval is a localized facies within Ringold unit E and, therefore, not a totally separate unit.

The upper portion of fine-grained unit consists of cohesive and compact, well-sorted fine sand grading upward into silty sand to silt. The lower portion of the subunit may grade downward into medium- to coarse-grained sand before transitioning into unit E. A single fining upward sequence such as this is characteristic of a fluvial point-bar deposit.

The fine-grained unit does appear to extend locally out into the channel of the Columbia River along the east side of the 300 Area (Figure 3-31). This is based on camera survey of the river bottom and recovery of core from aquifer tubes driven through the river bottom (300-FF-5 LFI [PNNL-16435]). Permeability within the fine-grained unit is generally lower than that for the gravelly Ringold unit E. One pump test yielded a saturated hydraulic conductivity of 41 m/d (134 ft/d) within the fine-grained interval. Other attempts to collect groundwater from this interval were met with much less or no yield. Groundwater movement through this interval is expected to be slow and significantly less than 1 m/d (3.2 ft/d). The interval appears to be locally incised by the river channel, but groundwater discharge to the river from the finer-grained unit would be small because of the low permeability of the sediment.

The distribution and thickness of the Ringold Formation undesignated fine-grained unit is highly variable across the 300 Area. It is thickest (up to 10 m [33.5 ft]) as a dome-shaped feature south and east of the former South Process Pond, as shown on the structure contour map in Figure 3-32. The unit is missing from the northern and southern portions of the 300 Area. Discontinuities such as this are to be expected for a fluvial-overbank/floodplain-type deposits like Ringold Formation undesignated fine-grained unit.

All but the top of these fine-grained strata show dark, chemically reduced shades of gray, green, and blue. At the top of the unit, however, is a rapid color change to shades of yellow, orange, or brown silt, up to 2.4 m (8 ft) thick (Figure 3-33). The color boundary does not appear to occur along a textural or structural boundary because the sediments above and below the boundary are identical. For this reason, it appears the color contrast is the result of secondary oxidation along the boundary with the highly permeable and transmissive flood deposits (Hanford formation), which lie directly above the fine-grained unit.

The top of Ringold undesignated fine-grained unit is highest just east and south of the South Process Pond.

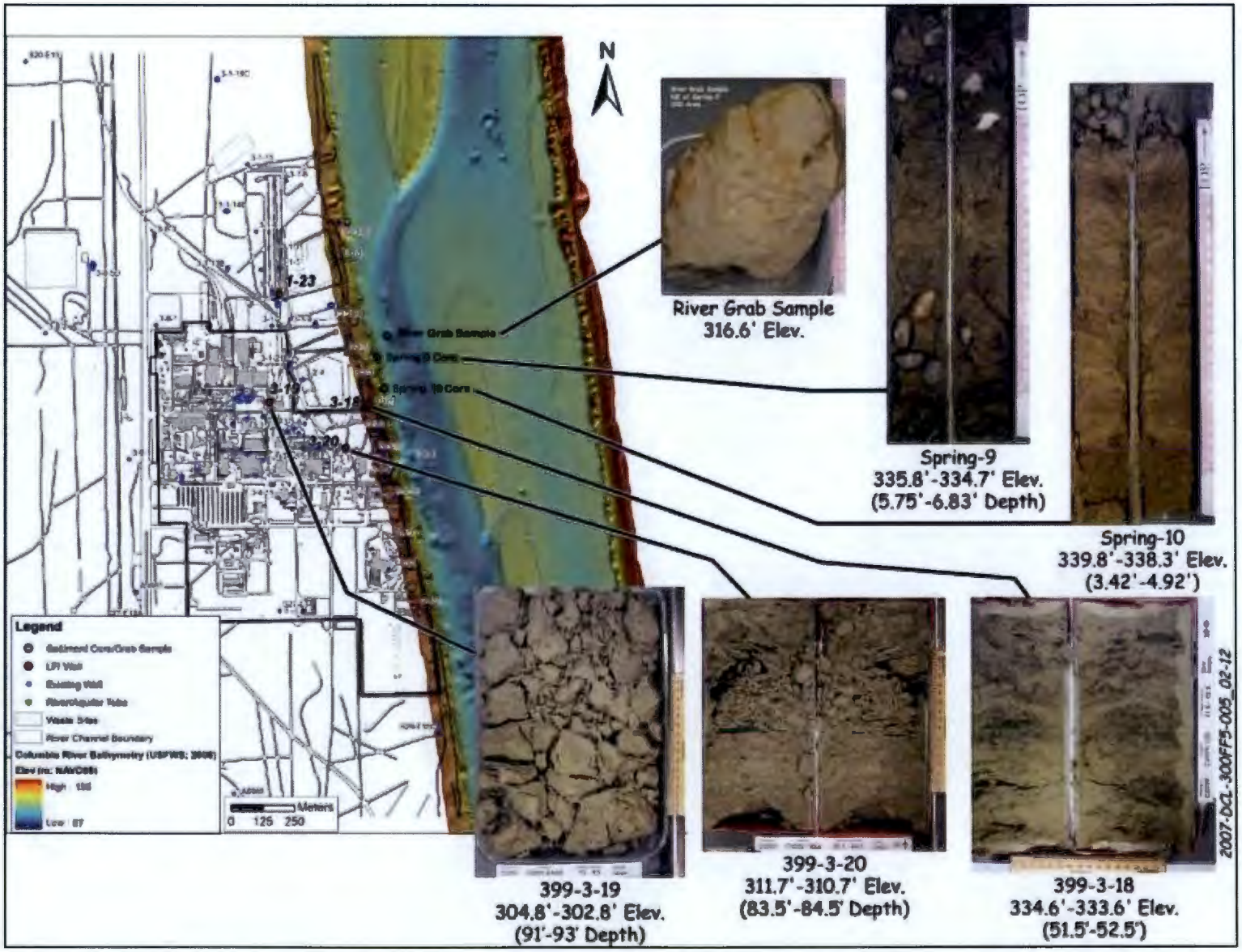
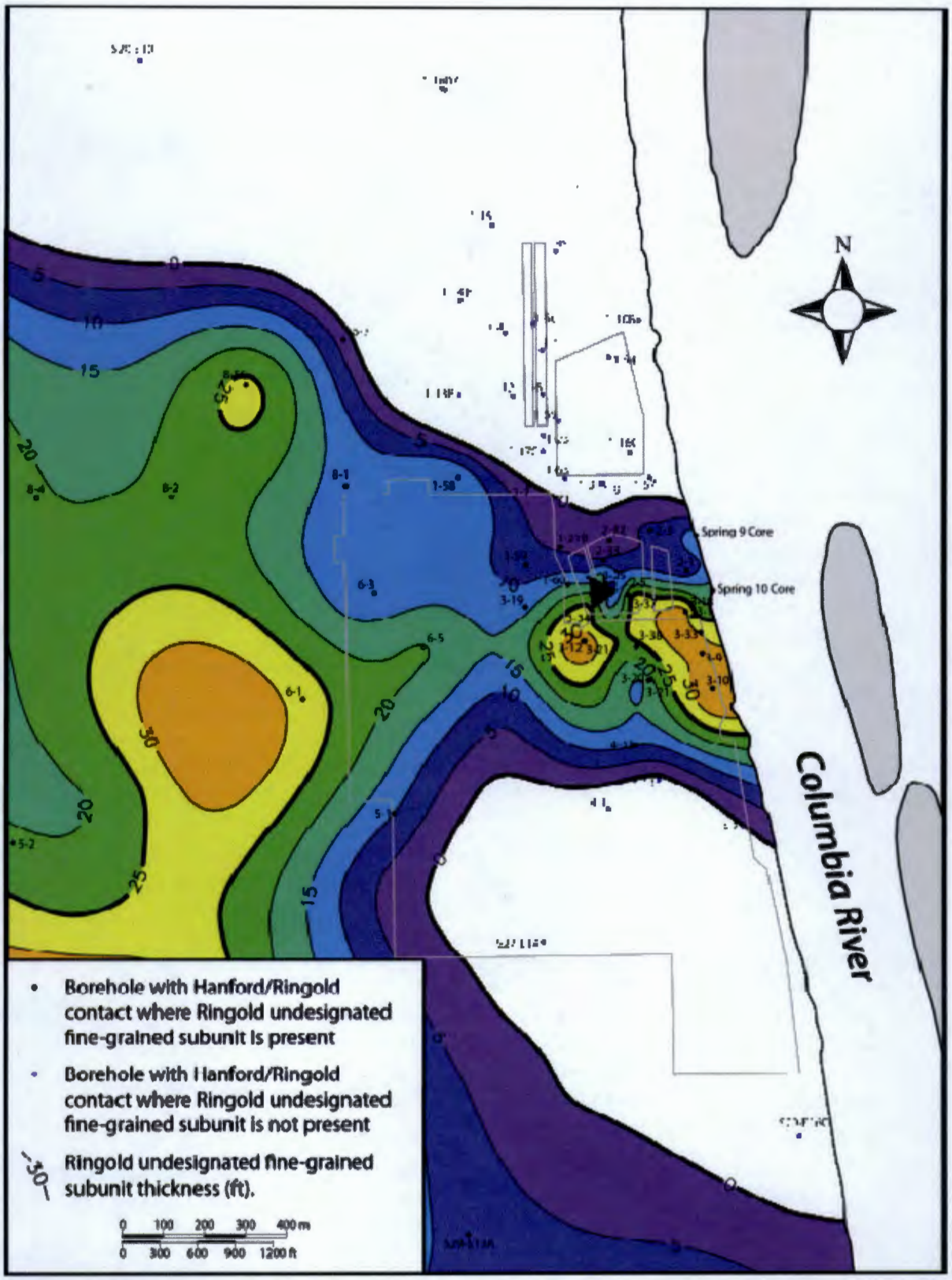


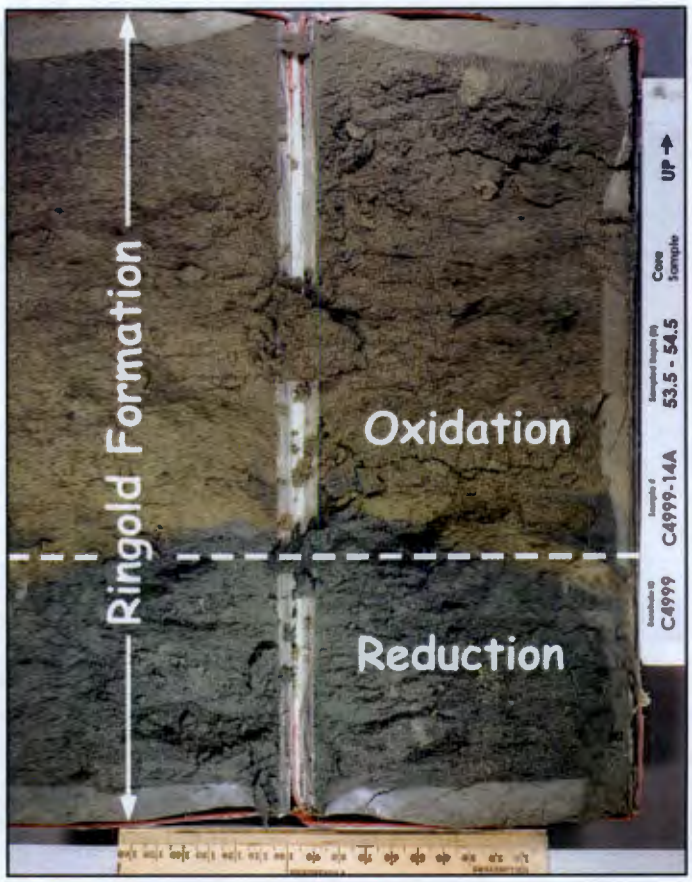
Figure 3-31. Map Showing Locations Where Sediment from the Finer-Grained Unit of Ringold Formation Have Been Collected from the 300 Area and Adjacent Columbia River Channel



Note: The unit is thickest in the east-central portion of the 300 Area while pinching out to the north and south. This unit may act as a local aquitard within the unconfined aquifer.

Figure 3-32. Isopach-Thickness Map of the Ringold Formation Undesignated Fine-Grained Unit

The thickness of the Hanford formation typically ranges from about 12 to 24 m (40 to 80 ft) thick within the 300 Area. The Hanford formation is thickest over paleochannels carved into the Ringold Formation by the floods. These paleochannels are represented in a structure-contour map of the Hanford formation-Ringold Formation contact (see Figure 3-24) where several paleochannels eroded into the Ringold Formation are apparent. The thalweg of the main channel nearly bisects the 300 Area while two distributary channels trend east and southeast off the main channel. One of these appears to be a spillover channel that runs along the northern edge of the former South Process Pond; the other channel runs southeast through DOE's IFRC site located in the southwest corner of the South Process Pond (Figure 3-24; see Chapter 1 for a description of the IFRC). Today, the water table is situated within the gravelly, highly permeable sediment of the Hanford formation everywhere beneath the 300 Area.



Note: The distinct color change from yellowish brown to greenish gray lies about 2.1 m (7 ft) below the contact with the Hanford formation, marking the oxidation front associated with the high-K flood gravels in Well 399-3-18.

Figure 3-33. Reduction-Oxidation Boundary in Silty Fine Sand of the Ringold Formation Undesignated Fine-Grained Unit

Within the Hanford formation, loose, clast-supported, muddy sandy gravel is the predominant sediment type (Figure 3-34). Lenses of matrix-supported gravelly sand occur sporadically. (The terms mud and muddy are used to describe undifferentiated silt- to clay-size particles.) The maximum size of gravels from the vadose zone observed in excavations within the South Process Pond (*Sampling and Hydrogeology of the Vadose Zone Beneath the 300 Area Process Ponds* [PNNL-14834]) was boulders up to several feet in diameter. Roundness on basalt gravel clasts is usually immature (subangular to subrounded) because of relatively recent erosion, transport, and rapid burial of the locally derived basaltic detritus. Gravel clasts of other compositions (quartzite, granite, gneiss, and volcanic porphyries) are commonly more rounded because of reworking by the floods of older fluvial deposits (e.g., Ringold Formation).

Colors are generally dark gray to black due to the high concentrations of basalt fragments, but grayish brown to brownish gray colors may occur, especially when mixed with reworked Ringold Formation sediment. The angularity of gravel clasts and poorly sorted nature of the Hanford formation is an indication that deposition and burial occurred very rapidly with little or no winnowing during deposition. This is consistent with the model for flood deposition that indicates immature flood deposits were dumped in place during very short-lived flood events that lasted only a week or two. This prevented the

rounding of gravel clasts as well as winnowing and sorting of the material that is more typical of fluvial deposits like the Ringold Formation.

The concentration of basalt rock fragments is much higher in the Hanford formation compared to the underlying Ringold Formation. This is especially true of the sand-sized fraction, which in the Hanford consists of up to 70 to 80 percent basalt compared to the sand fraction of the Ringold Formation, which typically consists of only 5 to 15 percent dark mafic grains. The reason for this is the Ice Age floods, which eroded the basalts underlying the Channeled Scabland of the Columbia Plateau. The Ringold Formation, on the other hand, is derived from mostly metamorphic and plutonic rocks eroded from the margins of the Columbia Plateau and slowly transported to the Pasco Basin via the Columbia River.

Note: The sediment is loose, composed of brownish-gray, clast-supported, poorly sorted, silty, sandy, pebble-cobble gravel. Clasts are mostly subangular to subrounded basalt; other clasts include granitics, gneiss, and quartzite as well as other volcanics. Absent in this sample is yellow-orange reworked Ringold mud that can make up the bulk of the matrix in mud-rich facies of the Hanford formation within the 300 Area. This grab sample was collected from the 6 to 6.7 m (20 to 22 ft) depth in Borehole 399-3-31 within the IFRC site.

Figure 3-34. Typical Appearance of Gravel-Dominated Facies of the Hanford Formation from the Vadose Zone within the 300 Area

In contrast to the Ringold Formation, the Hanford formation is generally unconsolidated due to its much younger age and insufficient amount of time for onsite weathering or secondary alteration to take place within the sediments. The depth of burial for the Hanford formation is reduced so relatively little compaction has occurred. As a result, the permeability of the Hanford formation is generally up to several orders of magnitude greater than the underlying Ringold Formation. Therefore, the contact between these two highly contrasting stratigraphic units may act as a distinct hydrologic boundary.

The lower, unsaturated portion of the Hanford formation was conveniently exposed in four backhoe excavations in 2003 (*Sampling and Hydrogeology of the Vadose Zone Beneath the 300 Area Process Ponds* [PNNL-14834]). These excavations provided a unique opportunity to examine the 3-D character of the Hanford formation. Two excavations each were dug beneath the former South and North Process Ponds, respectively, after the remediation activities were completed but prior to backfilling and regrading to their present-day configuration. Figures 3-35 and 3-36 show profiles for the two excavations beneath the former South Process Pond.

Flood deposits of the Hanford formation in the 300 Area are relatively heterogeneous and anisotropic. The matrix filling between gravel clasts is highly variable. The matrix may be filled or partially filled with sand, silt, or clay, or may be absent altogether, creating an openwork fabric. Some weak bedding and stratification were apparent in excavated pit exposures. However, because of the complex hydrodynamics involved in cataclysmic flooding, individual beds do not appear to extend very far laterally. For example, in Figure 3-36, most beds are discontinuous across the width of the trench. Hanford formation sediments are extremely permeable because of their generally loose nature, open-work fabric, and high effective porosity, especially within the mud-depleted facies.

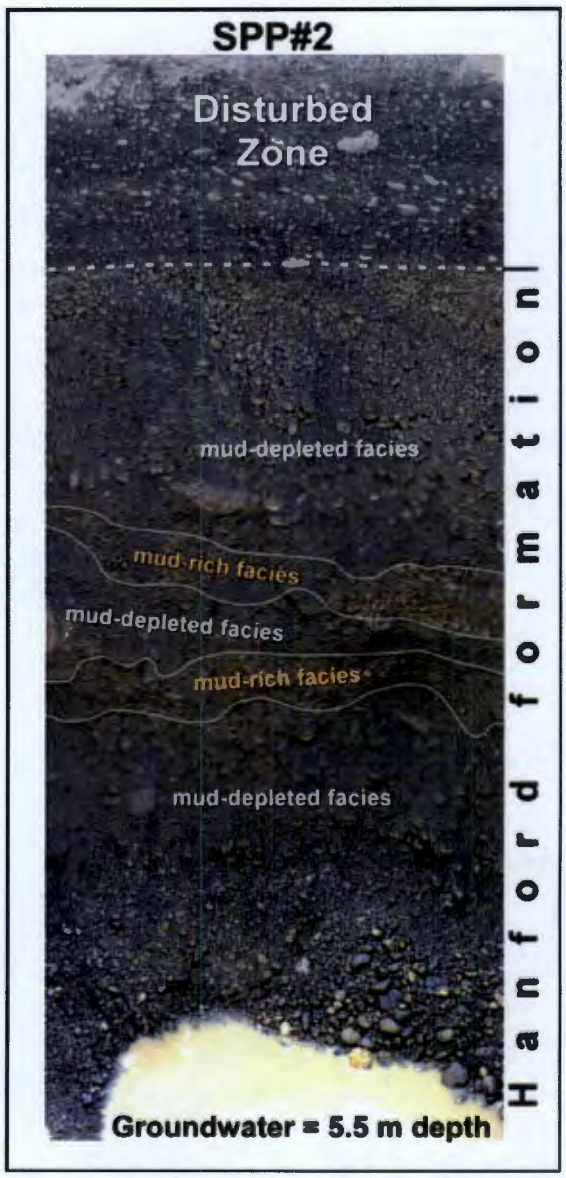
Based on these excavations and dozens of boreholes, at least two facies of the gravel-dominated Hanford formation are recognizable in the 300 Area, namely: (1) mud-depleted and (2) mud-rich facies

(Figures 3-35 and 3-36). While the framework (angular to subangular basaltic gravel) is the same for these two facies, the matrix material is drastically different. Often, the color of the sediment matrix is an indication facies type. The mud-depleted facies is dark gray to black (same color as basalt), while the mud-rich facies is a shade of yellow, brown, or orange due to concentrations of similarly colored, reworked Ringold mud.

Mud-Depleted Facies of the Hanford Formation. The mud-depleted facies has little or no fines between clast-supported gravels that make up the framework of the Hanford formation in the 300 Area (Figures 3-37 and 3-38). As such, the mud-depleted facies displays an open-framework fabric with lots of open pore spaces between clasts. This is what accounts for the extremely high hydraulic conductivity for the Hanford formation. Without fines to bind the sediment together, the mud-depleted facies is not only highly permeable but also extremely loose and, therefore, easily caves in on itself.

Mud-Rich Facies of the Hanford Formation. Occasionally, the matrix fill between clast-supported Hanford formation gravels consists of fine-grained, sticky silt to clayey silt that coats and fills the voids between gravel clasts (Figures 3-39 and 3-40). Often described as silty gravel in drill logs, this facies contains relatively small amounts of intermediary sand.

The source of the mud appears to be from the reworking of Ringold Formation, eroded off the White Bluffs immediately to the north and east (Figure 3-41). The mud may have also come from erosion of the Ringold Formation undesignated fine-grained unit that locally underlies the 300 Area. Interestingly, the mud-rich and mud-depleted facies are interstratified with each other (see Figures 3-35 and 3-36), suggesting there were periods when the floods did not transport as much reworked Ringold sediment. Shifting flood currents may have resulted in deposition of the mud-rich versus mud-depleted facies, or these may be the result of different floods, perhaps coming from different directions, or changes in flood stage during a single flood.



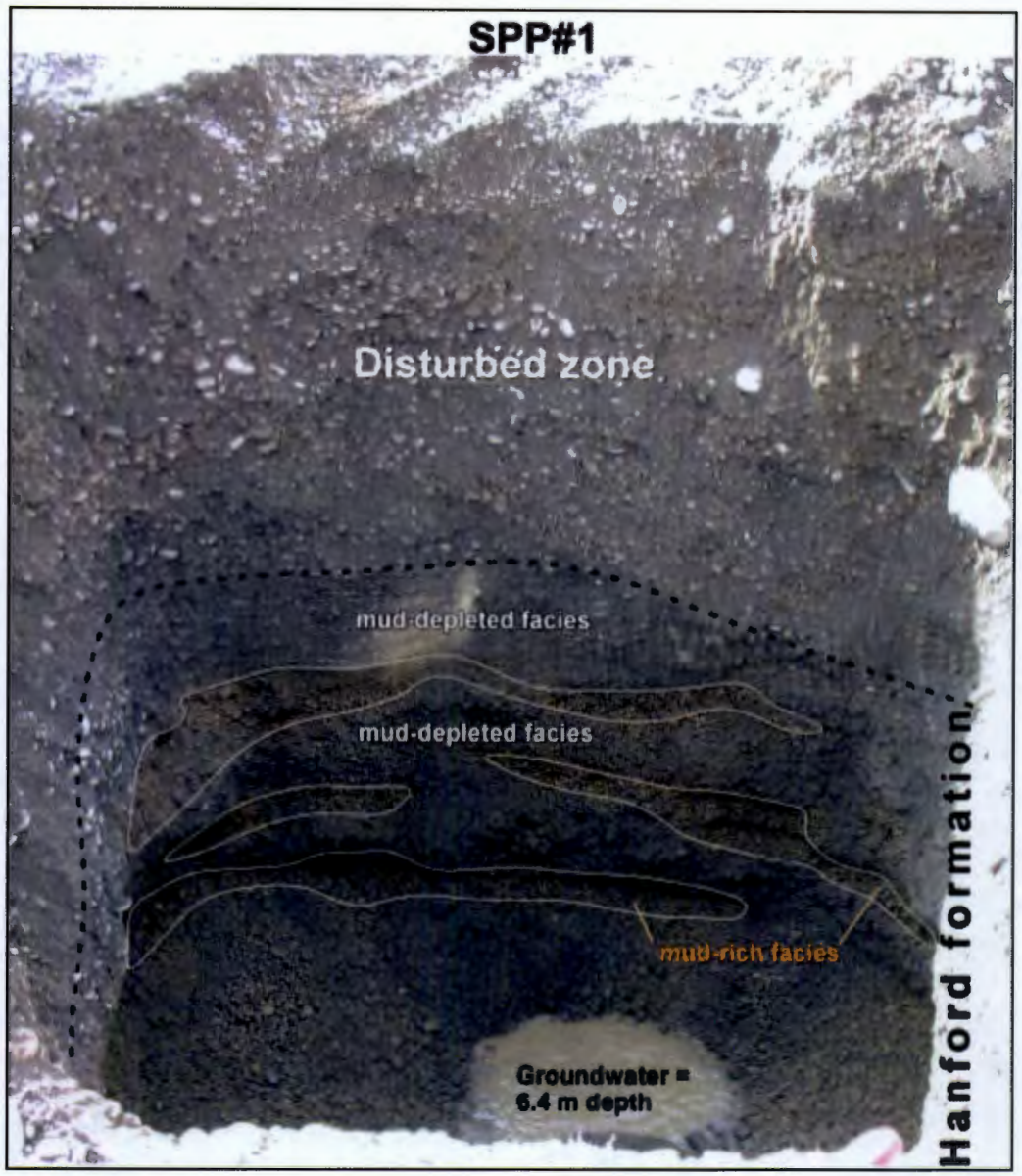
Note: Gravel-dominated, basaltic flood deposits with a mud-rich matrix alternate with those with an open-work to sandy matrix (mud-depleted facies).

Source: PNNL-14834, *Sampling and Hydrogeology of the Vadose Zone Beneath the 300 Area Process Ponds.*

Figure 3-35. Hanford Formation Exposed in 5.5 m (18 ft) Deep Backhoe Pit Excavated in the Southwest Corner of the Former South Process Pond in 2003

Mud-rich facies of the Hanford formation may act as local aquitards within the saturated Hanford formation. This was demonstrated by vertical flows observed in IFRC wells that occurred with changes in nearby river level ("Vertical Wellbore Flow Monitoring for Assessing Spatial and Temporal Flow Relationships with a Dynamic River Boundary" [Newcomer et al., 2010]). Apparently, the hydraulic

conductivity within the mud-rich Hanford formation interval was low enough that groundwater preferentially flowed through the sandpack around the well.



Source: PNNL- 14834, *Sampling and Hydrogeology of the Vadose Zone Beneath the 300 Area Process Ponds.*

Note: Higher concentrations of oxidized, yellow-brown Ringold silt and clay matrix fill (mud-rich facies) occur within subhorizontal layers. Matrix fill in mud-depleted facies consists of predominantly higher permeability basaltic sand with little or no fines.

Figure 3-36. Profile of Vadose Zone Pit Exposes the Hanford Formation on the East Side of the Former South Process Pond in 2003

Figure 3-37. Grab Samples of Mud-Depleted Facies of the Hanford Formation

Note: Both cores illustrate the open-work fabric within the basalt-rich, clast-supported gravel. Left: Note how matrices are free of sediment except for silt coatings on pebble clasts. Right: Loose, basalt-rich, sandy gravel lacking fines within the matrix.

Figure 3-38. Mud-Depleted Facies of the Hanford Formation in Sediment Cores from Well 399-1-19

Note: From Well 399-2-14, 5.5 to 6 m (18 to 19.5 ft) depth. Notice clumps of greenish-yellow, sticky silt and clay that adheres to the gravel clasts.

Figure 3-39. Mud-Rich Facies of the Hanford Formation Recovered from a Resonant-Sonic Core Barrel

Note: Left: Abundant fines coat and fill the matrices between gravel clasts. Yellow-orange stringer is a probable semiconsolidated, Ringold mud rip-up clast. The once-rounded rip-up clast has since been deformed during either flood deposition, post-flood compaction, or perhaps during collection of the resonant-sonic drill core. Well 399-1-23. Right: mottled mixture of multi-genetic brown Ringold Formation silt and dark gray basaltic sand (Well 399-2-25, 16 m [52 ft] depth).

Figure 3-40. Sediment Cores of the Mud-Rich Facies of the Hanford Formation

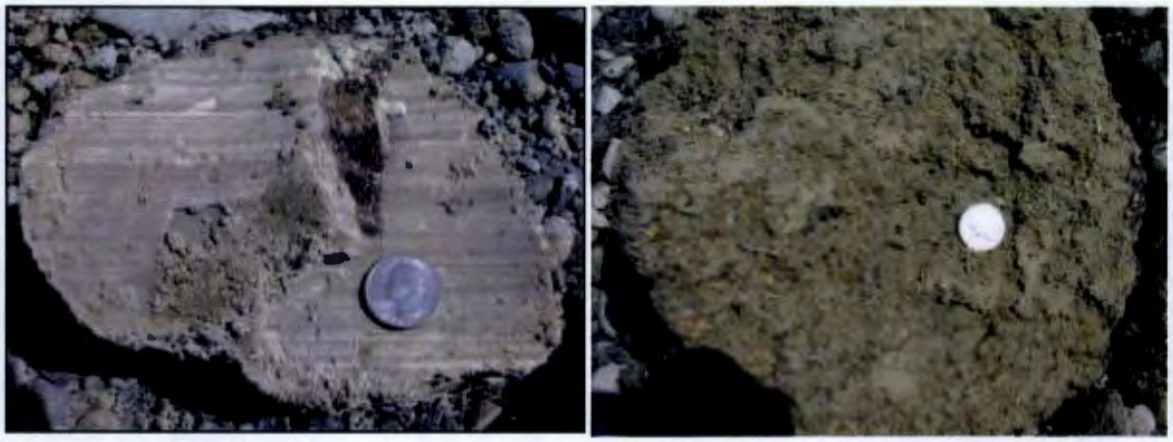
Note: The White Bluffs are an erosional escarpment that exposes hundreds of feet of Pliocene-age, fine-grained sediments of the Ringold Formation. Ice Age floods flowed from the upper left and upper right.

Figure 3-41. Aerial View, Looking Northeast, toward the 300 Area

Ringold Formation Rip-Up Clasts within the Hanford Formation. Some of the mud may also be derived from the post-depositional disintegration of unlithified Ringold rip-up clasts. Rip-up clasts, like those in Figures 3-42 and 3-43, that are up to 1.5 m (5 ft) thick have been identified in 300 Area boreholes (*Sampling and Hydrogeology of the Vadose Zone Beneath the 300 Area Process Ponds* [PNNL-14834]; *Drilling, Sampling, and Well-Installation Plan for the IFC Well Field, 300 Area* [PNNL-17512]).

Note: These boulder-sized clasts, composed of cohesive, oxidized Ringold Formation silt and clay, were ripped off the White Bluffs escarpment just upstream of, or from beneath, the 300 Area during cataclysmic Ice Age floods.

Figure 3-42. Rounded Rip-Up Clasts Removed from Backhoe Excavation from beneath the Former South Process Pond



Note: On the left is a well-laminated silt, originally deposited in a lake that filled the Pasco Basin between 3 to 5 million years ago. On the right is an olive-yellow silt with relict plant and animal traces from a Ringold Formation paleosol. Both sediment types are exposed in exposures of Ringold Formation in the White Bluffs upstream of the 300 Area.

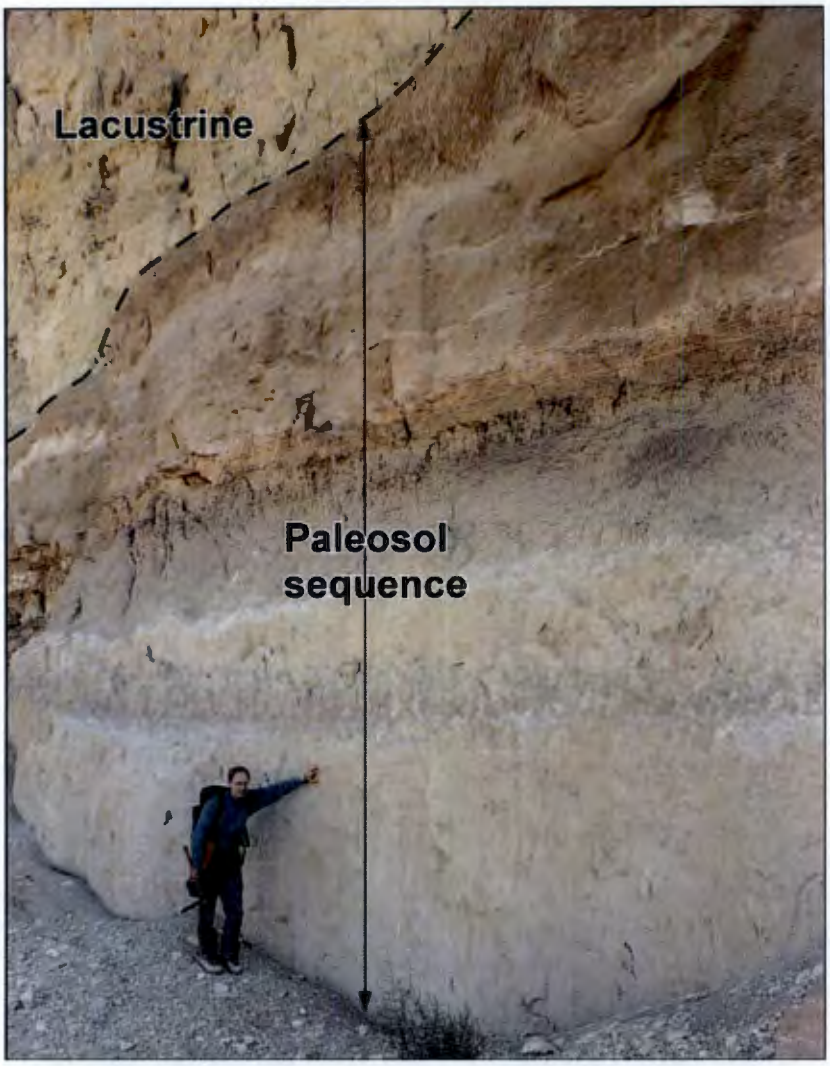
Figure 3-43. Interiors of Two Fine-Grained, Rounded Ringold Formation Rip-Up Clasts Removed by Backhoe from beneath the South Process Pond in 2003

Unique to the flood deposits in the 300 Area are rounded rip-up clasts of semi-consolidated, fine-grained Ringold Formation (Figures 3-42 and 3-43). These include clasts of calcium-carbonate-cemented caliche as well as clasts of compacted mud, originally deposited during Ringold time in either floodplain-overbank or lake environments. These same types of sediment are exposed in the Ringold Formation within the White Bluffs immediately across the river as well as upstream of the 300 Area (Figure 3-44).

Generally, Ringold rip-up clasts are larger than adjacent clasts, reflecting their short transport distance and lower bulk density, in contrast to basalt and other lithified clasts. The rounded nature of rip-up clasts indicates they were transported as detrital "grains," along with other materials, during flooding.

Normally, silt and clay are not a major component of high-energy, gravel-dominated flood deposits of the Hanford formation (Standardized Nomenclature for Post-Ringold Sediments [DOE/RL-2002-39]; A Geological Field Guide to the Mid-Columbia Basin [Bjornstad, 2006]). This is because the fine particles of silt and clay tended to remain in suspension during the short-duration (week or less), high-energy Ice Age flood events. Floodwaters never slowed down enough for the fine particles to settle out of suspension before all the water flushed out of the basin. Coarser particles of sand and gravel, on the other hand, could settle out and were deposited during flooding because of their larger size and higher density.

The 300 Area is different from most other locations on the Site, however, because it lies close to at least two sources of fine-grained Ringold Formation silt and clay. One source is directly beneath the site, and the other is the White Bluffs erosional escarpment immediately upstream (see Figure 3-40). Thus, it appears that significant amounts of fine-grained Ringold Formation silt and clay were incorporated into flood deposits as Ringold rip-up clasts before the clasts had a chance to totally disaggregate and move into suspension with the floodwater. Once in suspension, however, most fine particles of silt and clay were flushed out of the basin along with the ocean-bound floodwater. Rip-up clasts are relatively unconsolidated and, not surprisingly, would not be expected to survive flood transport far from their source, which explains why they are not observed far inland of the 300 Area and the Columbia River.



Source: BHI-00184, *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington.*

Note: Here a thick paleosol sequence is overlain by laminated lacustrine (lake) deposits. Deposits like these are a probable source for the many reworked Ringold rip-up clasts observed within the Hanford formation in the 300 Area.

Figure 3-44. Olive to Brown and Yellow Fine-Grained Upper Ringold Formation Deposits (Member of Savage Island) Exposed Upriver along the White Bluffs within a Mile of the 300 Area

Ringold rip-up clasts have also appeared in many boreholes drilled within the 300 Area (Figures 3-45 and 3-46). These can be identified where sharp boundaries exist between Ringold Formation silt with basaltic sand and gravel immediately above and below. In the past rip-up clasts have been mistaken as the top of the Ringold Formation.

Because some contaminants (including uranium) may have an affinity for mud-sized particles, the character and distribution of concentrated fine-grained material in the subsurface has special relevance. Although clast-supported pebble- to boulder-size gravel is the dominant sediment size in the 300 Area, the matrix between gravel clasts varies significantly between relatively permeable sandy gravel (see Figures 3-37 and 3-38) and less permeable muddy gravel (see Figures 3-39 and 3-40).

Note: This rip-up clast is similar to the oxidized silt within the Ringold Formation undesignated fine-grained unit that directly underlies portions of the 300 Area.

Figure 3-45. Loose, Basaltic Pebbly Sand Overlies the Top of a Semiconsolidated Ringold Formation Rip-Up Clast within the Hanford Formation at 9 to 10 m (30 to 33 ft) Depth, Well 399-2-14

Note: The inclined lamination in this vertical drill core indicates this sediment was not deposited in situ but rotated in transit before being redeposited during an Ice Age flood.

Figure 3-46. Portion of a 1.7 m (5.5 ft) Thick Compact Ringold Formation Rip-Up Clast, Composed of Cohesive Clayey Silt, in Well 399-3-26 from 6.4 to 6.7 m (21 to 22 ft) Depth

To summarize, Figure 3-47 is a conceptual model for the movement of sediment during Ice Age flooding. Each cataclysmic flood transported massive amounts of sediment, all within a period of a week or less. In the turbid column of floodwater was a stratified mixture of sediments being transported by the floods. At the base of the flow, along the sediment water interface, floodwaters carried everything, from large boulders that bounced and rolled along the bottom to finer-grained particles (sand to clay), as tractive bedload. Above the zone of traction, however, only the small particles of sand, silt, and clay were entrained within the highly turbulent floodwaters.

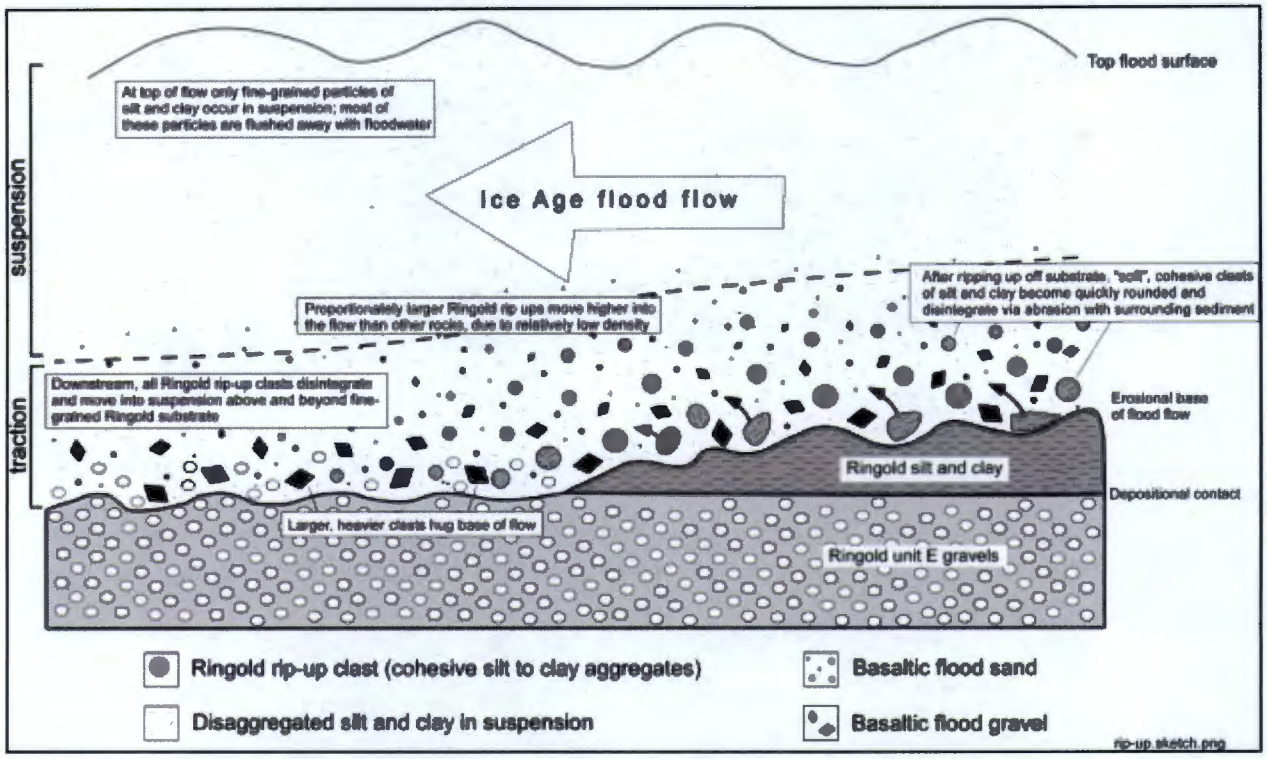


Figure 3-47. Model for Sediment Transport and Stratification during an Ice Age Flood Leading to the Formation of Ringold Rip-Up Clasts

Discordant clastic dikes (*Clastic Injection Dikes of the Pasco Basin and Vicinity* [BHI-01103]), which are common to the sand- and interbedded sand- to silt-dominated facies of the Hanford formation, rarely occur in the gravel-dominated facies, including the 300 Area.

3.4.2.3 Holocene Deposits

The most recently deposited sediment contains eolian sand and/or anthropogenic backfill of previously excavated sediment, coal plant fly-ash waste, etc. These deposits overlie most of the 300 Area and their typical thickness falls in the approximate range of 1 to 6 m (3.3 to 19.7 ft).

The contact between backfill and Hanford formation is difficult to discern based on drill cuttings or geophysical logs because the texture of the sediments is essentially the same. The contact is apparent, however, based on photographs of several backhoe pits excavated in 2003 (Figures 3-36 and 3-37). Disturbed sediments appear relatively homogeneous with no visible structure; this is in contrast to the in situ Hanford formation, which typically displays sedimentary fabric in the form of layering, stratification, and clast imbrication. Based on these photographs, the zone of anthropogenic disturbance extends below the bottom of the process pond excavation. Movement of heavy equipment and other

disturbances at the base of the excavated ponds caused disturbance for up to several meters below these excavations.

The 300 Area process ponds were used for the disposal of uranium-contaminated wastes between 1943 and 1975. Contaminated soils were selectively removed from beneath the ponds from 1994 to 2005. After remediation, excavations were backfilled with locally derived gravel-dominated sediments of the Hanford formation. Following backfilling, the surface was brought to a common elevation of about 115 m (377 ft).

3.4.3 Geologic Characteristics beneath the 400 Area Subregion

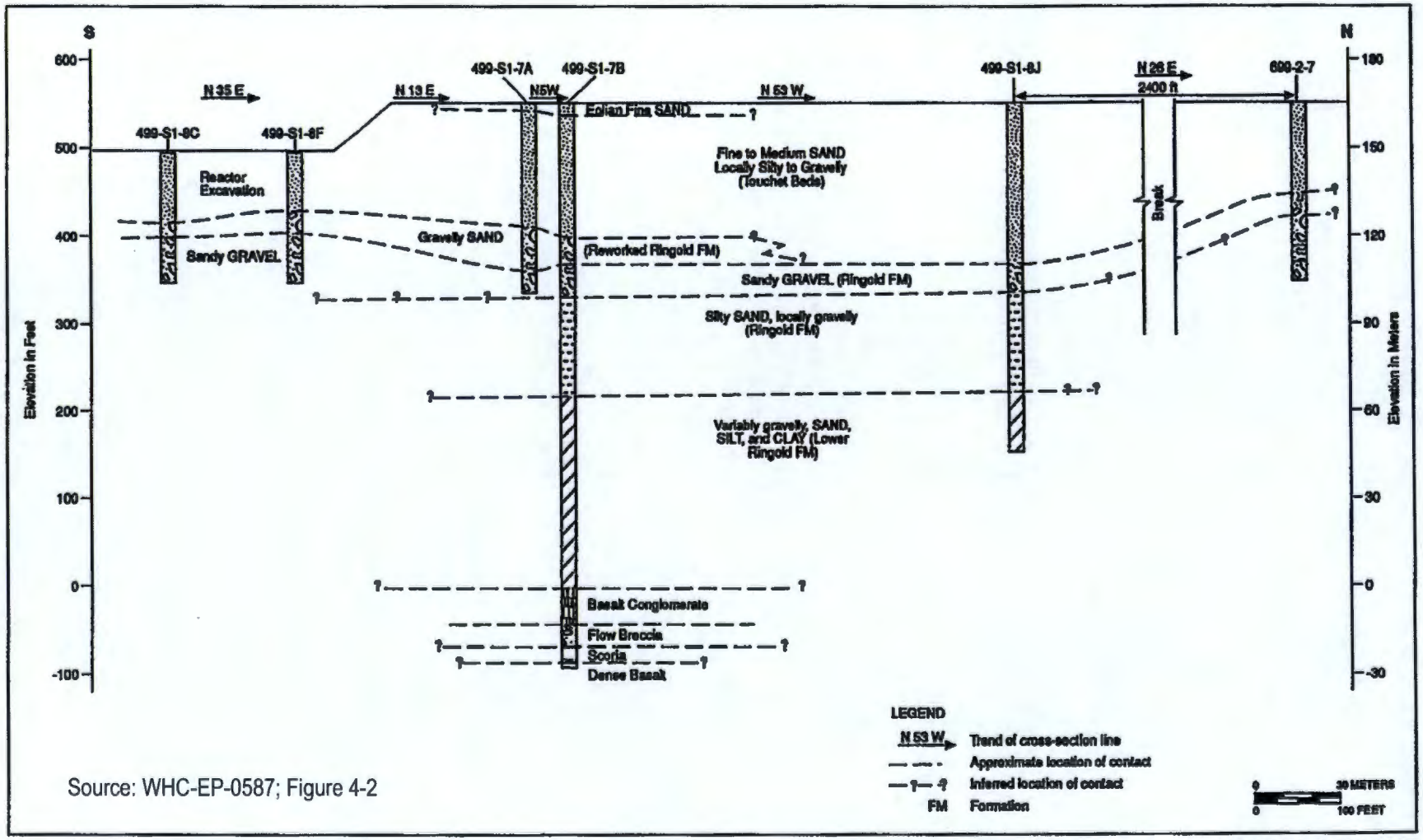
The 400 Area is situated in the west central portion of the 300 Decision Area and contains the FFTF and the FMEF. The hydrogeology beneath the 400 Area facilities is described in a report prepared in 1991 to evaluate the potential impacts on groundwater caused by waste disposal at the 400 Area Ponds (*Groundwater Impact Assessment Report for the 400 Area Ponds* [WHC-EP-0587]). Figure 3-48 is a cross section oriented south to north across the 400 Area that illustrates the principal stratigraphic features associated with the unconfined aquifer (Figure 3-49 is an index map for 400 Area monitoring wells). The following summary description is from that report unless otherwise cited.

The stratigraphic units of interest beneath the 400 Area are similar to those described in detail above for the 300 Area in Section 3.4.1, with the exception of the characteristics for Hanford formation sediments. At the ground surface, windblown deposits of fine- to medium-grained sand are present as stabilized dunes where not modified by human activities. The surficial deposits overlie sandy sediments of the Hanford formation that are referred to as the Touchet Beds. These deposits represent a less energetic depositional environment than the coarse-grained, open framework gravelly deposits in the 300 Area. Characteristic features of these dense sands include clastic dikes, which are vertical structures that range in width from several inches to several feet. Their origin is related to the formation of large lakes during periods that alternated with cataclysmic flooding of the Pasco Basin (depositional features associated with Ice Age floods are described in A Geological Field Guide to the Mid-Columbia Basin [Bjornstad, 2006]). The current water table resides near the base of the Hanford formation or in the upper portion of gravelly sediments, whose origin is the underlying Ringold Formation.

The unconfined aquifer system near the 400 Area probably includes all the saturated sediments that lie above the Ringold Formation lower mud unit, as defined in *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington* (BHI-00184), at Well 699-2-6A (located near Well 699-2-7, as shown in Figure 3-49). However, local areas of confined or semiconfined conditions may exist. The thickness of the unconfined aquifer is approximately 100 m (325 ft). Groundwater flow direction at the water table is generally toward the southeast.

3.4.4 Geologic Characteristics of the 600 Area Subregions

The stratigraphic intervals of interest beneath the several 600 Area subregion waste sites are similar to those described in detail above for the 300 Area. Surficial sediment is primarily sandy material present in stabilized sand dunes where not modified by human activities. At the 618-10 and 618-11 Burial Grounds, periodic range fires have influenced the natural vegetation. The ground surface at each of the burial grounds was stabilized in 1982 and 1983. Sediment at the water table is typically gravelly in nature, but with varying degrees of compactness and cementation, which causes variability in permeability.



Source: WHC-EP-0587; Figure 4-2

913 1728R/24215/10-16-92

Figure 3-48. Geologic Cross Section Showing Principal Geologic Units at the 400 Area

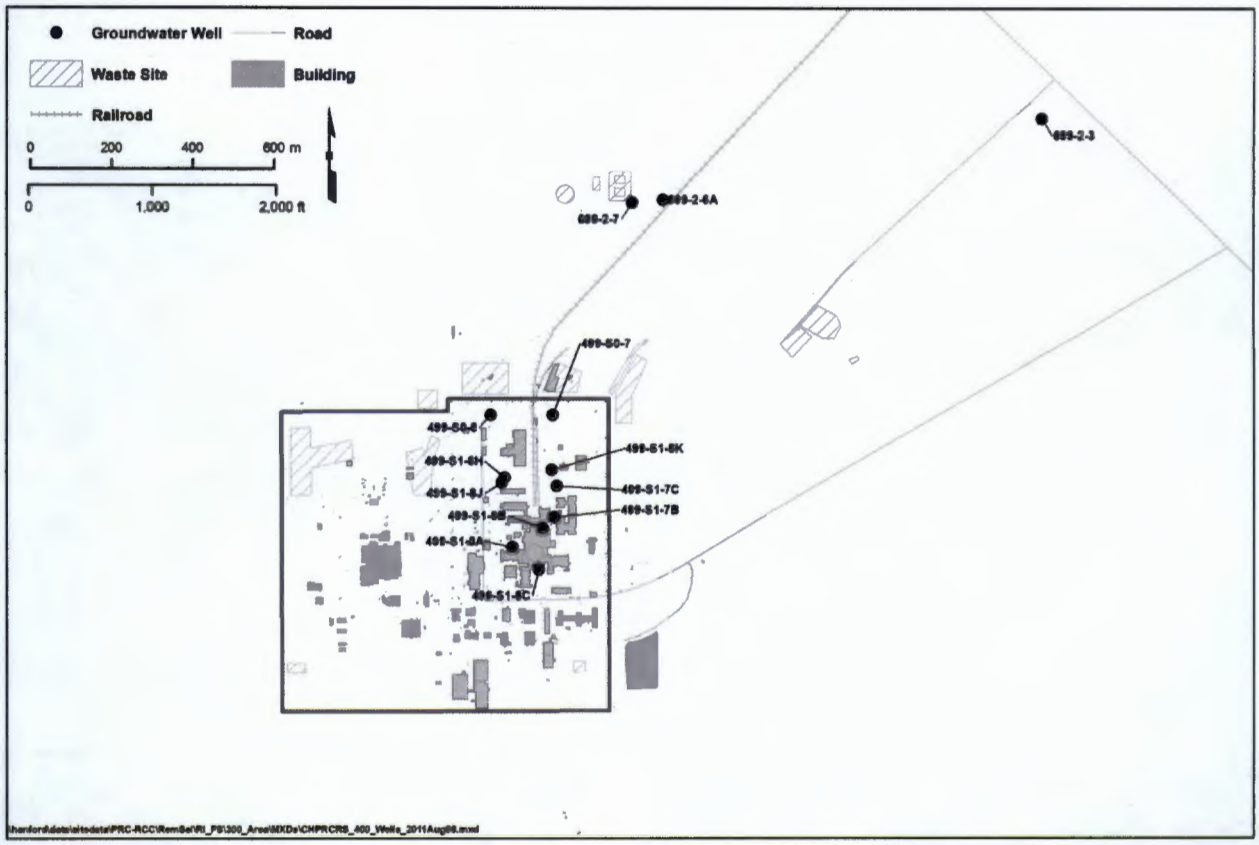


Figure 3-49. Location Map for Monitoring Wells at the 400 Area

3.4.4.1 618-11 Burial Ground Subregion

The hydrogeology near the 618-11 Burial Ground is described as part of an evaluation of the transport and fate of the tritium plume whose origin involves a release from the burial ground (*Evaluation of the Fate and Transport of Tritium Contaminated Groundwater from the 618-11 Burial Ground* [PNNL-15293]).

An additional gravelly interval referred to as the Cold Creek unit lies between the Hanford formation and underlying Ringold unit E sediments in some areas near this burial ground. The Cold Creek unit is less permeable than the Hanford sediment, but more permeable than the Ringold sediment. The movement of the tritium plume whose origin is the burial ground appears to be closely related to the lateral variability in aquifer permeability. Figures 3-50 and 3-51 illustrate the stratigraphic units and coverage by monitoring wells and provide the locations of monitoring wells.

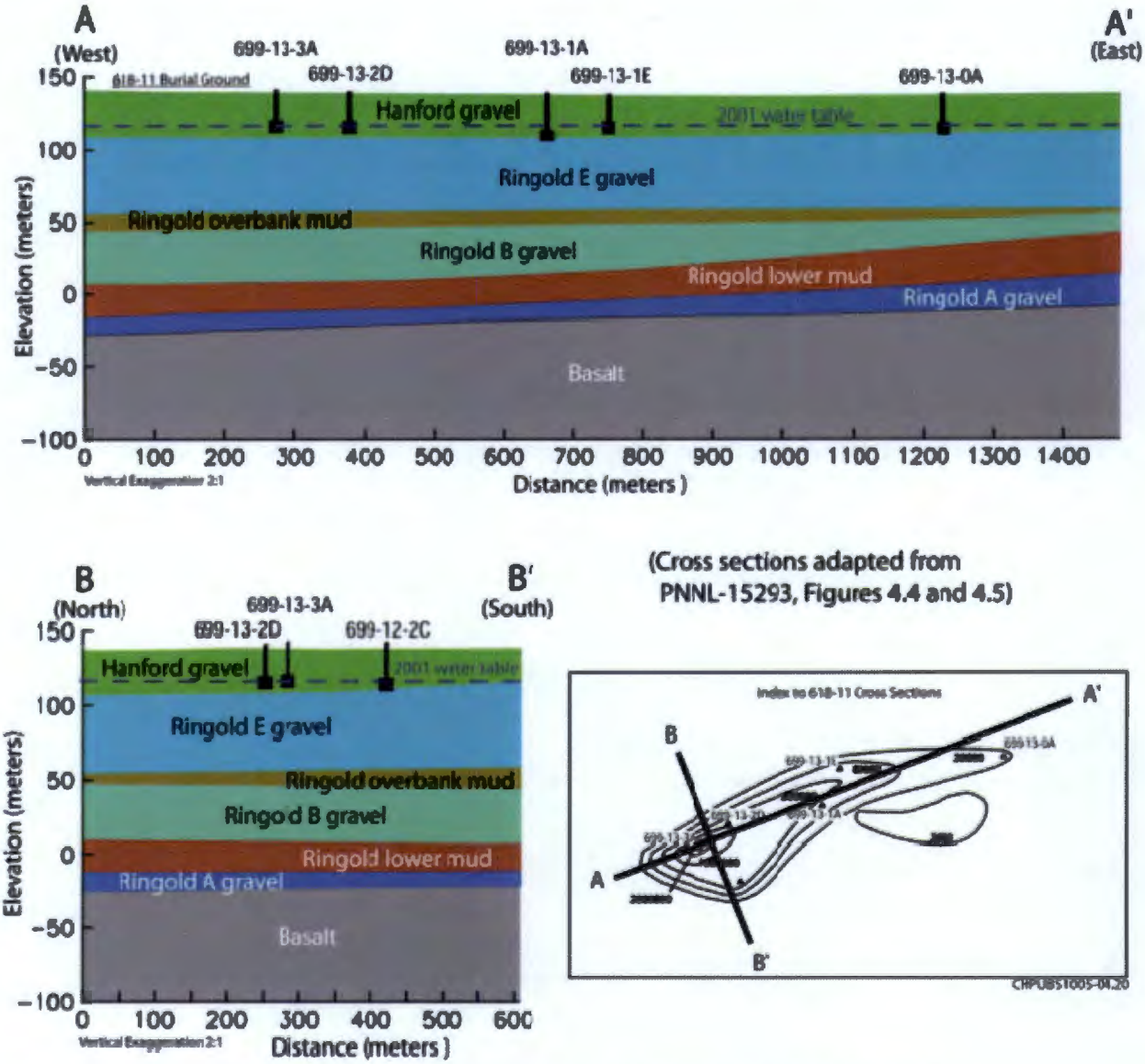


Figure 3-50. Geologic Cross Section Showing Principal Geologic Units near the 618-11 Burial Ground Subregion

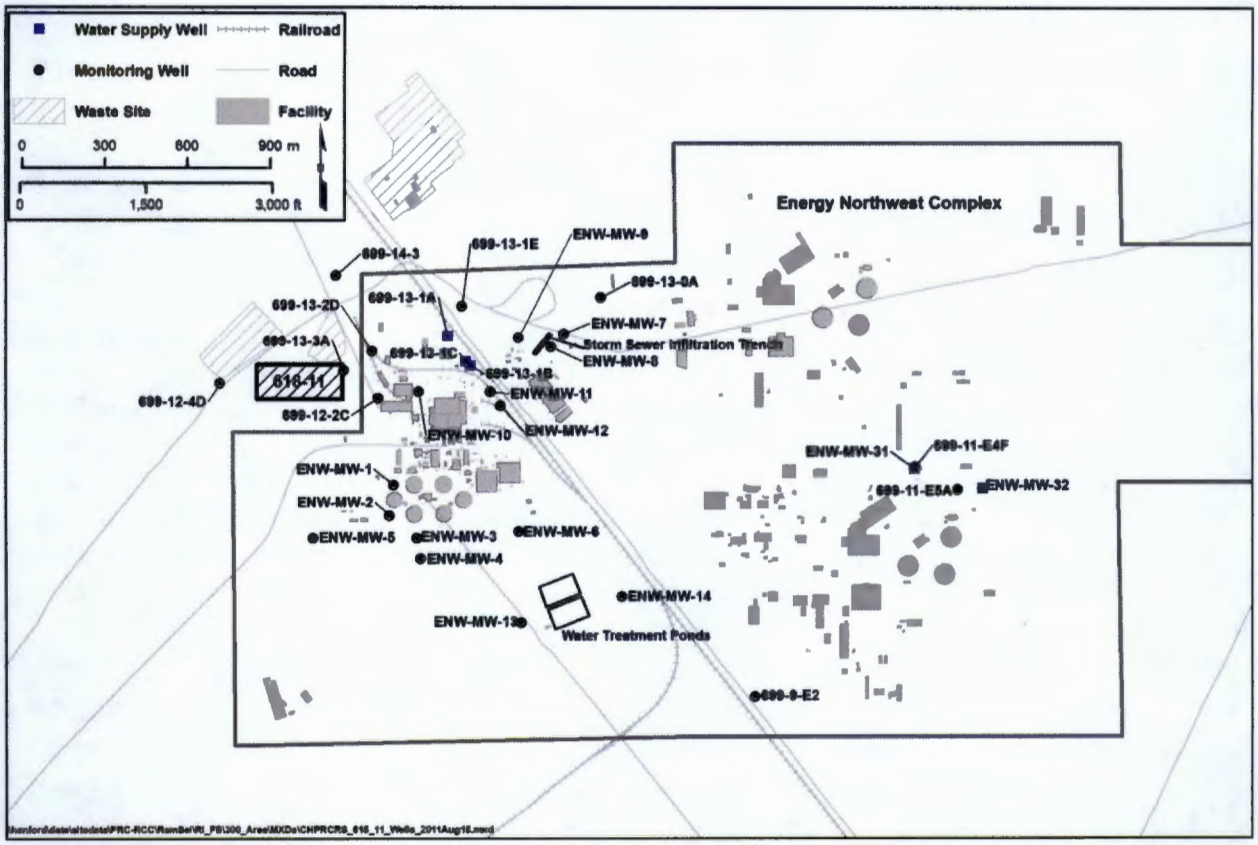


Figure 3-51. Location Map for Monitoring Wells at the 618-11 Burial Ground Subregion

3.4.4.2 618-10 Burial Ground/316-4 Cribs Subregion

The most recent information on the hydrogeology near the 618-10 Burial Ground and former 316-4 Crib comes from drilling associated with two monitoring wells in 2003. The new wells were drilled to characterize the vadose zone in the vicinity of the two waste sites with regard to radiological contamination (none found), develop a preliminary hydrogeologic model for the subregion, and expand the groundwater monitoring capability.

The land surface in this subregion is similar to most of the inland regions of the 300 Decision Area, in that it consists of stabilized windblown deposits, except where modified by human activities. The origin for the sand is weathering of the uppermost geologic formation (i.e., Hanford formation sediment), which forms the vadose zone beneath this subregion. The vadose zone sediment is primarily loosely consolidated sand and gravel. *Soil Gas Survey and Well Installations at the 618-10 Burial Ground, 300-FF-5 Operable Unit, Hanford Site, Washington* (PNNL-14320) presents geologists' descriptions of the stratigraphy encountered and geophysical logs for the two drill sites. These two boreholes did not extend downward to penetrate the entire unconfined aquifer. The water table lies in the uppermost portion of the Ringold Formation unit E (i.e., just below the contact with the overlying Hanford formation). Each new monitoring well was completed with a screened interval intended to monitor the uppermost portion of the unconfined aquifer. Figure 3-52 shows the coverage by monitoring wells.

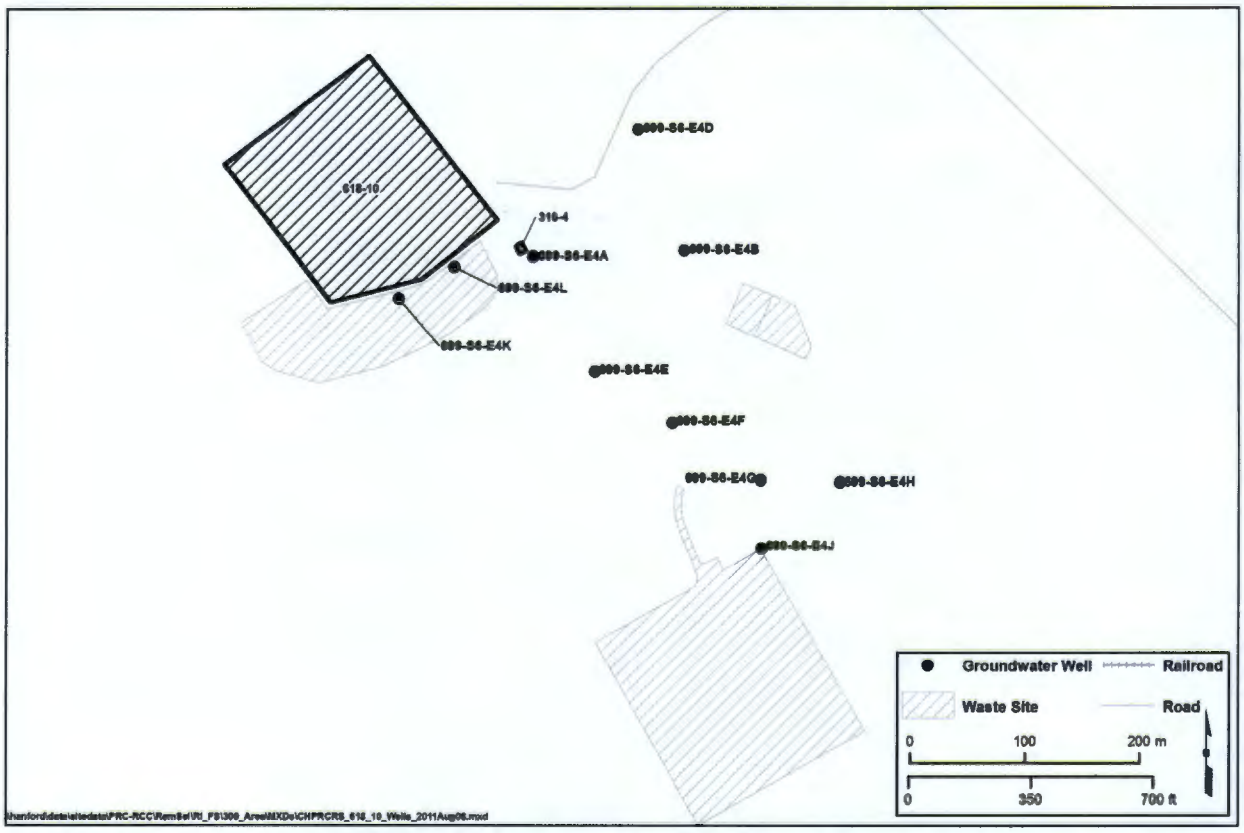


Figure 3-52. Location Map for Monitoring Wells at the 618-10 Burial Ground/316-4 Cribs Subregion

3.5 Soils and Vadose Zone

This section describes the soils and vadose zone within the 300 Decision Area. Section 3.4 presents detailed descriptions of the stratigraphy, lithology, and geologic characteristics beneath the 300 Area, 400 Area, and 600 Area subregions. Section 3.6 presents detailed descriptions of the hydrogeologic units,

including the portion of the deep vadose zone that is intermittently saturated (i.e., PRZ). Therefore, those descriptions will not be re-presented here; rather, vadose zone thicknesses within the various subregions and the soil physical property data applicable to contaminant fate and transport that were collected for the RI will be the focus.

3.5.1 Soils

In the *Investigation of the Chemical Explosion of an Ion Exchange Resin Column and Resulting Americium Contamination of Personnel in the 242-Z Building, August 30, 1976* (BNWI-1007-DEL), 15 soil types on the Site are described. The surface soils consist of sand, sand loams, and silty loams. Only four soil types are present within the 300 Decision Area (Figure 3-53). Surface soil types in the 300 Decision Area include:

- **Burbank Loamy Sand.** Burbank loamy sand is a dark-colored, coarse-textured soil underlain by gravel. Its surface soil is usually about 40 cm (16 in.) thick but may be as much as 75 cm (30 in.) thick. The gravel content of its subsoil ranges from 20 to 80 percent.
- **Ephrata Sandy Loam.** Ephrata sandy loam is found on level topography on the Site. Its surface is darkly colored and its subsoil is dark grayish-brown, medium-textured soil underlain by gravelly material.
- **Pasco Silt Loam.** Pasco silt loam is poorly drained very dark grayish-brown soil formed in recent alluvial material. Its subsoil is variable, consisting of stratified layers. It occurrence on site is very low.
- **Rupert Sand.** Rupert sand is brown to grayish brown coarse sand. Its color is dark grayish-brown at a depth of 90 cm (35 in.). This soil type is one of the most extensive deposited soils on the Site and predominates (87 percent) in the 300 RI/FS Area. Rupert sand is typically developed under grass, sagebrush, and hopsage in coarse sandy alluvial deposits that were mantled by windblown sand and forms hummocky terraces and dune-like ridges.

3.5.1.1 300 Area Industrial Complex Soil Types

Soil types in the 300 Area Industrial Complex are dominated by Rupert sand. The sand is present over 65 percent of the area. Over the remaining portion of the 300 Area, soil types consist of Burbank loamy sand and Ephrata sandy loam. The Burbank sand and Ephrata sandy loam are only present on the eastern half of the complex and interspersed with Rupert sand and many small area of backfill from construction activities and source interim remedial actions. Table 3-2 presents various recharges rates for soil types in the 300 Area Industrial Complex.

Table 3-2. Estimated Recharge Rates for 300 Area, 400 Area, and 600 Subregions—Disturbed Conditions

Major Soil Type	Estimated Recharge Rate (mm/yr [in./yr])			
	No Vegetation	Cheatgrass	Young Shrub-Steppe	Shrub-Steppe
Rupert Sand	44 (1.7)	22 (0.87)	8.0 (0.31)	4.0 (0.16)
Burbank Loamy Sand	52 (2.0)	26 (1.0)	3.0 (0.12)	3.0 (0.12)
Ephrata Sandy Loam	17 (0.67)	8.5 (0.33)	3.0 (0.12)	1.5 (0.059)
Pasco Silt Loam	No Data Available			

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

3.5.1.2 400 Area Soil Types

Rupert Sand is the only soil type is the 400 Area. The sand is interspersed with backfill from construction activities. Table 3-2 presents various recharges rates for soil types in the 400 Area Subregion.

3.5.1.3 Soil Types of the 618-10 Burial Ground/316-4 Crib and 618-10 Burial Ground Subregions

Soil types in the 618-10 Burial Ground/316-4 Crib and 618-10 Burial Ground Subregions are also dominated by Rupert sand. The sand is present over 85 percent of the 600 Area. Over the remaining portion of the 600 Area, the soil types consist of Burbank loamy sand, Ephrata sandy loam, and Pasco silt loam. With exception of road construction, very little construction and source remedial action has been completed in the 600 Area. Therefore, little backfill is present in the 600 Area. Table 3-2 presents various recharges rates for soil types in the 618-10 Burial Ground/316-4 Crib and 618-10 Burial Ground Subregions.

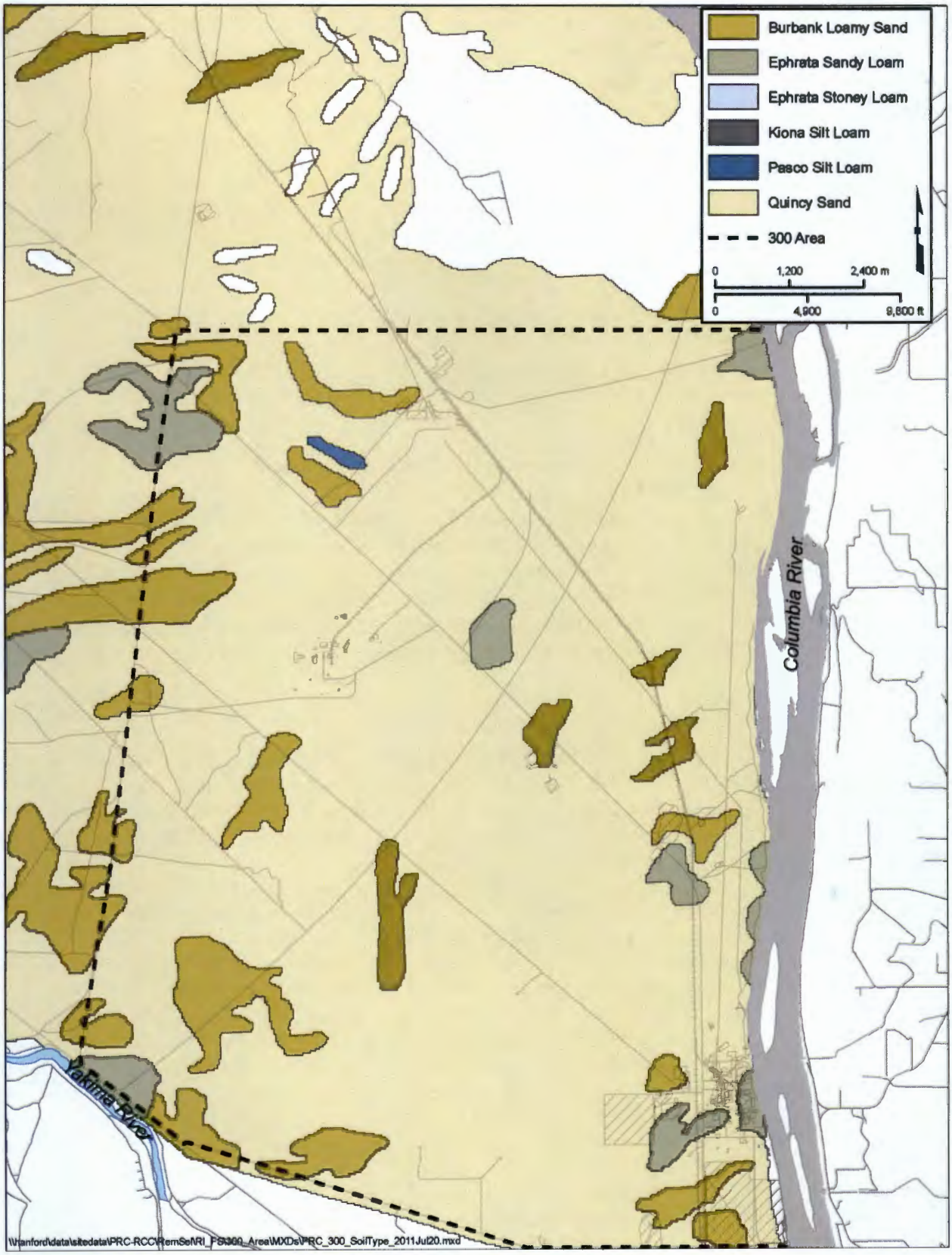


Figure 3-53. Soil Types of the 300 Decision Area

3.5.2 Vadose Zone

The vadose zone (i.e., unsaturated zone above the water table) is the geologic profile extending from ground surface to the water table. It includes the soil at the surface; the capillary fringe zone above the principal water bearing zone, and the combined rock, soil, air, and moisture interface linking the two. This important region above the water table is a significant buffer to the movement of liquids and contaminants released near the surface.

Unsaturated flow of moisture/liquid in the vadose zone is highly complex and influenced by the hydraulic properties of soil, vegetation cover, and recharge. Movement of moisture in the vadose zone is mainly controlled by the hydraulic conductivity and the difference in hydraulic head between two points (i.e., hydraulic gradient). In general, coarser-grained soils have higher hydraulic conductivities as compared to finer-grained sediments. Hydraulic conductivity and hydraulic gradient along with stratigraphy, porosity, grain size, grain size orientation, degree of saturation, and recharge control the migration of liquids in the vadose zone. If the migrating liquids contained dissolved contaminant, the contaminants will also be transported unless retained as a result of soil interactions (200 Areas RI/FS Implementation Plan–ERP [DOE/RL-98-28]).

In the vadose zone, the pressure head is negative under unsaturated conditions (200 Areas RI/FS Implementation Plan–ERP [DOE/RL-98-28]). This reflects the fact that water in the unsaturated zone is held in the soil pores under negative pressure by surface tension forces (200 Areas RI/FS Implementation Plan–ERP [DOE/RL-98-28]). If the volume of water in the vadose zone equals the volume that can be retained by surface tension forces (field capacity), no water is available to migrate. As additional liquid is added to the vadose zone, it will migrate vertically under the force of gravity. This results because an increase in water content reduces the surface tension forces holding the moisture within the pore spaces, thus increasing the moisture flux. Soil properties such as hydraulic conductivity are important for an understanding of contaminant fate and transport.

3.5.2.1 300 Area Industrial Complex

Within the 300 Area, the thickness of the vadose zone varies. The vadose zone thickness varies because of natural and artificial influences, such as changes in the Columbia River stage. Across the 300 Area, the vadose zone ranges from about 15 m (49 ft) to less than 1 m (3 ft) along the Columbia River. As described in Section 3.4, the vadose zone is comprised of backfill materials and unconsolidated gravel and sand of the Hanford formation.

The Site's arid climate keeps the vadose zone soil moisture relatively low, although remedial action (dust suppression water), pipelines, and site infrastructure contribute to increased soil moisture and contribute to artificial recharge. There are 67 sites (i.e., French drains; septic; heating, ventilation, and air conditioning [HVAC] sites) in the 300 Area that contribute to moisture content in vadose zone soils. Most of these sites have a "not accepted or rejected site" classification. As such, the moisture content in the vadose zone is primarily the result of effluent discharges to the soil column (which ceased in the mid-1990s), natural and artificial (dust suppression water, active discharge) recharge, and contribution from river stage. With reduction in artificial recharge, precipitation is now considered the main source of recharge; however, fluctuations in river stage and the flux from artificial recharge also contribute to recharge.

Table 3-3 presents soil physical properties measured during the RI. Table 3-4 contains van Genuchten parameters and fitted vertical saturated hydraulic conductivities applicable to the backfill, vadose zone, and saturated zone in the 300 Area. Table 3-5 presents soil bulk density values for the Hanford formation and Ringold unit E, in addition to the bulk density data presented in Table 3-3 obtained from soils collected in the vadose zone in support of the RI/FS.

Table 3-3. Physical Properties of Soil in the 300 Area Subregion

Site	Hanford/ Ringold	Interval	Depth (ft)	Grain Size (% Passing Sieve)												Classification (%)			Porosity (%)	Moisture (%)	Density (kg/m^3)	
				3 in.	1.5 in.	0.75 in.	0.375 in.	No. 4	No. 10	No. 20	No. 40	No. 60	No. 100	No. 140	No. 200	Gravel	Sand	Silt/Clay			Bulk	Dry
Well C7653		Insufficient Recoveries for Physical Properties																				
Well C7654	Hanford	I-001	10.2to12.7	100	100	61.8	40.9	30.6	24.4	14.7	7.0	5.2	4.2	3.8	3.4	69.4	27.2	3.4	8.9	4.12	2,414	2,292
	Hanford	I-008	27.7 to 30.2	100	100	66.2	54.7	47.4	40.5	35.5	27.1	18.2	12.4	10.4	8.9	52.6	38.5	8.9	24.6	9.47	1,999	1,948
Well C7655	Hanford	I-002	12.4 to 14.3	100	100	87.7	82.4	79.3	77.3	74.6	61.0	37.4	19.5	14.8	11.8	20.7	67.5	11.8	36.3	2.61	1,740	1,688
Well C7656	Hanford	I-006	23.5 to 26.0	100	100	86.9	68.1	49.7	28.0	15.1	6.2	4.0	2.9	2.6	2.3	50.3	47.4	2.3	7.5	5.00	2,452	2,385
	Hanford	I-007	26.0 to 28.5	100	100	100	100	99.1	97.4	96.1	94.9	77.4	35.8	25.8	21.0	0.9	78.1	21.0	29.2	5.85	1,877	1,727
Well C7657	Hanford	I-003	24.7 to 27.2	100	75.1	63.5	55.0	47.0	39.7	31.4	25.1	21.5	18.3	16.6	15.0	53.0	32.0	15.0	16.2	2.09	2,222	2,187
	Hanford	I-009	41.2 to 43.7	100	100.0	77.0	58.6	46.4	31.8	13.7	9.2	7.6	6.3	5.7	5.1	53.6	41.3	5.1	9.7	5.49	2,393	2,308
Well C7658	Hanford	I-003	25.0 to 27.0	100	79.0	56.9	47.7	40.4	33.0	28.6	17.5	12.0	9.5	8.6	7.9	59.6	32.5	7.9	17.7	6.09	2,180	2,119
	Hanford	I-008	37.5 to 40.0	100	100.0	82.2	66.0	55.4	45.3	31.5	24.4	21.1	18.4	16.9	15.5	44.6	39.8	15.5	11.6	3.54	2,344	2,276
Well C7659	Hanford	I-003	25.3 to 27.8	100	72.7	58.3	51.6	47.0	43.1	41.4	29.7	15.7	10.4	8.7	7.5	53.0	39.5	7.5	28.0	4.34	1,908	1,866
	Hanford	I-008	37.7 to 40.2	100	75.1	49.2	37.6	27.9	17.3	7.6	3.8	2.9	2.5	2.2	2.0	72.1	25.8	2.0	17.0	6.33	2,199	2,118
Well C7660	Hanford	I-006	25.5 to 28.0	100	92.7	69.9	49.6	39.4	31.4	17.6	8.1	6.5	5.5	5.0	4.6	60.6	34.8	4.6	3.7	4.69	2,552	2,500
Well C7661		Insufficient Recoveries for Physical Properties																				
Well C7662	Hanford	I-003	24.5 to 27.0	100	100	80.9	63.7	45.5	29.3	24.8	19.2	15.5	12.4	10.9	9.7	54.5	35.8	9.7	14.1	4.43	2,276	2,206
Well C7663	Hanford	I-002	22.5 to 25.0	100	90.2	77.8	71.7	62.1	50.3	42.9	30.8	21.4	15.0	12.6	11.0	37.9	51.1	11.0	24.7	4.44	1,996	1,929
	Hanford	I-003	25.0 to 27.5	100	100	91.9	86.9	80.8	74.0	67.1	59.5	54.2	50.0	47.3	44.4	19.2	36.3	44.4	24.7	13.6	1,994	1,717
	Hanford	I-004	27.5 to 30.0	100	92.9	92.9	92.9	92.8	92.5	91.2	89.6	88.0	85.6	82.8	79.1	7.2	13.8	79.1	27.0	16.2	1,935	1,509

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Particle size analysis was performed in accordance with *Standard Test Method for Particle-Size Analysis of Soils* (ASTM D422-63). Sediment moisture content was determined in accordance with the *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass* (ASTM D2216-05). Density was determined in accordance with the *Standard Test Method for Particle-Size Analysis of Soils* (ASTM D2937-04). Density is reported both as bulk density and as dry density. Porosity is a calculated value determined by the following equation and reported as a percent.

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

For purposes of calculating porosity, normal particle density is assumed to be 2.65 g/cm^3 (165.434 lb/ft^3).

The following summarize the results of physical testing of the vadose zone samples.

- **Grain size:** As expected, most of the vadose zone soil is sandy gravels with the notable exception of Well C7663 Interval I-004, which appears to be primarily silt/clay. The geologist's log for this well reported 20 percent sand and approximately 50 percent silt for the interval running from 7.3 to 9.8 m (24 to 32 ft) bgs.

- **Moisture percent:** The Site's arid climate keeps the vadose zone soil moisture relatively low. Ongoing facility use and dust suppression water are existing sources of artificial recharge. Historically, effluent discharge to the soil column increased soil moisture beneath waste sites, and some drainage may continue in areas where large volumes of liquid waste were formerly discharged. Percent moisture ranged from slightly more than 2 percent to less than 9 percent with the notable exceptions of C7663 Intervals I-003 and I-004 with moisture percentages of 13.6 and 16.2, respectively.

- **Bulk density:** Density ranged from 1,740 to 2,552 kg/m^3 (108.6 to 159.3 lb/ft^3).

- **Calculated porosity:** Porosity ranged from 3.7 to 36.3 percent. The average porosity of samples was 18.8 percent.

3.5.2.2 400 Area

Low moisture conditions dominate in the vadose zone in this subregion. Elevated zones of moisture may be present associated with the 400 PPSS and 17 other active facilities (i.e., French drains, septic systems). The 400 PPSS routinely discharges effluent to the ground, although a portion of the waste stream is also directed to the Energy Northwest sewer system. Moisture content and impact on groundwater from these sources has not been evaluated. Precipitation remains the likely source of recharge in the 400 Area.

In the 400 Area, the vadose zone is approximately 49 m (160 ft) thick and thins to the east towards the Columbia River. The only soil type identified in the 400 Area is the Rupert sand. The vadose zone within the 400 Area Subregion is comprised of recent eolian deposits near the surface (i.e., silt, sand, and backfill) and the gravel-dominated sequences of the Hanford formation (unit 1). Lithologic changes within the gravel-dominated sequence include finer-grained sand and silt lenses.

Table 3-4 presents the van Genuchten parameters applicable to the 400 Area. Table 3-5 presents soil bulk density values for the Hanford formation and the Ringold unit E.

Table 3-4. van Genuchten Parameters

Soil Type	Formation	Total Porosity	Diffusive Porosity	van Genuchten Alpha (1/cm)	van Genuchten (n)	Residual Saturation	Horizontal Saturated K (cm/s)	Vertical Saturated K (cm/s)
BF	Hanford	0.276	0.262	0.019	1.4	0.162	5.98E-04	5.98E-04
VZ	Hanford	0.280	0.250	0.08235	2.09315	0.1516	1.73611	0.173611
SZ	Hanford	0.280	0.250	0.08235	2.09315	0.1516	1.73611	0.173611

Sources:

PNNL-15125, *Flow and Transport in the Hanford 300 Area Vadose Zone-Aquifer-River System.*

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

ECF-200MW1-10-0080, *200-MW-1 Contaminant Fate and Transport Model to Evaluate Impacts to Groundwater in Support of DOE/RL-2008-38 Decisional Draft.*

BF = backfill

SZ = saturated zone

VZ = vadose zone

Table 3-5. Bulk Density Values for Hanford Formation and Ringold Unit E in the 300 Area

Formation	Number of Samples	Bulk Density (g/cm^3 [lb/ft^3])			
		Low	High	Mean	Standard Deviation
Hanford Formation	26	1.60 (99.9)	2.30 (144)	1.91 (119)	0.21 (13)
Ringold Unit E	18	1.63 (102)	2.17 (136)	1.90 (119)	0.15 (9.4)
Hanford Formation (RI data)	16	1.74 (108.6)	2.55 (159.3)	2.15 (134.5)	0.24 (15.0)

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

3.5.2.3 618-10/ Burial Ground/316-4 Cribs and 618-11 Burial Ground Subregions

With exception of dust suppression water used for remedial action, and the contribution of liquid from 600-58 and 600-255 (accepted and not accepted sites, respectively), there is little or no sources of artificial recharge in the two 600 Area subregions. The moisture content in the vadose zone is the result of minor effluent discharges to the soil column, which ceased by 1994, natural recharge, and river stage near the Columbia River. Tables 3-4 and 3-5 present van Genuchten parameters and soil bulk density values, respectively, for soils within the 618-10/ Burial Ground/316-4 Cribs and 618-11 Burial Ground subregions.

3.6 Hydrogeology

This section describes those aspects of the geologic and hydrologic setting for the various subregions of the 300 Decision Area that are relevant to describing contamination issues in the subsurface, selecting a remedial action alternative, and developing a technology-based remedial action, if warranted. The presentation begins with a description of subsurface intervals of sediment that transmit water, followed by descriptions of how groundwater flows through those units, the geochemical characteristics of the units, and finally the interaction between the 300 Area aquifer system and the Columbia River.

Beneath the 300 Area, the key aspects of hydrogeology are:

- The vadose zone, particularly beneath former liquid waste disposal sites
- The saturated portion of Hanford formation sediment
- The isolated zones of finer-grained sediment in the unconfined aquifer
- The interface between the unconfined aquifer and the Columbia River channel

Some characteristics at the 300 Area are unique to the Site (e.g., groundwater flow velocities can be very high, with tracers observed to move up to 18 m (59 ft)/d). Groundwater converges from several directions beneath the 300 Area, bringing in contamination from non-Hanford Site origin in some cases. The hydraulic gradient is directed upward, and there is no evidence of contaminated groundwater having migrated across the river to aquifers beneath Franklin County.

Beneath other subregions, such as the 400 Area and the 618-10 and 618-11 Burial Ground subregions, the hydrogeology relevant to contamination issues is relatively simple. Where contaminants have affected groundwater, the impacts appear to be contained within the upper portion of the unconfined aquifer, and typically within saturated Hanford formation sediment. Describing the movement of groundwater and the variability in geochemical characteristics is less complicated for the inland subregions than beneath the 300 Area because of the increased distance from the Columbia River.

Intentional disposal of significant volumes of hazardous or radiological liquid waste to the ground has not occurred in the 300 Area since 1994 and at the 618-10 Burial Ground subregion since 1956; none has occurred at the 618-11 Burial Ground and 400 Area (Technical Baseline Report [BHI-00012], pp. 2-3 to 2-62). Therefore, under current subsurface conditions, contamination that is present is dispersed under relatively natural hydrologic conditions. Natural hydrologic conditions are significantly different from conditions that prevailed when large volumes of liquid effluent were being disposed to infiltration facilities, such as the North and South Process Ponds (1943 to 1975) and 300 Area Process Trenches (1975 to 1994), and prior to construction of dams on the Columbia River just upstream of the Site.

3.6.1 Hydrology Beneath the 300 Area

Defining subsurface intervals for characterizing the movement of vadose zone moisture and groundwater closely parallels the definition of stratigraphic intervals, as described in Section 3.4. Hydrologic units are defined to facilitate computer simulation of groundwater flow and are more concerned with grouping common characteristics as they relate to flow, rather than to characteristics that relate to depositional environment. A principal difficulty in defining a hydrologic unit, particularly for computer simulations, comes from the need to accommodate heterogeneity in the ability to transmit water in any particular interval. This circumstance adds complexity to attempts to simulate groundwater flow and contaminant transport, and is particularly true for 300 Area subsurface pathways. Figure 3-54 shows the various hydrologic and stratigraphic intervals defined for the subsurface at the 300 Area. Similar conditions exist at the outlying 400 Area and 618-10 and 618-11 subregions.

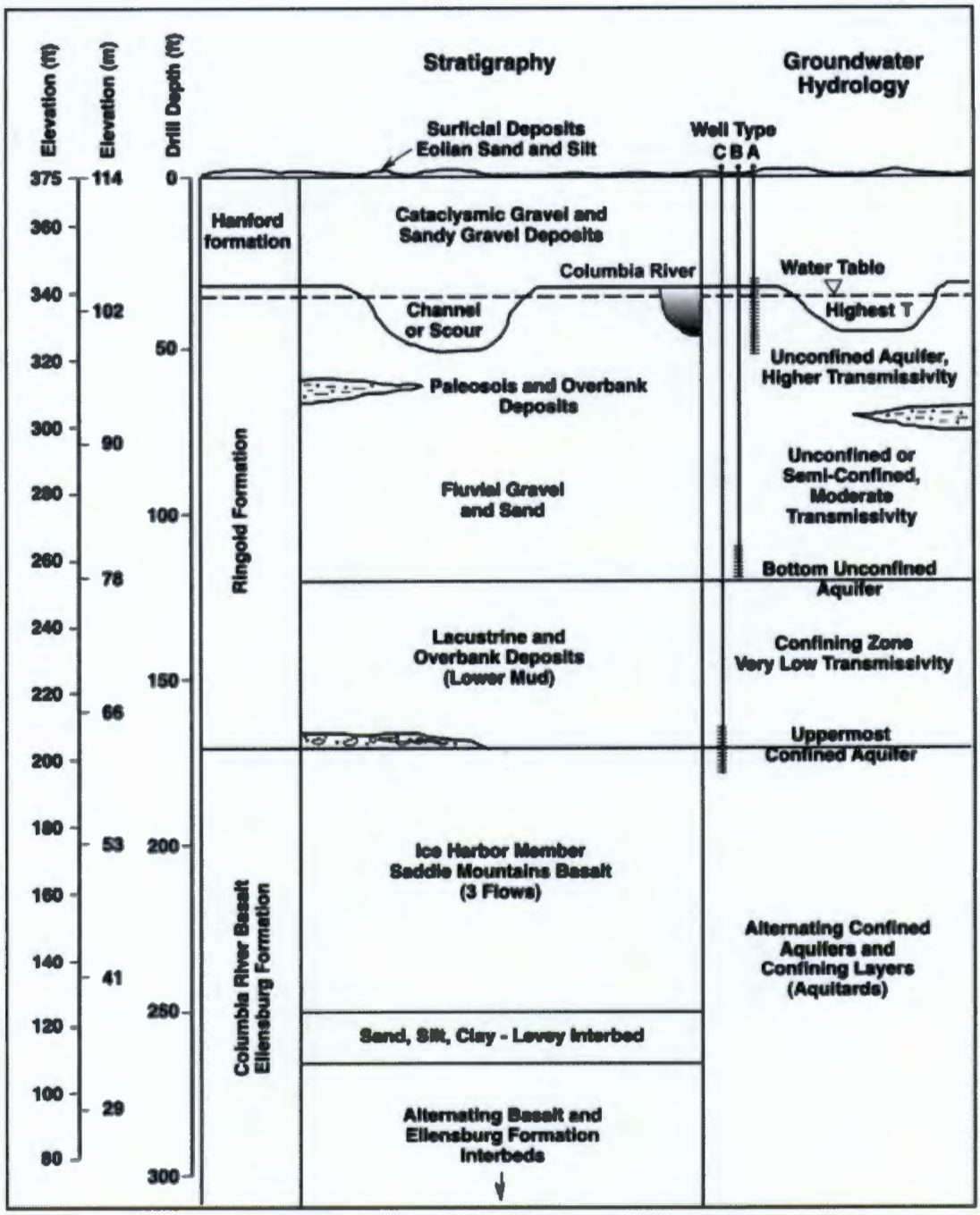


Figure 3-54. Schematic Showing the Principal Stratigraphic Units and Hydrologic Units Defined for the 300 Area

3.6.1.1 Hydrologic Units and Their Characteristics: 300 Area

Section 3.4 presents a detailed description of 300 Area geology. Additional detailed descriptions of the geology and hydrology are available in earlier published reports (e.g., 300-FF-5 LFI [PNNL-16435], pp. 3.1 to 3.18; *Geology and Groundwater Quality Beneath the 300 Area, Hanford Site, Washington* [PNL-2949], pp. 4-1 to 4-12; and *Geology and Hydrology of the 300 Area and Vicinity, Hanford Site, South-Central Washington* [WHC-EP-0500], pp. 11 to 58). A detailed description of hydrostratigraphic

units as used in recent computer simulations of groundwater flow is presented in 300 Area 3-D Groundwater Models (*Three-Dimensional Groundwater Models of the 300 Area at the Hanford Site, Washington State* [PNNL-17708], pp. 2.1 to 2.13). The following brief descriptions of the various hydrogeologic intervals are modified from summary descriptions in *Volatile Organic Compound Investigation Results, 300 Area, Hanford Site, Washington* (hereinafter referred to as the 300 Area VOC Investigation Results [PNNL-17666], pp. 2.10 to 2.12) and the 300 Area RI/FS Work Plan (DOE/RL-2009-30, pp. 2.56 to 2.75), unless otherwise cited.

Surface Sediment. The most recently deposited sediment contains reworked Hanford formation sandy gravel, eolian silt and sand, and/or anthropogenic backfill of previously excavated sediment, coal plant ash waste, etc. These deposits overlie most of the 300 Area and their typical thickness falls in the approximate range of 1 to 6 m (3.3 to 19.7 ft). However, pavement and building foundations cover much of the 300 Area ground surface, so only a portion of the surface is available for infiltration of natural precipitation through surficial sediment. Evapotranspiration limits recharge that could mobilize and leach vadose zone contaminants to a fraction of the annual average precipitation rate.

Estimates for the annual average recharge rate for surficial sediment in the 300 Decision Area come from a site approximately 10 km (6.2 mi) northwest of the 300 Area and near the 618-10 Burial Ground subregion. A value of approximately 62 mm/yr (2.4 in/yr) for disturbed, unvegetated conditions has been reported for that site (*Compendium of Data for the Hanford Site (Fiscal Years 2004 to 2008) Applicable to Estimation of Recharge Rates* [PNNL-17841], pp. 4.1 to 4.11). Estimates at a second location at the northwest corner of the 300 Area (i.e., at the drill site for Well 699-S20-E10) suggest approximately 2 mm/yr (0.08 in/yr) for undisturbed, vegetated conditions (*Borehole Data Package for One CY 2005 CERCLA Well 699-S20-E10, 300-FF-5 Operable Unit, Hanford Site, Washington* [PNNL-15417], pp. 23 to 29). The difference in values for these two sites illustrates the importance of vegetative cover and the resulting evapotranspiration that occurs. Higher recharge rates may occur locally and episodically during periods of thunderstorms, rapid snowmelt, and discharges associated with facilities and activities (e.g., consolidated runoff from buildings and parking lots; water line breaks; application of dust suppression liquids; or irrigation).

Hanford Formation. The gravel-dominated sediment of the informally defined Hanford formation forms the remainder of the vadose zone and the upper portion of the unconfined aquifer. Cataclysmic flooding throughout the Pasco Basin during the Pleistocene epoch (approximately 1.8 million to 10,000 years before present) caused erosion into the Ringold Formation sediments at the 300 Area. These erosional channels and depressions were then filled with the much younger, coarse-grained sediment referred to as the Hanford formation.

This stratigraphic interval contains unconsolidated and clast-supported sediment, with pebble- to boulder-sized gravel, and a poorly sorted matrix of fine- to coarse-grained sand. Silt content varies and locally fills most or all matrices between gravel clasts. Occasionally, matrix is missing, which produces an open-framework fabric. The water table is situated within the gravelly, highly permeable sediment of the Hanford formation. The total thickness of the Hanford formation typically falls in the range of 13 to 19 m (42.6 to 62.3 ft) (see cross section Figures 3-17 to 3-22 in Section 3.4). An erosional unconformity representing a large time gap separates the Hanford formation from the underlying Ringold Formation.

Recent drilling for hydrogeologic characterization of the vadose zone and upper portion of the unconfined aquifer did not reveal easily distinguishable or readily mapped facies/hydrogeologic changes within this formation, at least within central 300 Area locations covered by the boreholes (300-FF-5 LFI [PNNL-16435]; 300 Area VOC Investigation Results [PNNL-17666]). Within the Hanford formation, there are isolated occurrences of older, reworked Ringold Formation sediment, which is distinguished by

its more cohesive sediment structure, color, and/or degree of sorting. The reworked Ringold Formation sediment also may contain zones with higher clay and silt content, and large rip-up clasts of Ringold sediment, up to 0.7 m (2.3 ft) in diameter, are occasionally encountered (*Sampling and Hydrogeology of the Vadose Zone Beneath the 300 Area Process Ponds* [PNNL-14834], pp. 4 to 8).

The saturated portion of the Hanford formation (i.e., portion below the water table) exhibits very high permeability compared to the underlying stratigraphic intervals, with hydraulic conductivity measured in many hundreds to thousands of meters per day (see Section 3.6.1.2 that follows). One implication of high permeability in the upper portion of the unconfined aquifer is that if contaminants from the vadose zone enter the aquifer, they are rapidly dispersed laterally before there is much opportunity to contaminate deeper intervals in the aquifer. However, because of the highly variable hydraulic gradients that result from river stage fluctuations, vertical mixing does occur to some extent, especially in the zone of groundwater/river water interaction near the river (see Section 3.6.4).

Most groundwater contamination is contained within the upper portion of the unconfined aquifer and within the saturated sediment of the Hanford formation. Figure 3-55, a "saturated thickness" contour map, illustrates the volume of groundwater within this interval. Note that the extent of this interval varies with the elevation of the water table. Groundwater from the upper portion of the unconfined aquifer ultimately discharges to the Columbia River. In addition, some groundwater is removed from this interval on a regular basis with a water supply well that serves PNNL's 331 Life Sciences Building (i.e., Well 399-4-12; see Section 3.7.1).

At the base of the interval of saturated Hanford formation sediment is a major erosional unconformity. Below the unconformity, either of two principal lithofacies within Ringold unit E may be present: a coarse gravel facies or a relatively finer-grained facies of silt and sand. Figure 3-56 shows the elevation contours for the contact between the Hanford and underlying Ringold formations, and which of the two lithofacies is present at the contact. The shapes of these contours clearly reveal paleochannels that have been carved into the Ringold sediment, resulting in preferential pathways for groundwater flow in saturated Hanford sediment.

Ringold Unit E: Coarse Gravel. The coarse gravel lithofacies of the Ringold Formation is composed of fluvial sediment that ranges from gravel to silty/sandy gravel, with a thickness in the range 11 to 16 m (36 to 52.5 ft). Compared to the overlying Hanford sediment, Ringold gravelly sediment contains fewer basalt fragments, greater consolidation (induration), more rounded and better sorted grains, increased amounts of silt and clay, color differences, and somewhat higher amounts of naturally occurring potassium-40. The chemistry of the groundwater in the two formations is also different, as revealed by lower specific conductance (electrical conductivity) in the Ringold sediment.

Saturated Ringold gravelly sediment is much less permeable than the overlying saturated Hanford formation sediment because of the greater consolidation of grains, cementation, and matrix material. The highest estimate for hydraulic conductivity in recent testing of the Ringold sediment indicated 39 m/d (128 ft/d), which is lower by at least an order of magnitude than the overlying Hanford sediment (see Section 3.6.1.2). While no tracer test results or plume-tracking data sets are available, movement in coarse Ringold sediment is expected to be slow compared to the overlying Hanford sediment, and probably significantly slower than 1 m/d (3.2 ft/d).

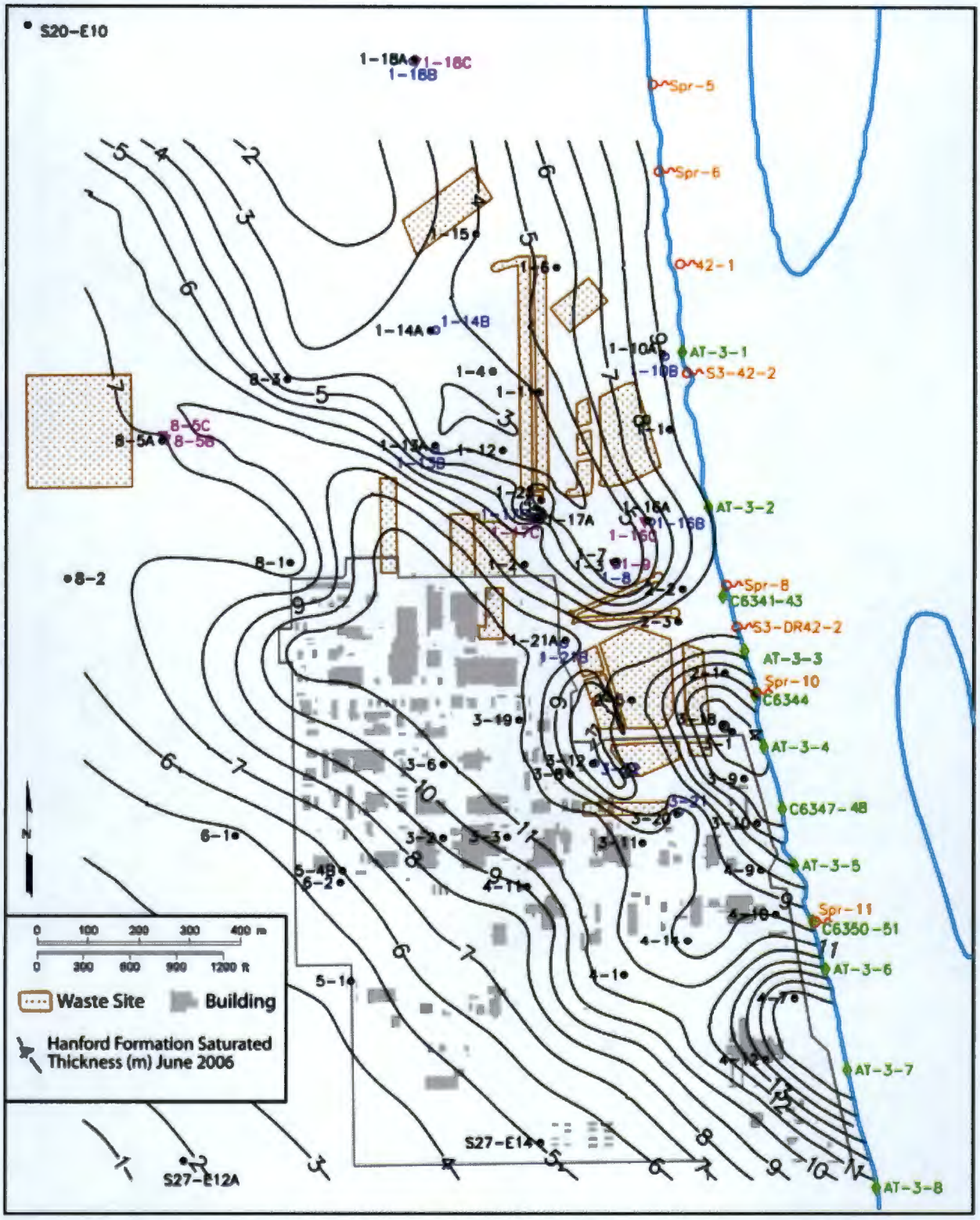
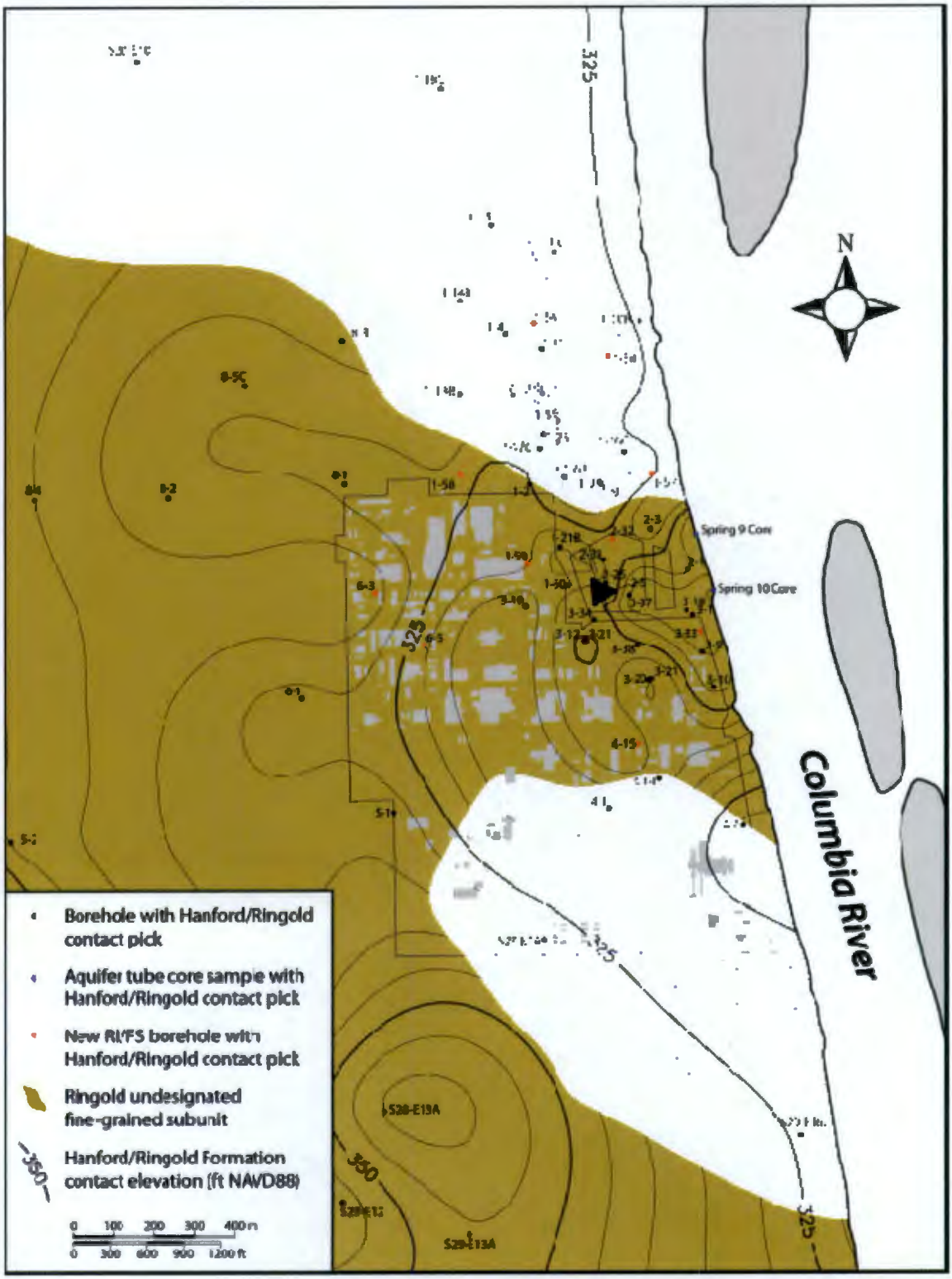


Figure 3-55. Contour Map Showing Thickness of Saturated Hanford Formation Sediment



Note: Brown shaded area shows where finer-grained Ringold sediment is present at the contact; white areas are sandy gravel.

Figure 3-56. Structure Contours Showing the Elevation of the Contact between the Hanford Formation and Underlying Ringold Formation

Ringold Unit E: Finer-Grained Interval. This interval of Ringold sediment contains lithofacies that are predominantly silt or fine-, medium-, and coarse-grained sand. Within this interval, grain size appears to increase with depth. During a recent characterization drilling program in the central portion of the 300 Area (300 Area VOC Investigation Results [PNNL-17666]), the finer-grained interval was encountered at or near the Hanford/Ringold contact and the various lithofacies were confirmed by grab and core samples. Where observed, the interval ranges in thickness from 4 to 10 m (23 to 32 ft).

Permeability is similar to or lower than the Ringold gravelly sediment (i.e., very low to moderate), with the highest value for hydraulic conductivity from recent testing estimated to be 41 m/d (134 ft/d). Some of the attempts to collect groundwater samples from this interval during characterization drilling were met with no water yield at all from the sediment. Groundwater movement through this interval is expected to be slow and significantly less than 1 m/d (3.2 ft/d). The interval is incised by the river channel, but groundwater discharge to the river would be small because of the low permeability of the sediment.

Ringold Formation Lower Mud Unit. The Ringold Formation lower mud unit underlies the Ringold Formation gravelly sediment. The lower mud unit contains silty clay to silty sand sediment, with very low permeability. The distinct, easily identified contact between Ringold unit E and the lower mud unit is the lower boundary of the unconfined aquifer system. In addition to clear sediment differences, the lower mud unit can be distinguished from the overlying sediment by a higher level of natural potassium-40 activity, as revealed by geophysical logging. The lower mud unit is an aquitard that separates the unconfined aquifer from deeper confined aquifers within the mud unit, and within the underlying Columbia River Basalt Group.

3.6.1.2 Hydraulic Properties for Hydrologic Units: 300 Area

Table 3-6 shows a summary of single well hydraulic test results from recently drilled characterization boreholes. A 3-D groundwater flow model report (300 Area 3-D Groundwater Models [PNNL-17708]) presents detailed descriptions of all available hydraulic tests for the 300 Area aquifers.

3.6.1.3 Groundwater Flow Patterns: 300 Area

Groundwater flow patterns for the upper portion of the unconfined aquifer beneath the 300 Area can be inferred from contours showing the elevation of the water table (flow direction is approximately perpendicular to the contours). In general, regional groundwater flow converges into the 300 Area from the northwest, west, and southwest, causing a generally southeasterly or easterly flow direction beneath the 300 Area (Figure 3-57). During the seasonal period of high Columbia River flow in the spring months, movement beneath the 300 Area becomes more southerly, and during the seasonal period of low Columbia River flow, movement becomes more easterly. 300 Area 3-D Groundwater Models (PNNL-17708) presents detailed descriptions of seasonal variability, as revealed by 3-D computer simulation of groundwater flow.

The rate of movement for groundwater plumes can be relatively high, with a recent tracer test revealing a rate as high as 15 m/d (49 ft/d) (*300 Area Uranium Stabilization Through Polyphosphate Injection: Final Report* [PNNL-18529], pp. 3.41 to 3.50). Several historical contaminant release events have been tracked from their presumed source locations along the downgradient flow path, which also indicates similar relatively high rates for plume movement, with movement of a PCE release reaching an estimated 18 m (59 ft)/d (300 Area VOC Investigation Results [PNNL-17666], p. 3.2). Actual groundwater flow velocities within the aquifer can be even higher than the net movement rate revealed by tracking tracers and plumes. This is because plume movement may include a "back and forth" component caused by changes in Columbia River stage fluctuations and resulting shifts in the orientation of hydraulic gradients.

Table 3-6. Hydraulic Conductivity Estimates from Recent Drilling, 300 Area

Stratigraphic Formation	Vertical Sequence of Lithofacies Encountered (Typical)	300-FF-5 LFI (PNNL-16435)			300 Area VOC Investigation Results (PNNL-17666)			
		399-3-18	399-3-19	399-3-20	399-3-21	399-2-5	399-4-14	399-3-22
Hanford	Sandy gravel		≥2,000	>2,000	568	≥300	≥300	≥400
Hanford	Sandy gravel		2,200		No result			
Ringold	Muddy sandy gravel							
Ringold	Mud							
Ringold	Muddy sand							
Ringold	Sandy mud							
Ringold	Fine sand	0.04						
Ringold	Fine-medium sand	0.36		21.7	1.04			0.61
Ringold	Medium-coarse sand	No result		41.2	No result	1.73	No result	
Ringold	Coarse sand							
Ringold	Silty sandy gravel				0.27		2.85	
Ringold	Silty sandy gravel				0.34			
Ringold	Silty sandy gravel	38.9			2.03		1.12	1.51
Ringold	Silty sandy gravel	3.82			1.47	≥ 0.01		No result
Ringold	Clayey silt	Aquitard						

Sources:

PNNL-16435, *Limited Field Investigation Report for Uranium Contamination in the 300-FF-5 Operable Unit at the 300 Area, Hanford Site, Washington.*

PNNL-17439, *300 Area VOC Program Slug Test Characterization Results for Selected Test/Depth Intervals for Wells 399-2-5, 399-3-22, and 399-4-14.*

PNNL-17666, *Volatile Organic Compound Investigation Results, 300 Area, Hanford Site, Washington.*

SGW-36424, *Borehole Summary Report for 300-FF-5 Operable Unit TCE Characterization Monitoring Wells C5575, C5706, C5707, and C5708.*

Note: Hydraulic conductivity values (K_h) in meters per day, as measured using slug tests in individual boreholes. Shading indicates finer-grained interval of concern for VOC contamination.

LFI = limited field investigation

VOC = volatile organic compound

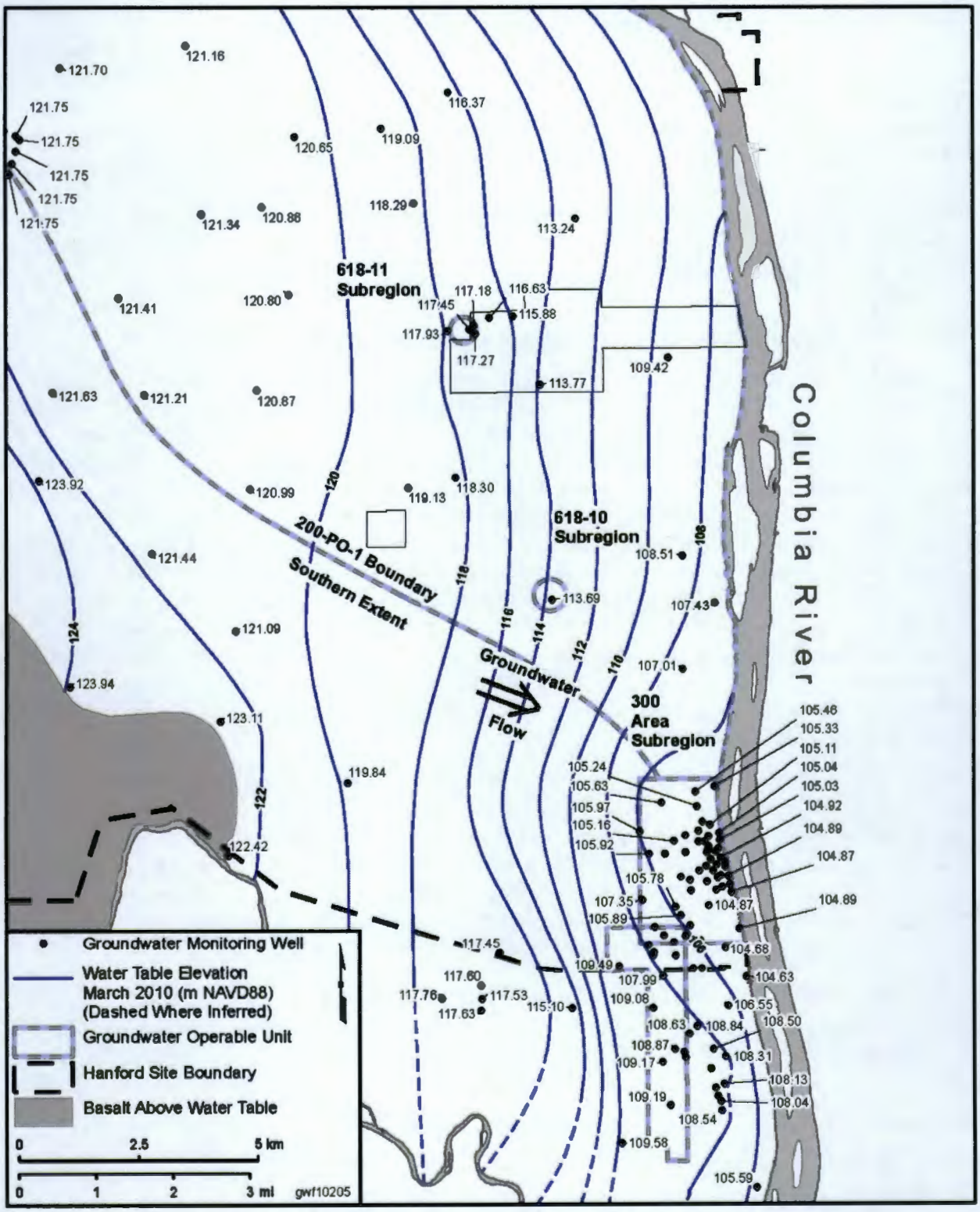


Figure 3-57. Water Table Elevation Contours for the 300 Area: Average Conditions

At the 300 Area, Columbia River stage fluctuations create dynamic hydrologic conditions in the unconfined aquifer. Hydraulic gradients change rapidly in steepness and orientation as the river stage fluctuates on daily, weekly, seasonal, and multiyear cycles (300 Area 3-D Groundwater Models [PNNL-17708], pp. 2.14 to 2.32). The water table currently moves up and down through a range of several meters, creating a subsurface zone that is alternately saturated and unsaturated with groundwater, some of which contains contamination. Complicating the scene even further uranium interacts with sediment, thus forming a zone where contamination is potentially sequestered and slowed in its ultimate transport to the river (*Uranium Contamination in the Subsurface Beneath the 300 Area, Hanford Site, Washington* [PNNL-17034], pp. 3.4 to 3.15; "Building Conceptual Models of Field-Scale Uranium Reactive Transport in a Dynamic Vadose Zone-Aquifer-River System" [Yabusaki et al., 2008], pp. 21 to 23).

3.6.1.4 Geochemical Characteristics of the Unconfined Aquifer: 300 Area

Groundwater in the unconfined aquifer can be described in general terms as a calcium-bicarbonate type groundwater (*Hydrologic Studies Within the Columbia Plateau, Washington: An Integration of Current Knowledge* [RHO-BWI-ST-5], pp. III-78 to III-83). However, considerable variability in the chemical and physical parameters associated with groundwater in the various hydrologic units of interest to this RI/FS exists. For example, the specific conductance of groundwater in saturated Hanford sediment is higher than in the underlying Ringold sediment (specific conductance is a measure of dissolved salts). Dissolved oxygen is higher in saturated Hanford sediment as compared to deeper intervals. Table 3-7 illustrates some of the principal differences in the geochemical characteristics of the various hydrologic units. Plots showing the various proportions of major cations and anions have been used to characterize the different hydrologic units in the 300 Area (300-FF-5 LFI [PNNL-16435], pp. 4.1 to 4.4). Figure 3-58 presents an example, based on sampling that occurred during characterization drilling at Well 399-3-18. The shapes of the "Stiff" diagrams for the various intervals reveal the differences in water chemistry, which reflects the composition of the sediments and their depositional history, among other potential factors such as contamination.

Changes in geochemical environment in saturated Hanford formation sediment are most pronounced near the Columbia River, where river water intrudes into the aquifer. River water is lower in bicarbonate content than groundwater, resulting in lower ionic strength, which can influence the transport of certain contaminants (see Chapter 5). (Note: Lower bicarbonate content enhances the tendency for uranium to adsorb onto sediment. The magnitude of this exchange and the significance regarding persistence of the plume are not clearly defined. Research activities being conducted under the Integrated Field-Scale Research Challenge Project will contribute to improved understanding.)

3.6.1.5 Groundwater and Columbia River Water Systems: 300 Area

Section 3.3.2 described the basic features and processes associated with the relationship between the unconfined aquifer and the Columbia River at the Site. Hydraulic aspects that are most significant at the 300 Area are as follows:

- Pressure wave propagation because of fluctuating river stage
- Intrusion of river water into the aquifer
- Preferential pathways for groundwater discharge to the river
- Layering or mixing of river water in the aquifer

Table 3-7. Summary of Chemical and Physical Parameters for Hydrologic Units, 300 Area

Well Name	Alkalinity (mg/L)	Dissolved Oxygen (mg/L)	Nitrate (mg/L)	pH	Specific Conductance (µS/cm)	Sulfate (mg/L)	Temperature (°C)	Uranium (µg/L)
Upper portion of unconfined aquifer, including the water table (saturated Hanford gravels):								
399-1-10A	125	9.2	24.7	7.6	428	54.7	16.6	35
399-1-16A	122	9.1	23.7	7.4	422	53.1	16.6	58
399-1-7	130	9.1	27.3	7.4	476	58.1	17.0	79
399-3-20	129	9.0	24.0	7.5	454	52.3	17.8	56
399-1-17A	129	9.3	26.1	7.4	484	58.0	17.1	70
399-1-21A	125	9.3	22.9	7.5	449	49.5	16.8	28
399-3-12	125	9.8	25.3	7.5	443	46.3	17.7	41
399-1-18A	130	9.7	27.1	7.9	474	60.5	16.9	6
Upper portion of unconfined aquifer, finer-grained interval, TCE contamination (Ringold Formation Unit E):								
399-3-18 (2)[1]	---	5.1	---	7.8	363	---	19.0	---
399-3-18 (3)[1]	---	4.7	---	8.0	213	---	15.9	---
399-3-18 (4)[1]	---	6.1 - 7.0	---	8.3 - 8.4	158 - 164	---	16.7 - 17.4	---
399-3-20 (4)[1]	---	0.7 - 2.1	---	7.6 - 7.9	276 - 285	---	19.6 - 21.2	---
399-3-21 (2)[2]	110	1.1	7.8	7.9	303	27.1	18.6	1
399-3-21 (3)[2]	140	2.9	U	8.1	295	1.7	16.6	0
Lower portion of unconfined aquifer (Ringold Formation Unit E):								
399-1-10B	158	1.3	U	7.8	315	U	16.3	0
399-1-16B	126	0.7	1.3	8.0	325	23.7	16.4	11
399-1-8	152	0.4	1.2	7.4	312	3.1	17.4	3
399-3-21	160	0.4	0.3	8.0	373	11.3	16.9	0
399-1-17B	174	0.4	U	7.8	358	U	17.1	U
399-1-21B	152	1.6	0.2	8.1	295	U	17.2	0
399-3-22	176	0.0	U	7.9	372	7.7	17.4	0
399-1-18B	183	0.3	0.2	7.7	372	U	17.0	0
Uppermost confined aquifer (Ringold Formation lower mud unit):								
399-1-16C	183	0.6	U	8.1	375	U	15.6	U
399-1-9	187	4.2	U	8.1	367	U	15.9	1
399-1-17C	187	0.0	0.1	8.3	386	U	16.3	0
399-1-18C	153	0.0	U	7.0	329	U	16.2	0
Columbia River[3], nearshore samples:								
300 Area shore	---	---	1.3	8.3	146	9.7	22.5	1

Table production notes

Wells: HEIS query using DaVE for period 1/1/2008 to 12/21/2010; summary statistics using DaVE

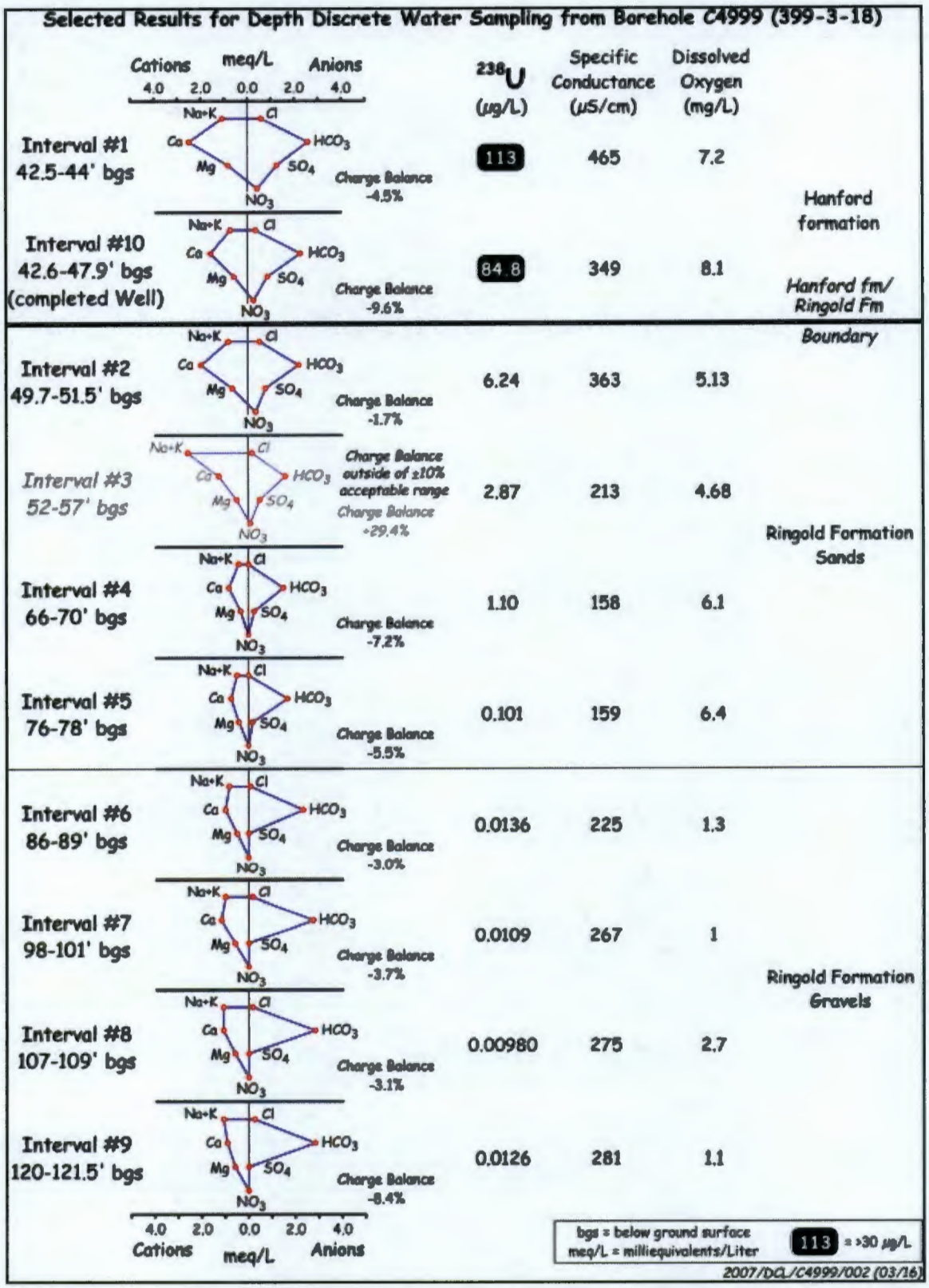
Columbia River: HEIS query 12/22/10 for nearshore samples; samples collected August/September

U = nondetect; " --- " = no measurement

[1] Additional sample information in PNNL-16435; (#) indicates drilling interval

[2] Additional sample information in PNNL-17666; (#) indicates drilling interval

[3] Nitrate as nitrogen converted using 4.4268 multiplier; U-238 in pCi/L converted to U in µg/L using 2.97 multiplier



Source: PNNL-16435, *Limited Field Investigation Report for Uranium Contamination in the 300-FF-5 Operable Unit at the 300 Area, Hanford Site, Washington.*

Figure 3-58. Stiff Chemistry Diagrams for Groundwater Samples from Characterization Borehole 399-3-18

Pressure Wave Propagation. The Columbia River stage at the 300 Area is monitored at gauging station SWS-1, located at the water intake structure approximately east of the former 338 Building. The river stage fluctuates with daily, weekly, seasonal, and multiyear cycles (see Figure 3-6). As the river rises, pressure also increases in the aquifer beneath the 300 Area, causing the water table to move upward; when the river falls, the water table also moves back downward. The water table also rises because of a lessening or actual reversal of the hydraulic gradient between the aquifer and the river. Differences in the permeability of the sediment in the unconfined aquifer cause variations in the rate and extent of the response to stage changes at different monitoring well locations. Figure 3-59 shows water levels in three wells that are located at increasing distance inland from the river. The apparent lack of a clear separation of elevations among the wells indicates that the water table rises a similar amount throughout the 300 Area in response to a rise in river stage. Closer inspection does suggest typically higher elevations at wells near the river during periods of high river stage, which promotes intrusion of river water into the aquifer.

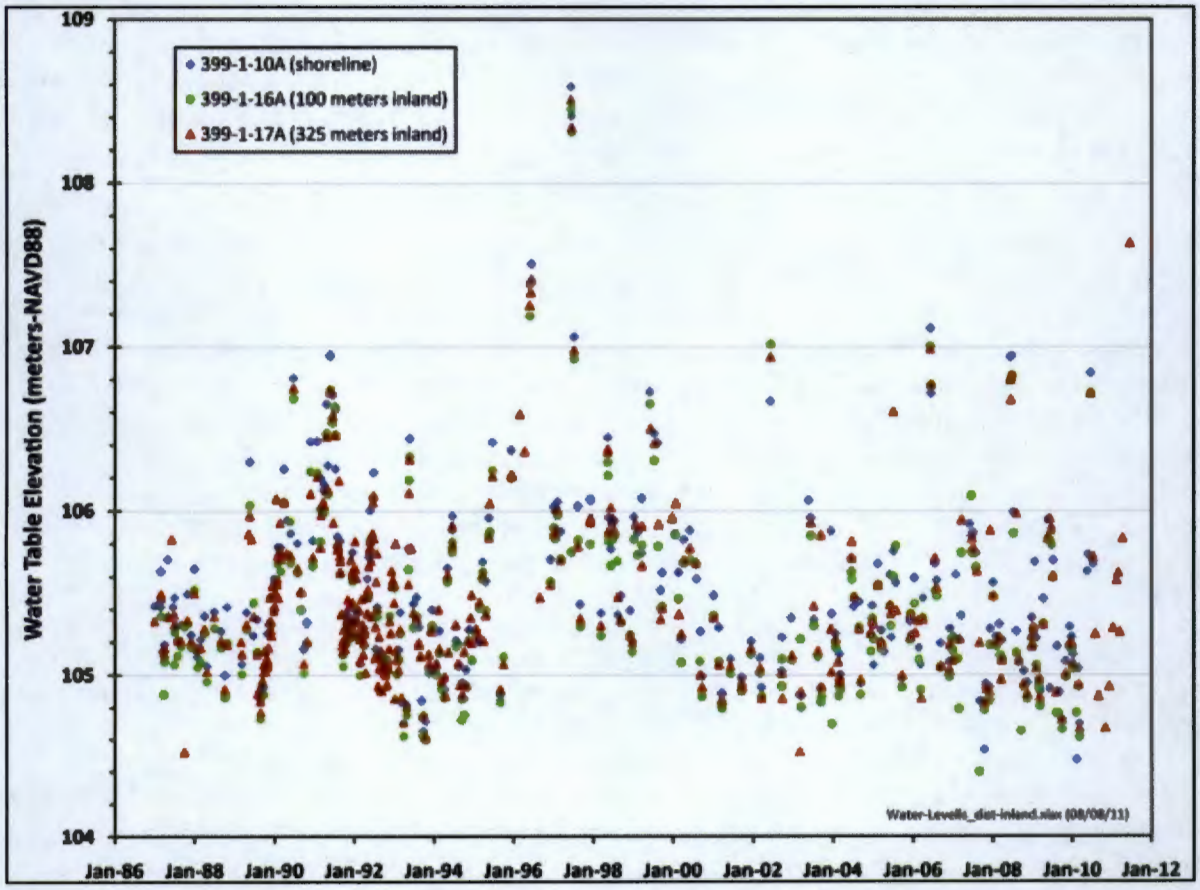


Figure 3-59. Hydrographs Illustrating the Propagation of the Pressure Wave Created by Columbia River Stage Fluctuations

The cyclic pressure waves created by river stage fluctuations are superimposed on artificial changes in hydraulic head during aquifer testing, which is done to determine aquifer hydraulic properties for computer simulation of groundwater flow and other activities. Recent research has resulted in a method to remove the influence of the fluctuating river stage during aquifer tests, so that interpretation of the artificially induced changes becomes more reliable ("Removal of River-Stage Fluctuations from Well Response Using Multiple Regression" [Spane and Mackley, 2010]). A guide to using the method

developed is available in the *Guide to Using Multiple Regression in Excel (MRCX v.1.1) for Removal of River Stage Effects from Well Water Levels* (PNNL-19775).

The hydraulic characteristics in the zone through which the water table fluctuates play a significant role in the transport of some contaminants, notably uranium. Knowledge of these characteristics is necessary to construct conceptual model(s) and computer simulations of groundwater movement and contaminant transport between the overlying vadose zone and underlying aquifer. The zone through which the water table fluctuates is referred to as the periodically rewetted zone (PRZ), because of the alternating saturated and unsaturated conditions.

Intrusion of River Water. In addition to causing a rise in water table elevation, high river stage conditions also promote the intrusion of river water into the unconfined aquifer. Depending on a variety of factors (e.g., sediment texture; height of river stage; duration of high stage), river water may flow in laterally along the water table and/or may mix with approaching groundwater. One method used to characterize the degree of intrusion uses specific conductance to differentiate groundwater from river water. In saturated Hanford formation sediment beneath the 300 Area, specific conductance is typically approximately 475 μS/cm; the free-flowing stream of the river is about 135 μS/cm. Therefore, if a groundwater sample from a well shows a specific conductance of less than approximately 475 μS/cm, there is a good chance that river water has intruded at the well. Figure 3-60 illustrates the extent to which river water can be inferred as intruding, using specific conductance of groundwater samples as the guide.

Preferential Pathways for Groundwater Discharge. Field sampling activities were conducted in 2008 through 2010 in support of an RI of Hanford Site releases to the Columbia River (Columbia River RI Report [WCH-380]). The study used a device known as the Trident Probe to measure specific conductance and temperature of pore water (Section 2.1.7). Because groundwater has higher specific conductance than surface water and is warmer than surface water in winter, the data could be used to map areas of groundwater upwelling (discharge) during periods of low river stage. Relatively large temperature differences are considered indicative of relatively high groundwater discharge volumes. Specific conductance of porewater was found to decrease when the river stage increased, indicating less groundwater discharge during periods of moderate to high river stage. Evidence of groundwater upwelling was most notable along the 300 Area shoreline and across the river on the east bank of the Columbia River (Figure 2-7).

At the 300 Area, the channel incises the several stratigraphic intervals of interest within the unconfined aquifer system. The most contaminated interval (i.e., the saturated sediment of the Hanford formation) is completely incised by the channel, so groundwater discharge from that sediment is potentially exposed over a broad area of riverbed on the Hanford Site side of the thalweg (deepest part of the channel). This area of potential exposure has been estimated at approximately 0.17 km^2 (0.06 mi^2) (Figure 3-61; "Effect of Rapidly Changing River Stage on Uranium Flux through the Hyporheic Zone" [Fritz and Arntzen, 2007]). In some areas, a layer of recent alluvium covers the area of potential exposure. Where the riverbed alluvium consists of coarse grained sediment (gravel, cobbles, boulders), river water is entrained in the pore space.

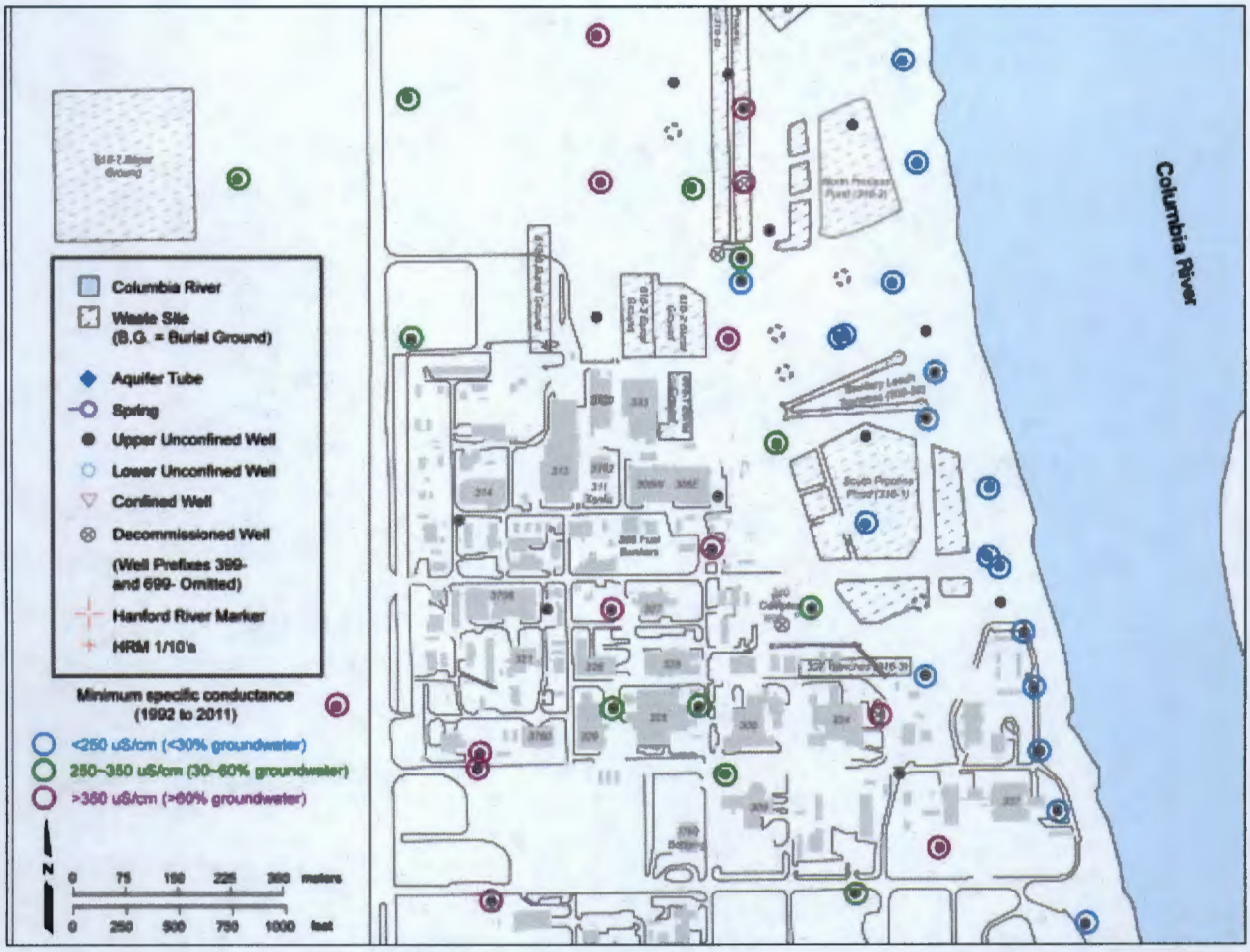
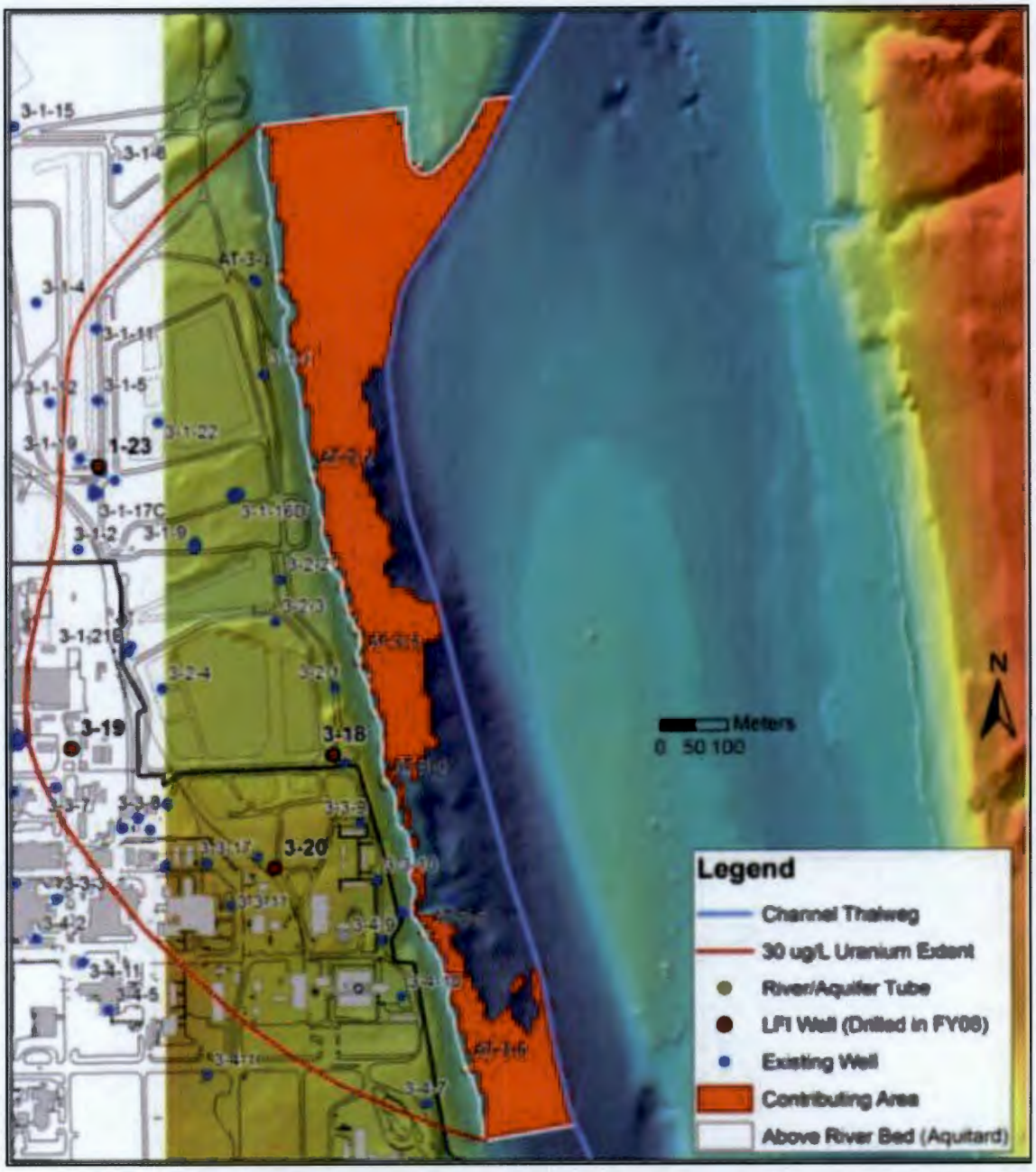


Figure 3-60. Map Showing the Potential Inland Extent of River Water Intrusion, as Indicated by Specific Conductance Fluctuations at Monitoring Wells

Sites of potential exposure of contaminants carried by groundwater include the riverbed substrate and riverbank springs that appear during periods of low river stage. Springs regularly appear at several locations along the 300 Area shoreline, and more have been documented to appear on an intermittent basis at additional locations along the entire 300 Decision Area shoreline (*Investigation of Ground-Water Seepage from the Hanford Shoreline of the Columbia River* [PNL-5289], pp. A.1 to A.6; *1988 Hanford Riverbank Springs Characterization Report* [PNL-7500], pp. 24 to 27; *Sampling and Analysis of the 300-FF-5 Operable Unit Springs and Near Shore Sediments and River Water* [WHC-SD-EN-TI-125], pp. A.1 to A.3; *Survey of Radiological and Chemical Contaminants in the Near-Shore Environment at the Hanford Site 300 Area* [PNNL-13692], pp. 3.2 to 3.5). Riverbank springs, along with sediment at the spring and near-shore river water, are monitored under DOE's Public Safety and Resource Protection Program (*Environmental Monitoring Plan United States Department of Energy Richland Operations Office* [DOE/RL-91-50], pp. IIIA-14 to IIIA-20). The results of this monitoring are reported annually in the Hanford Site Environmental Report (e.g., 2009 Sitewide Environmental Report [PNNL-19455], pp. 8.45 to 8.52).



Source: "Effect of Rapidly Changing River Stage on Uranium Flux through the Hyporheic Zone" (Fritz and Arntzen, 2007).

Figure 3-61. Map Showing Areas of Preferential Groundwater Discharge from the Saturated Hanford Formation Hydrologic Unit

A research project to investigate groundwater discharge through the riverbed adjacent to the 300 Area began in 2008 and involved geophysical surveys of the channel, which helped to reveal the exposure extent of the various stratigraphic intervals, and the installation of fiber optics cables on the riverbed. These cables recorded temperature along their length (which extend to 1 km [0.62 mi]) and have the capability to reveal areas of preferential groundwater discharge, as indicated by temperature anomalies. Results of this effort are described in *Use of Electrical Imaging and Distributed Temperature Sensing*

Methods to Characterize Surface Water—Groundwater Exchange Regulating Uranium Transport at the Hanford 300 Area, Washington (Slater et al., 2010).

Groundwater/River Water Interaction. The hyporheic zone in proximity to the Columbia River at the 300 Area is dynamic in terms of highly variable hydraulic gradients and groundwater geochemistry. Daily, weekly, seasonal, and multi-year cycles in river stage fluctuations are the principal drivers for these dynamic conditions.

Two phenomena are possible when river water intrudes into the aquifer during periods of high river stage: layering of river water over groundwater at the water table, and mixing between the intruding river water and groundwater because of rapid changes in hydraulic gradients as the river stage rises and falls. The groundwater monitoring program reveals evidence for both phenomena. Wells are typically purged of up to three borehole volumes prior to sampling, so the water that returns to the well following purging comes from the most transmissive interval(s) covered by the screen. Layering, if present, is likely to be "homogenized" during the purging process. In spite of this, it is possible to infer the degree of contaminant dilution that may be occurring at near-river locations, using the specific conductance of the sample as an indicator.

The subsurface zone beneath the river shoreline where groundwater and river water meet is also dynamic with respect to geochemical environment, which varies in response to short- and long-term seasonal variations in Columbia River flow. While simple mixing between groundwater and river water reduces the concentrations of any contamination that may be present, there are additional considerations for contaminants that do not remain fully dissolved in the face of a changing geochemical environment. Uranium in the aquifer beneath the 300 Area is an example.

The principal impact of river water intruding into the unconfined aquifer beneath or near to the river is simple dilution when the two water types mix. This mixing zone has been the subject of research to investigate the fate and transport of uranium beneath the 300 Area shoreline (Yabusaki et al., 2008). Using a hypothetical tracer to mimic river water, Yabusaki et al. (2008) simulated the expansion and contraction of the mixing zone during a seasonal cycle of the river. The scale of their simulated mixing zone is comparable to the distances of inland extent of river water influence shown in Figure 3-60.

3.6.2 Hydrogeology beneath the 400 Area

The 400 Area is situated in the west central portion of the 300 Decision Area. The 400 Area contains the FFTF and the FMEF. The hydrogeology beneath the 400 Area facilities is described in a report prepared in 1991 to evaluate the potential impacts on groundwater caused by waste disposal at the 400 Area Ponds (*Groundwater Impact Assessment Report for the 400 Area Ponds* [WHC-EP-0587], pp. 28 to 37). Figure 3-48 is a cross section oriented south to north across the 400 Area that illustrates the principal stratigraphic features associated with the unconfined aquifer. The following summary description is from *Groundwater Impact Assessment Report for the 400 Area Ponds* (WHC-EP-0587), unless otherwise cited.

The stratigraphic and hydrologic units of interest beneath the 400 Area are similar to those described in detail above for the 300 Area, with the exception of the characteristics for Hanford formation sediments. At the ground surface, windblown deposits of fine- to medium-grained sand are present as stabilized dunes where not modified by human activities. The surficial deposits overlie sandy sediments of the Hanford formation that are referred to as the Touchet Beds. These deposits represent a less energetic depositional environment than the coarse-grained, open framework gravelly deposits in the 300 Area. Characteristic features of these dense sands include clastic dikes, which are vertical structures that range in width from several inches to several feet. Their origin is related to the formation of large lakes during periods that alternated with cataclysmic flooding of the Pasco Basin (depositional features associated with

Ice Age floods are described in A Geological Field Guide to the Mid-Columbia Basin [Bjornstad, 2006]). The current water table resides near the base of the Hanford formation or in the upper portion of gravelly sediments, whose origin is the underlying Ringold Formation.

The unconfined aquifer system near the 400 Area probably includes all the saturated sediments that lie above the Ringold Formation lower mud unit, as defined in *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington* (BHI-00184), at Well 699-2-6A (located near Well 699-2-7). However, local areas of confined or semiconfined conditions may exist. The thickness of the unconfined aquifer is approximately 100 m (325 ft). Groundwater flow direction at the water table is generally toward the southeast.

3.6.3 Hydrogeology beneath the 618-11 Burial Ground Subregion

The hydrogeology near the 618-11 Burial Ground is described as part of an evaluation of the transport and fate of the H-3 plume whose origin involves a release from the burial ground (*Evaluation of the Fate and Transport of Tritium Contaminated Groundwater from the 618-11 Burial Ground* [PNNL-15293], pp. 4.1 to 4.13). An additional gravelly interval referred to as the Cold Creek unit lies between the Hanford formation and underlying Ringold unit E sediments in some areas near this burial ground. The Cold Creek unit is less permeable than the Hanford sediment, but more permeable than the Ringold sediment. The movement of the tritium plume whose origin is the burial ground appears to be closely related to the lateral variability in aquifer permeability. Figure 3-50 illustrates the stratigraphic units and coverage by monitoring wells. Figure 3-51 provides a location map for monitoring wells.

3.6.4 Hydrogeology beneath the 618-10 Burial Ground/316-4 Cribs Subregion

The most recent information on the hydrogeology near the 618-10 Burial Ground and former 316-4 Crib comes from drilling associated with two monitoring wells in 2003. The new wells were drilled to characterize the vadose zone near the two waste sites with regard to radiological contamination (none found), develop a preliminary hydrogeologic model for the subregion, and expand the groundwater monitoring capability. Figure 3-52 is an index map for monitoring wells at this subregion.

The land surface in this subregion is similar to most of the inland regions of the 300 Decision Area, in that it consists of stabilized windblown deposits, except where modified by human activities. The origin for the sand is weathering of the uppermost geologic formation (i.e., Hanford formation sediment) which forms the vadose zone beneath this subregion. The vadose zone sediment is primarily loosely consolidated sand and gravel. Geologists' descriptions of the stratigraphy encountered and geophysical logs for the two drill sites are presented in *Soil Gas Survey and Well Installations at the 618-10 Burial Ground, 300-FF-5 Operable Unit* (PNNL-14320). These two boreholes did not extend downward to penetrate the entire unconfined aquifer. The water table lies in the uppermost portion of the Ringold Formation unit E (i.e., just below the contact with the overlying Hanford formation). Each new monitoring well was completed with a screened interval intended to monitor the uppermost portion of the unconfined aquifer.

3.7 Artificial Water Systems

3.7.1 300 Area Water Distribution System

The city of Richland has supplied all potable water to the 300 Area since 1998. The potable water system is used primarily for fire suppression, demolition construction activities, dust control, and domestic activities (i.e., bathrooms, showers, and drinking fountains). The existing water supply from the city of Richland to the 300 Area consists of two 41 cm (16 in.) mains feeding a pressure boosting and water distribution facility identified as the 385 Booster Station. The 385 Booster Station boosts the water

pressure from the city of Richland's 345 to 414 kPa (50 to 60 psi) supply pressure to approximately 793 kPa (115 psi) and distributes the water through looped underground piping systems throughout the 300 Area for potable (domestic) requirements as well as fire protection and process water uses.

In addition, some water is pumped directly from the Columbia River by 312 Facility 3,785 L/min (1,000 gal/min) 60 hp electrical biological pump to provide raw water to PNNL's Life Sciences Building (331 Building) at the 300 Area. Well 399-4-12 supplies the remainder of the raw water used in the 331 Building, as described in Section 3.7.2.

3.7.2 Water Supply Well 399-4-12

Well 399-4-12 (A8089) was completed in December 1980 as a water supply well for fisheries research activities being conducted in PNNL's Life Sciences Building (331 Building) at the 300 Area. The well is located adjacent to the building on its south side. The well consists of a 30 cm (12 in.) carbon steel casing that is perforated between 15 and 21 m (49 and 69 ft) bgs. Water is removed using a high volume electric submersible pump. Very little information was collected during drilling, with only a driller's log being kept (i.e., there are no geological or geophysical logs available for the borehole). However, based on conditions observed at nearby drill sites and the ability of the well to produce water, it is apparent that the perforated interval is positioned in Hanford formation sediment.

Anecdotal information (C.S. Abernethy, personal communication, around 2004) indicates that the well was put in service sometime in 1982. Initial testing of the well produced up to 3,028 L/min (800 gal/min) with a drawdown of 2.54 cm (1 in.). Handwritten records containing analytical results for groundwater from the well show a sampling date of October 1, 1982. Withdrawal rate at the time was approximately 1,514 L/min (400 gal/min) and total dissolved uranium was measured as 53 µg/L. By design, groundwater from the well is mixed with Columbia River water before supplying aquariums in the building, with discharge from the aquariums returned to the river via an outfall. The outfall was originally a permitted National Pollutant Discharge Elimination System (NPDES) discharge, but that requirement was dropped and the return flow now is overland into the river. The return flow at the river is monitored under the SESP (Sample ID is 22768; Site Name is "300 Area Outfall 13"; common name for the flow is "Abernethy Creek"). The 331 Building aquaculture facility staff, who monitor the discharge semi annually for TCE and uranium, also monitor the return flow.

Water quality at the well has been monitored quarterly in the past, and is currently monitored semi annually under *300-FF-5 Operable Unit Sampling and Analysis Plan* (DOE/RL-2002-11). Constituents monitored include major anions, cations, gross alpha, and gross beta, along with COPCs uranium and VOCs. Figure 3-62 illustrates the rate of groundwater withdrawn from the well since 2003 and the concentration of uranium in that water. During the past several years, a typical withdrawal rate is 795 L/min (210 gal/min) and a typical uranium concentration is 22 µg/L. These values equate to removing uranium at a rate of about 9.2 kg/yr (20 lb/yr) from the aquifer. The rate at which aquarium water discharges from the building is also shown on the figure ("Outfall 013A").

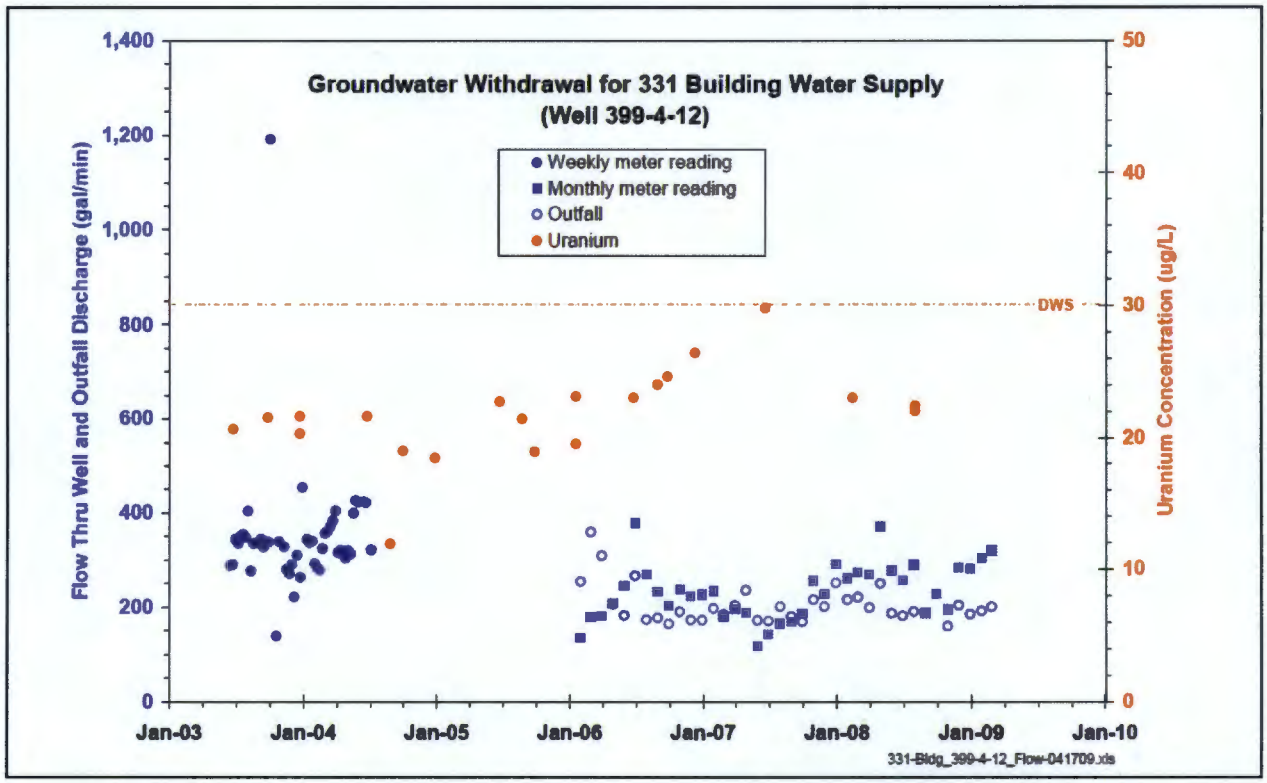


Figure 3-62. Groundwater Withdrawal at the PNNL Life Sciences Building (331 Building)

3.8 Demography and Land Use

A detailed discussion of the distribution of the population surrounding the Site, including adjacent counties and cities is presented in the NEPA Characterization Report (PNNL-6415). The 2009 population estimate from the U.S. Census Bureau was that 47,530 people lived in the city of Richland, the closest population center to the Site. An estimated 58,650 people lived in Pasco and 67,810 people lived in Kennewick. Native American descendants living in the region around the site include members of the following federally recognized groups: the Confederated Tribes and Bands of the Yakama Nations, the Confederated Tribes of the Umatilla Indian Reservation, the Nez Perce Tribe, and the Confederated Tribes of the Colville Reservation. No human population is currently living at the Site.

The local economy is driven by three major sectors: DOE and its contractors operating the Site, Energy Northwest (formerly the Washington Public Power Supply System) in operation of a nuclear power plant, and the agricultural community, including a substantial food processing component. Additional employment sectors driving the local economy and future land uses include "other major employers," such as non-DOE contractor employers in the region, tourism, and healthcare.

Through the NEPA process, DOE worked for seven years during the 1990s to evaluate future land use alternatives. Congress specifically directed completion of the Hanford Site land-use plan in the *National Defense Authorization Act for Fiscal Year 1997*. This process was conducted in coordination with nine cooperating agencies and consulting Tribal governments, including the U.S. Department of the Interior (Bureau of Land Management, Bureau of Reclamation, and the USFWS); the city of Richland; Benton, Franklin, and Grant Counties; the Nez Perce Tribe; and the Confederated Tribes of the Umatilla Indian Reservation. Although not a cooperating agency, the Yakama Nation participated at points throughout the impact statement (EIS) process. This effort resulted in the Hanford CLUP (DOE/EIS-0222-F) that DOE

adopted and implemented in 64 FR 61615, "Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS)." The intent of the Hanford CLUP (DOE/EIS-0222-F) is to provide a land-use plan for DOE's Hanford Site for at least the next 50-year planning period and lasting as long as DOE retains legal control of some portion of the real estate (CLUP: Supplemental Analysis [DOE/EIS-0222-SA-01]). An amendment to this ROD clarifying the plan's implementing procedures (73 FR 55824, "Amended Record of Decision for the Hanford Comprehensive Land-Use Plan Environmental Impact Statement") was issued in September 2008. The Hanford CLUP (DOE/EIS-0222-F) and CLUP: Supplemental Analysis (DOE/EIS-0222-SA-01) present a land-use map, the full set of nine land-use designations that define the permissible uses for each area of the site, and the implementing procedures that govern the review and approval of future land uses. The general objectives for groundwater and vadose zone cleanup are consistent with the intended use of the land. In 2000, a Presidential Proclamation (65 FR 37253, "Establishment of the Hanford Reach National Monument") under authority of the *American Antiquities Act of 1906* created the HRNM, setting aside half of the Hanford Site, including land adjacent to the Columbia River north of the 300 Area, for the preservation of natural and cultural resources.

These documents established long-term goals for the use of the Site. The reasonably anticipated future land use for the 300 Area is industrial. Table 3-8 presents the current and potential land uses for the 300, 400, and 600 Areas. Figure 3-63 presents the 300 Area land-use designations including the HRNM. While most of these areas will be designated industrial, a small parcel located north of the 300 Area will be designated as conservation.

Table 3-8. Current and Reasonably Anticipated Future Land Use

Zone	Current Land Use	Reasonably Anticipated Future Land Use
Near Field	Industrial	Industrial-Exclusive
Far Field	Industrial for the next 150 years or other negotiated time	Conservation (mining) reserved for management and protection of archaeological, cultural, ecological, and natural resources

Source: 64 FR 61615, "Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS)."

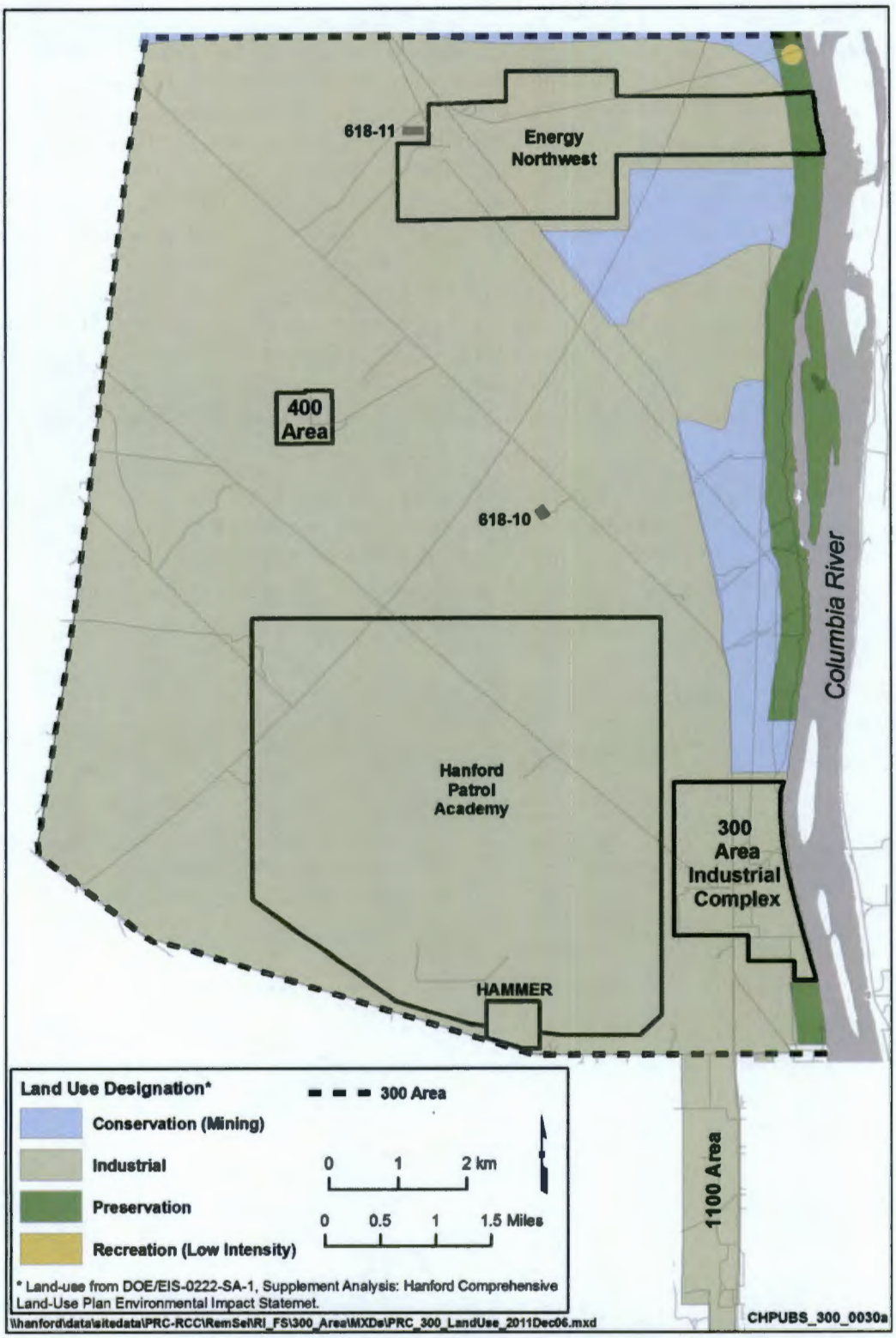


Figure 3-63. Hanford Site, Showing Land-Use Designations including the HRNM

The stretch of the Columbia River flowing through the Site is referred to as the Hanford Reach. It is a free-flowing stretch of the Columbia River. The river, islands, gravel bars, sloughs, riparian areas, and dune field of the Hanford Reach provide a variety of habitats that are now rare along the Columbia River due to the extensive reservoir system, development, and agriculture. Since 1943, DOE (or its predecessor federal entities) has held title to the lands that make up the Hanford Reach. Administration of this unit is multi-jurisdictional and complex, with the USFWS, Bureau of Land Management, DOE, and various state and local agencies each playing specific roles.

The USFWS manages most of the HRNM through a Permit and Memorandum of Understanding granted by DOE in 2001. The portion of HRNM lands that are managed by the USFWS are included in the *Hanford Reach National Monument: Final Comprehensive Conservation Plan and Environmental Impact Statement Adams, Benton, Grant and Franklin Counties, Washington* (USFWS, 2008). The remaining HRNM lands that are managed by DOE are undergoing or supporting environmental cleanup. In a memorandum (*Hanford Reach National Monument* [Clinton, 2000]), the President directed the Secretary of Energy to consult with the Secretary of the Interior on how best to protect the lands around the HRNM permanently. Much of the area contains shrub-steppe habitat and other objects of scientific and historic interests that are protected within HRNM lands. The President specifically included the possibility of adding lands to the HRNM as they are remediated.

Tribal fishing rights are recognized on rivers within the ceded lands, including the Columbia River, which flows through the Hanford Site. In addition to fishing rights, the Tribes retained the privilege to hunt, gather roots and berries, and pasture horses and cattle on open and unclaimed lands. It is the position of DOE that the Hanford Site, like other ceded lands that were settled or used for specific purposes, is not open and unclaimed land. While reserving all rights to assert their respective positions, the Tribes are participants in DOE's land-use planning process, and DOE considers Tribal Nation concerns in that process. Cleanup actions will support the reasonably anticipated future land use. DOE is committed to establishing cleanup goals that are at least as protective as the interim action RODs.

3.9 Ecology

The unique habitat of the Site is located in the mid-latitude, semi-arid climate of the Columbia Plateau with the last free-flowing section of the Columbia River flowing through it; supporting a rich diversity of plant and animal species (2009 Sitewide Environmental Report [PNNL-19455]). Species diversity is maintained through the long-standing management practices of DOE, which leaves most of the land area relatively undisturbed. Only about six percent of Site land has been disturbed or is actively used by DOE for waste disposal and storage. Thus, the native terrestrial and aquatic ecological resources found on the Site are becoming increasingly rare and highly valuable as agricultural, industrial, and residential development continues to grow throughout the region.

The HRNM was established by the Presidential Proclamation (*Hanford Reach National Monument* [Clinton, 2000]) to place high priority on shrub-steppe community habitat maintenance and enhancement for native species. 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.

The discussion in this section relies heavily on the RCBRA Report (DOE/RL-2007-21, Draft B). This document characterized the ecology of the River Corridor to support justifiable management practices for the River Corridor. In doing this, three key ecological study zones were identified: the upland, riparian,

and near-shore river zones. Each ecological zone within the River Corridor supports a unique community of plants and animals, and this zone approach is reflected in this section.

Upland Zone. The upland zone is the largest zone and consists of land adjacent to the main channel of the Columbia River above the river high-water mark that extends inland from the Columbia River. Terrestrial, and generally dry, the upland zone is not influenced by river flow. The upland zone depends on precipitation for its water supply (RCBRA Report [DOE/RL-2007-21, Draft B]).

Historically, much of the upland habitat in the River Corridor was likely a community dominated by sagebrush and an understory of bunchgrasses. The majority of the upland environment within the operational areas is highly disturbed or consists of barren areas adjacent to reactor facilities. Vegetation is dominated by non-native annual species. Most operational areas, including waste sites, were maintained free of vegetation for contamination control, fire prevention, and housekeeping purposes. Some of the areas no longer used have begun to revegetate naturally, and remediated upland CERCLA waste sites are being revegetated to promote the colonization by native species. The upland environment outside the operational areas is relatively undisturbed and consists of large areas of undisturbed, relatively native habitat.

Riparian Zone. The riparian zone extends from the point on the riverbank where upland vegetation is no longer dominant to the shoreline of the Columbia River. Typically narrow, the riparian zone varies in width, depending on the slope of the riverbank. The transition from the upland zone vegetation to riparian vegetation is generally abrupt. The vegetation that grows in the riparian zone along the river shoreline is thicker and taller than that in the upland area, attracting a broader range of wildlife species. The small mammals, birds, and reptiles common to the upland environment are also likely to inhabit the riparian environment (RCBRA Report [DOE/RL-2007-21, Draft B]).

Near-Shore Aquatic Zone. The near-shore aquatic zone consists of a narrow band of the Columbia River adjacent to the shoreline. The near-shore aquatic zone evaluated in this report extends from the low-water mark on the shoreline to roughly 1.8 m (6 ft) in depth. The aquatic vegetation found in the near-shore zone supports aquatic insect populations, benthic taxa (species and organisms that live in or on the bottom of the river), birds, and fish. At least 44 species of fish live in the Columbia River adjacent to the Site, and some use the river as a migration route to and from upstream spawning areas. The shoreline areas provide rearing habitat for many fish species including spawning habitat for threatened and endangered fish species (RCBRA Report [DOE/RL-2007-21, Draft B]).

Knowledge of the ecological setting is a compilation of ecological data obtained from multiple biological inventories of plant and wildlife species and ecological characterizations from the reports provided below:

- The NEPA Characterization Report (PNNL-6415) provides a detailed summary of the ecology, biological resources, and hydrology for the entire Site, with selected information grouped by major operational areas.
- *United States Department of the Interior Record of Decision – Hanford Reach of the Columbia River: Final Environmental Impact Statement for Comprehensive River Conservation Studies* (DOI, 1996) provides general information on the riparian and aquatic environments found within the Hanford Reach.
- *Literature Review of Environmental Documents in Support of the 100 and 300 Area River Corridor Baseline Risk Assessment* (hereinafter called RCBRA Literature Review [PNNL-SA-41467]) provides detailed characterization data for the 100 and 300 Areas, including comprehensive lists of plant and wildlife species occurring in or near the study area.

DOE has been conducting ecological characterization on the Site since the early 1970s and produces annual environmental reports (e.g., 2009 Sitewide Environmental Report [PNNL-19455]). Other ecological reports pertaining to the River Corridor include Nature Conservancy surveys.

3.9.1 River Corridor Flora

Historically, much of the River Corridor upland zone was a native shrub-steppe habitat. The most prevalent shrub was big sagebrush (*Artemisia tridentata*), with smaller quantities of rabbitbrush (*Chrysothamnus* sp. and *Ericameria* sp.), and an understory dominated by Sandberg's bluegrass (*Poa secunda* formerly *sandbergii*). During the Euro-American settlement of the area, a large portion of the reactor area was disturbed by farming. Construction activities for the reactor projects further disturbed the vegetation and soils in the area. These two major changes in land use resulted in changes to the native plant community, creating areas that have been kept free of vegetation and areas that have partially recovered to various levels of plant succession (RCBRA Report [DOE/RL-2007-21, Draft B]).

The vegetation in the River Corridor upland zone operating areas is typically sparse and consists of early successional species such as cheatgrass (*Bromus tectorum*), Russian thistle (*Salsola kali*), tumblemustard (*Sisymbrium altissimum*), and bur ragweed (*Ambrosia acanthicarpa*). Most operating areas, including waste sites, were historically maintained to be free of vegetation for contamination control, fire prevention, and maintenance purposes. Large areas of cheatgrass and exotic annual species present in the 100-D, 100-F, White Bluffs, and Hanford Townsite areas that resulted from pre-Hanford Site farming and homesteading are described as "abandoned old fields." More detailed descriptions of vegetation by reactor area can be found in the RCBRA Literature Review (PNNL-SA-41467). The 100-IU-2 and 100-IU-6 OUs consist of large areas of undisturbed native habit. Figure 3-64 illustrates distribution of vegetation types before the 2000 wildfire. Figure 3-65 shows the burn area.

Vegetation found in riparian zones reflects the transition between aquatic and upland ecosystems. Changes to the composition of shoreline vegetation over time have been influenced by moderation in the river elevation changes controlled by the Priest Rapids Dam, approximately 18.5 km (10 mi) upstream of the Site. Due to steepness of the shoreline, the transition from riparian to upland vegetation is abrupt. Dominant vegetation within the riparian zone includes mulberry (*Morus alba*), willow (*Salix* sp.), Siberian elm (*Ulmus pumila*), northern wormwood (*Artemisia campestris*), sweet clover (*Melilotus alba* or *M. officinalis*), and reed canarygrass (*Phalaris arundinacea*) (RCBRA Report [DOE/RL-2007-21, Draft B]).

Vegetation in the near-shore river zone consists of macrophytes and periphyton. Macrophytes are sparse in the Columbia River due to strong currents, rocky bottom, and frequently fluctuating water levels. Where macrophytes are found, they commonly include duckweed (*Lemna* sp.) and the native rooted pondweeds (*Potamogeton* spp. and *Elodea canadensis*). Macrophytes provide food and shelter for juvenile fish and spawning areas for some species of warm-water game fish. Since the late 1980s, Eurasian milfoil (*Myriophyllum spicatum*), an introduced macrophyte, has increased to nuisance levels and may encourage increased sedimentation of fine particulate matter. Periphyton communities develop on suitable solid substrate wherever there is sufficient light for photosynthesis and adequate currents to prevent sediment from covering the colonies.

Up-to-date and comprehensive lists of plants found on the Site can be found in the NEPA Characterization Report (PNNL-6415) and *Vascular Plants of the Hanford Site* (PNNL-13688), respectively.

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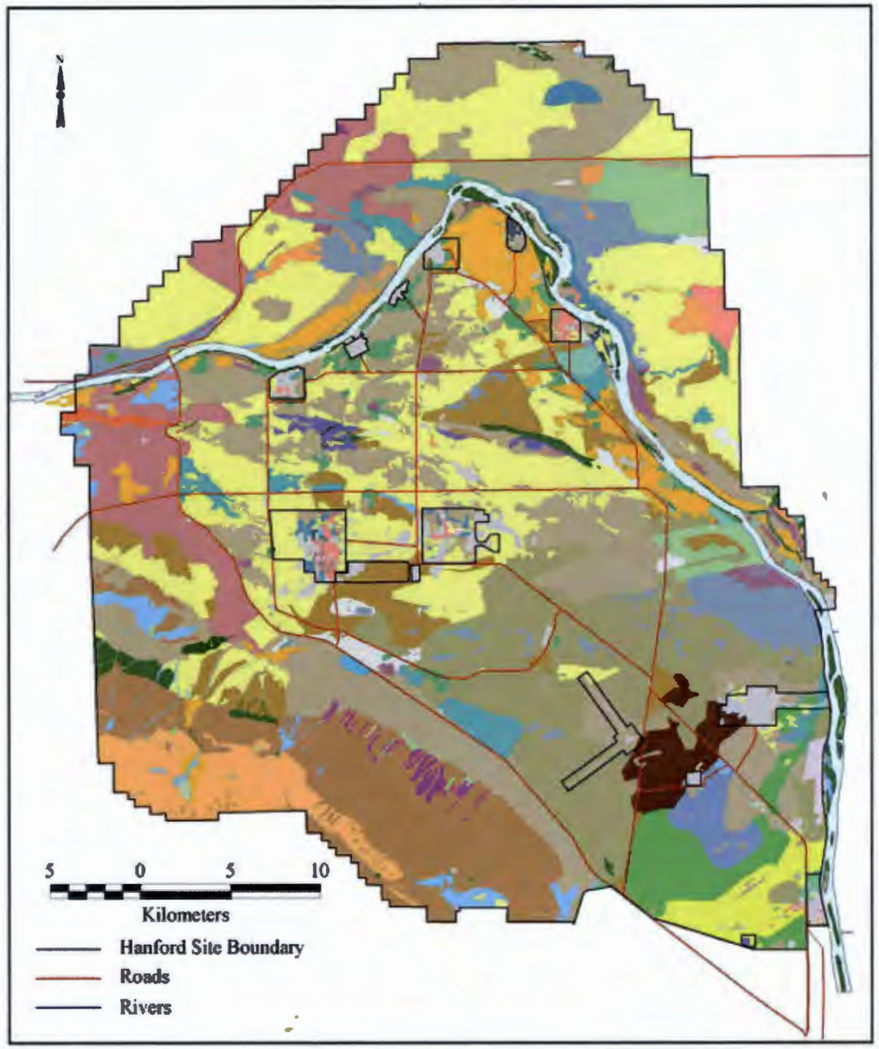

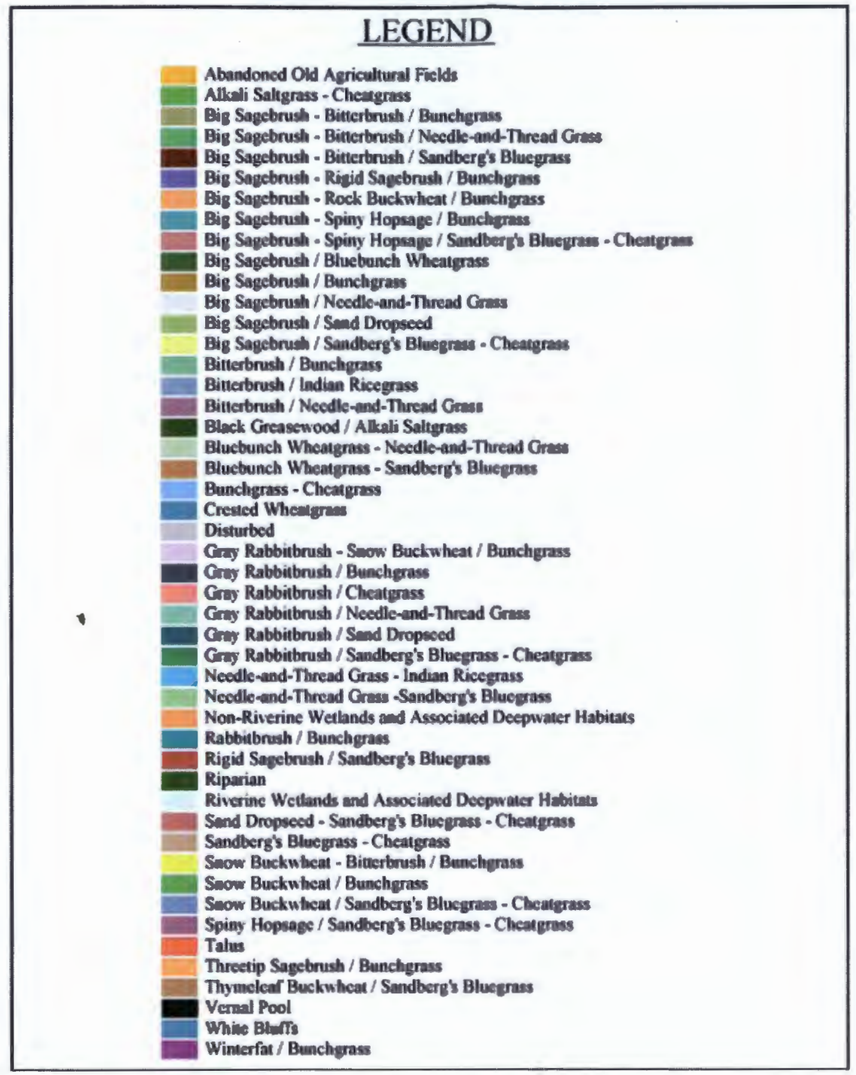

Source: PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization.*

Figure 3-64. Distribution of Vegetation Types and Area before the 2000 Fire

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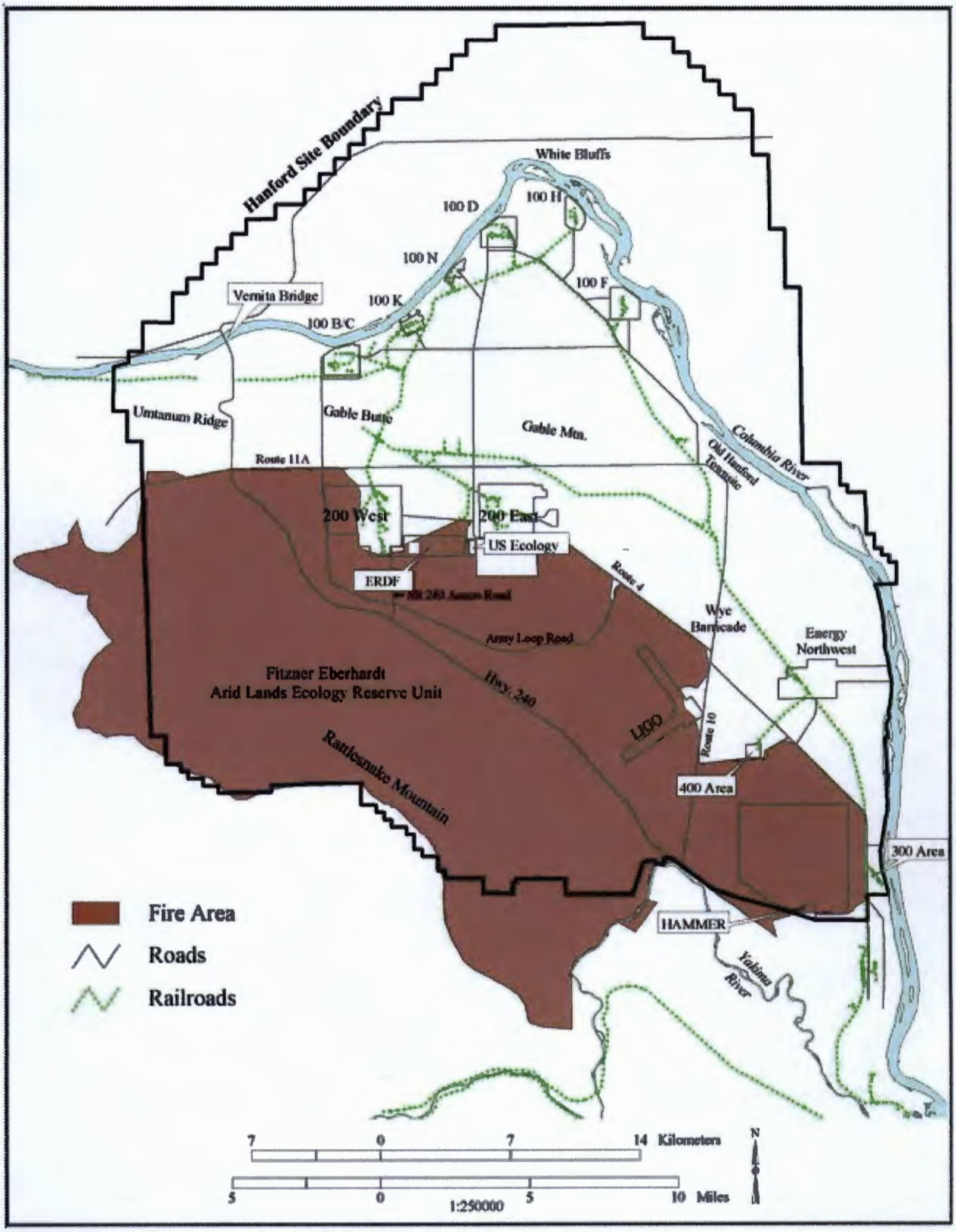


Source: PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization.*

Figure 3-65. Burned Area after June 27 to July 2, 2000 Fire

3.9.2 River Corridor Fauna

Wildlife use of habitat overlaps considerably between the riparian and upland zones. Use of the riparian zone is likely higher than that of the upland zone associated with the CERCLA waste sites due to its proximity to the Columbia River. River access results in greater species diversity and the presence of higher density and higher stature vegetation that remains productive over a longer period of time (RCBRA Report [DOE/RL-2007-21, Draft B]). Species lists have been compiled for the major classes of vertebrates that have been observed on the Site or within the Hanford Reach of the Columbia River and include 46 species of mammals, 145 species of birds, 10 species of reptiles, 5 species of amphibians, and more than 45 species of fish (NEPA Characterization Report [PNNL-6415]). As invertebrates are concerned, a total of 1,509 species-level identifications have been completed, and the collection of 40,000 specimens has resulted in the identification of 43 new taxa and 142 new findings in the state of Washington (*Biodiversity Inventory and Analysis of the Hanford Site Final Report 1994-1999* [Soll et al., 1999]). The high diversity of insect species on the Site reflects the size, complexity, and relatively undisturbed quality of the shrub-steppe habitat. Appendix H presents an extensive list of species known or potentially occurring on the Site classified by habitat type.

Mammals of the upland environment that might be found in and adjacent to the 100 and 300 Areas include the mule deer (*Odocoileus hemionus*), badger (*Taxidea taxus*), coyote (*Canis latrans*), Great Basin pocket mouse (*Perognathus parvus*), northern pocket gopher (*Thomomys talpoides*), black-tailed jackrabbit (*Lepus californicus*), and cottontail rabbit (*Sylvilagus nuttalii*) (*100 Areas CERCLA Ecological Investigations* [WHC-EP-0620]). The abundance of these species and the occurrence of others vary according to the soil type and vegetative community. While other large mammals, such as elk (*Cervus elaphus*), are infrequently observed in the 100 and 300 Areas' upland reactor areas, the number of individual large mammals present per unit area may increase as habitat quality and shrub cover improve through natural recovery and waste site restoration. Some mammals common to the upland environment are also likely to use and inhabit the riparian environment, including the western harvest mouse (*Reithrodontomys megalotis*), the Great Basin pocket mouse (*Perognathus parvus*), and the deer mouse (*Peromyscus maniculatus*) (*Synthesis of Ecological Data Collected in the Riparian and Riverine Environments of the Hanford Reach*, hereinafter called Synthesis of Riparian and Riverine Data [PNNL-14516]). A complete list of mammals observed and expected in all habitats of the 100 Area is provided in *100 Areas CERCLA Ecological Investigations* (WHC-EP-0620). The NEPA Characterization Report (PNNL-6415) presents a complete listing of Hanford Site wildlife species.

Along with the aforementioned mammals, bats are known to inhabit the upland environment in and adjacent to the 100 and 300 Areas. In summer 2006, a colony of bats was discovered in the 183-F Clearwell and subsequently determined to consist of more than 2,000 bats, making it the largest known colony in eastern Washington (*Identification and Protection of a Bat Colony in the 183-F Clearwell: Mitigation of Bat Habitat on the Hanford Site* [WCH-312]). Several species found to inhabit the clearwell are listed on the Washington State Priority Habitats and Species programs list. As such, steps have been taken by DOE and its contractors to maintain and protect the 183-F Clearwell and flume to allow the bat colony to thrive using passive access restrictions like signs and fencing ("Protection of Bat Colony at the 183-F Clearwell" [09-AMRC-0055]).

Several species of birds present in the upland zone rely on structures such as buildings, fences, and utility poles for some of their habitat needs. Raptors, such as red-tailed hawks (*Buteo jamaicensis*), are present, and frequently nest on buildings, utility poles and towers, and trees along the river. Nonvegetated areas provide nesting habitat for nighthawks (*Chordeiles minor*) and killdeer (*Charadrius vociferus*). Canada geese (*Branta canadensis*) use open cheatgrass areas for winter grazing. Following restoration, improvements in shrub coverage will provide important habitat for native shrub-steppe bird species such

as the horned lark (*Eremophila alpestris*), western meadowlark (*Sturnella neglecta*), savannah sparrow (*Passerculus sandwichensis*), loggerhead shrike (*Lanius ludovicianus*), and possibly sage sparrow (*Amphispiza belli*). Raptors will continue to be present, but as the shrubs develop and the open grassy areas shrink in size, wintering geese will likely avoid the area, preferring the cheatgrass areas associated with nearby abandoned farm fields and orchards. A list of bird species observed in the 100 Area is available in *100 Areas CERCLA Ecological Investigations* (WHC-EP-0620). The NEPA Characterization Report (PNNL-6415) presents a catalogue of Hanford Site avian species.

The Synthesis of Riparian and Riverine Data (PNNL-14516) provides information on bird populations with respect to riparian vegetation. Location data are available in the electronic Environmental Monitoring and Compliance Project database managed by PNNL. Research efforts have accomplished the following:

- Assessed winter bird populations in cottonwood/willow (*Populus/Salix*) communities of the Columbia River shoreline ("A Vagrant Occurrence of the Black Phoebe in Southeastern Washington" [Rickard, 1964]; "Comparison of Winter Bird Populations After a Decade" [Rickard and Rickard, 1972])
- Quantified shorebird response to water fluctuations in the Columbia River near-shore environment ("Avian Interactions with Mid-Columbia River Water Level Fluctuations" [Books, 1985])
- Evaluated habitat selection and use by spring migrant passerines ("Riparian Stopover Habitat Selection by Spring Transient Landbirds of South-Central Washington" [Duberstein, 1997])

The information gathered during these research efforts has been used to document the status and ecology of the Hanford Site's avian wildlife.

Common reptiles found in upland environments at the Site include the rattlesnake (*Crotalus viridis*), gopher snake (*Pituophis melanoleucus*), yellow-bellied racer (*Coluber constrictor*), and side blotch lizard (*Uta stansburiana*) (*Habitat Types on the Hanford Site: Wildlife and Plant Species of Concern* [PNL-8942]; *A Synthesis of Ecological Data from the 100 Areas of the Hanford Site* [WHC-EP-0601]). A variety of snakes common to the upland areas may also use the riparian habitat. Other reptiles that may be found in the riparian zone include the western terrestrial garter snake (*Thamnophis sirtalis*) and the painted turtle (*Chrysemys picta*) (*Herpetofauna of the Hanford Nuclear Reservation, Grant, Franklin and Benton Counties, Washington* [Hallock, 1998]; Synthesis of Riparian and Riverine Data [PNNL-14516]). Amphibians in the riparian and near-shore environments of the Hanford Reach include mostly Woodhouse's toads (*Bufo woodhousii*), but bullfrogs (*Rana catesbeiana*) and Great Basin spadefoot toads (*Scaphiopus intermontanus*) may also be present (Synthesis of Riparian and Riverine Data [PNNL-14516]).

The dominant ground-dwelling invertebrate species in the upland environment are harvester ants (*Pogonomyrmex owyheei*) and darkling beetles (family *Tenebrionidae*). Harvester ants, which can exist on vegetated and nonvegetated soils, have been documented on waste sites (*Characterization of the Hanford 300 Area Burial Grounds: Task IV – Biological Transport* [PNL-2774]). Darkling beetles, however, rely on vegetative matter in the soil during their larval stage and, therefore, are not expected to occur in areas void of vegetation (*Darkling Beetle Populations (*Tenebrionidae*) of the Hanford Site in Southcentral Washington* [PNL-2465]). Areas that were not used as waste sites or have not been affected by Site operations likely have less soil disturbance and may support a more robust and diverse community of soil-dwelling fauna than previously disturbed or remediated sites.

More than 45 species of fish have been identified in the Hanford Reach of the Columbia River. Of these species, Chinook salmon (*Oncorhynchus tshawytscha*), sockeye salmon (*Oncorhynchus nerka*), coho salmon (*Oncorhynchus kisutch*), and steelhead (*Oncorhynchus mykiss*) use the river as a migration route to and from upstream spawning areas and are of the greatest economic importance. Other fish of importance to sport anglers are the native mountain whitefish (*Prosopium williamsoni*) and white sturgeon (*Acipenser transmontanus*). Introduced species like smallmouth bass (*Micropterus dolomieui*), black crappie (*Pomoxis nigromaculatus*), channel catfish (*Ictalurus punctatus*), and walleye (*Stizostedion vitreum*) are also popular. Other large fish populations include introduced common carp (*Cyprinus carpio*) and native species such as redside shiner (*Richardsonius balteatus*) and large-scale suckers (*Catostomus macrocheilus*). Smaller fish, such as sculpin (*Cottus* sp.), are associated with shoreline habitats and have small home ranges (RCBRA Report [DOE/RL-2007-21, Draft B]).

3.9.3 Threatened and Endangered Species

A variety of species are recognized by state or federal agencies as having special status based on the species' risk of extinction. Threatened and endangered species are considered at risk and, as such, these species were not identified for sacrificial sampling and subsequent analyses for the risk assessment effort. Data for selected surrogate species were required for contaminant or biological characterization based on the guild in which the special status species were identified (*Risk Assessment Work Plan for the 100 Area and 300 Area Component of the RCBRA* [DOE/RL-2004-37]). The state and federal list of species of concern, including candidate, sensitive, and monitored species, thought or known to occur on the Hanford Site is updated regularly in the NEPA Characterization Report (PNNL-6415). No plants, invertebrates, reptiles, amphibians, or mammals on the federal list of threatened and endangered wildlife and plants are known to occur on the Site (RCBRA Literature Review [PNNL-SA-41467]).

Two species of federally listed endangered fish, the Upper Columbia River spring-run Chinook salmon and the steelhead, occur in the Hanford Reach. The spring-run Chinook salmon do not spawn in the Hanford Reach, but use it as a migration corridor. Steelhead spawning has been observed in the Hanford Reach. The bull trout is listed as a threatened species, but is not considered a resident species and is rarely observed in the Hanford Reach (*100-B/C Pilot Project Risk Assessment Report* [DOE/RL-2005-40]). DOE employs the following protective measures for endangered salmon and steelhead:

- Water diversions meet state screening criteria or appropriate administrative controls, including discharges that meet NPDES permit requirements. Removal of native riparian or emergent vegetation is minimized. Where possible, construction projects do not simplify shoreline structures and final construction produces banks at a 3:1 slope.
- Silt-loaded surface runoff is minimized along the shoreline, and disruptive activities in the river or on the shoreline are avoided from April to November.

Although the bald eagle has been removed from the federal list of 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 Site under the *Bald Eagle Site Management Plan for the Hanford Site, South-Central Washington* (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 to 400 m (2,600 to 2,400 ft). The Washington State Department of Fish and Wildlife requires protection of roosting trees for bald eagle habitat and foraging areas ("Permanent Regulations," "Bald Eagle Protection Rules" [WAC-232-12-292]).

Tables 3-9 and 3-10 lists those flora and fauna species that are listed by the state of Washington as being threatened or endangered including candidate, sensitive, and monitored species, thought or known to occur on the Site.

Table 3-9. Flora Threatened and Endangered Species List

Scientific Name	Common Name	State Status	Federal Status
Upland			
Oenothera caespitosa ssp. *caespitosa*	caespitose evening-primrose	SS	
Orobanche californica	California broomrape	SX	
Astragalus columbianus	Columbia milk-vetch	SS	FCo
Nicotiana attenuata	coyote tobacco	SS	
Cuscuta denticulata	desert dodder	ST	
Camissonia pygmaea	dwarf evening-primrose	SS	
Astragalus geyeri	Geyer's milk-vetch	ST	
Cryptantha leucophaea	gray cryptantha	SS	FCo
Aliciella leptomeria	Great Basin gilia	ST	
Lomatium tuberosum	Hoover's desert parsley	SS	FCo
Loeflingia squarrosa var. *squarrosa*	loeflingia	ST	
Cryptantha scoparia	miner's candle	SS	
Erigeron piperianus	Piper's daisy	SS	
Cistanthe rosea	rosy pussypaws	ST	
Calochortus macrocarpus	sagebrush-mariposa lily	SE	
Camissonia minor	small-flower evening primrose	SS	
Cryptantha spiculifera	Snake River cryptantha	SS	
Ribes cereum	squaw currant	SE	
Mimulus suksdorfii	Suksdorf's monkey-flower	SS	
Eriogonum codium	Umtanum desert buckwheat	SE	FC
Eatonella nivea	white etonella	ST	
Riparian			
Lipocarpha aristulata	awned halfchaff sedge	ST	
Eleocharis rostellata	beaked spike-rush	SS	
Hypericum majus	Canadian St. John's-wort	SS	
Anagallis minima	chaffweed	ST	

Table 3-9. Flora Threatened and Endangered Species List

Scientific Name	Common Name	State Status	Federal Status
Ammannia robusta	grand redstem	ST	
Rotala ramosior	lowland toothcup	ST	
Rorippa columbiae	persistantsepal yellowcress	SE	FCo

FC = Federal Candidate
FCo = Federal Species of ConcernSE = State Endangered
SS = State Sensitive
ST = State Threatened
SX = State Possibly Extinct/ Extirpated

Table 3-10. Fauna Threatened and Endangered Species List

Scientific Name	Common Name	State Status	Federal Status
Birds			
Pelecanus erythrorhynchos	American white pelican	SE	
Haliaeetus leucocephalus	bald eagle	SS	FCo
Athene cunicularia	burrowing owl	SC	FCo
Gavia immer	common loon	SS	
Buteo regalis	ferruginous hawk	ST	FCo
Otus flammeolus	flammulated owl	SC	
Aquila chrysaetos	golden eagle	SC	
Centrocercus urophasianus	greater sage grouse	ST	FC
Melanerpes lewis	Lewis' woodpecker	SC	
Lanius ludovicianus	loggerhead shrike	SC	FCo
Accipiter gentilis	northern goshawk	SC	FCo
Falco peregrinus	peregrine falcon	SS	FCo
Amphispiza belli	sage sparrow	SC	
Oreoscoptes montanus	sage thrasher	SC	
Grus canadensis	sandhill crane	SE	
Aechmophorus occidenalis	western grebe	SC	
Mammals			
Lepus californicus	black-tailed jackrabbit	SC	
Sorex merriami	Merriam's shrew	SC	
Urocitellus townsendii (formerly	Townsend's ground squirrel	SC	FCo

Table 3-10. Fauna Threatened and Endangered Species List

Scientific Name	Common Name	State Status	Federal Status
Spermophilus townsendii)			
Urocitellus washingtoni (formerly (*Spermophilus washingtoni*)	Washington ground squirrel	SC	FC
Lepus townsendii	white-tailed jackrabbit	SC	
Reptiles/Amphibians			
Sceloporus graciosus	northern sagebrush lizard	SC	FCo
Masticophis taeniatus	striped whipsnake	SC	
Aquatics			
Salvelinus confluentus	bull trout	SC	FT
Anodonta californiensis	California floater (mussel)	SC	FCo
Oncorhynchus tshawytscha	chinook salmon	SC	FE
Rhinichthys falcatus	leopard dace	SC	
Catostormus platyrhynchus	mountain sucker	SC	
Lampetra tridentata	Pacific lamprey	SM	FCo
Oncorhynchus mykiss	rainbow trout (steelhead)	SC	FT
Lampetra ayresii	river lamprey	SC	FCo
Fisherola nuttalli	shortface lanx (snail)	SC	

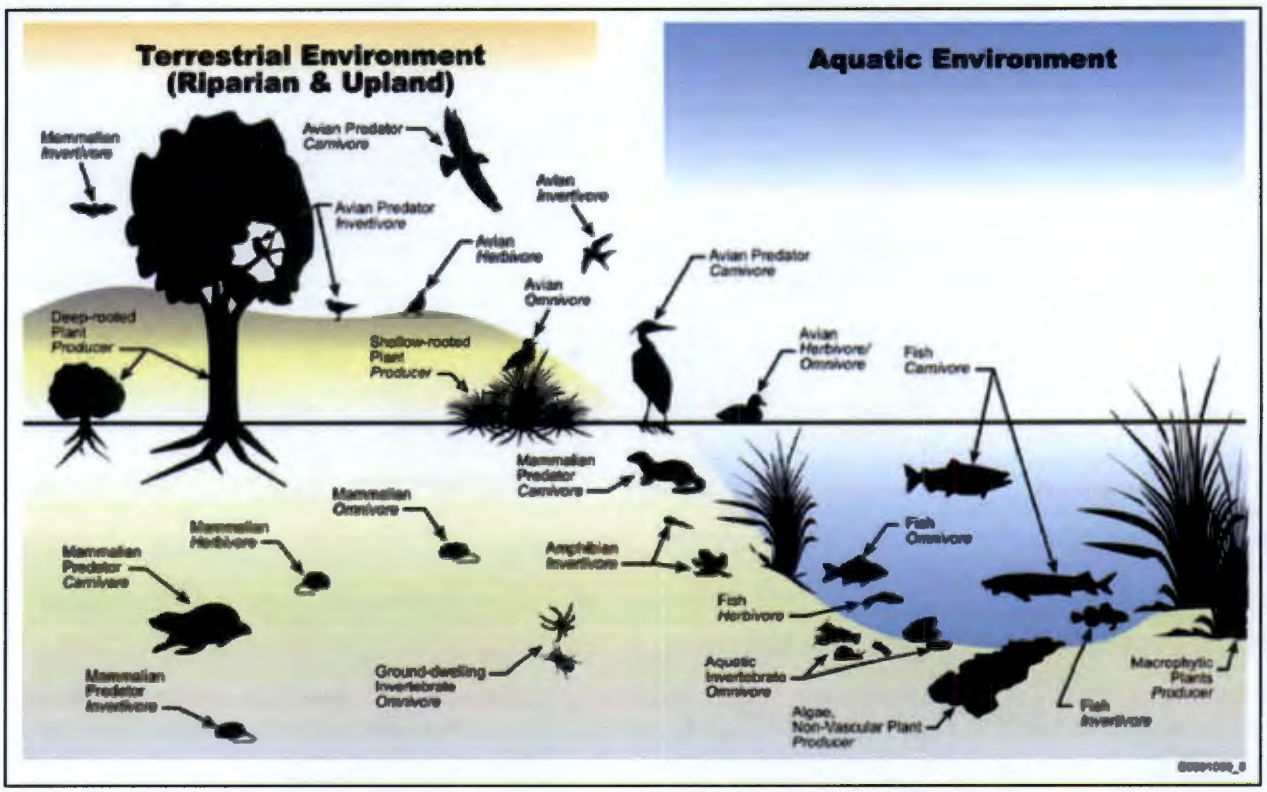
FC = Federal Candidate
FCo = Federal Species of Concern
FE = Federal Endangered
FT = Federal Threatened
SC = State CandidateSE = State Endangered
SM = State Monitored
SS = State SensitiveST = State Threatened

3.9.4 River Corridor Food Web and Receptors

Consideration of ecological receptors in the risk assessment requires an understanding of relationships among biotic community members. One such relationship, trophic transfer of contaminants, is an important element in ecological risk assessments. To develop a conceptual model based on trophic guilds, EPA (*Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments: Interim Final* [EPA 540-R-97-006]) recommends defining the functional ecosystem components with regard to their role in the food web. Given the complexity of trophic interactions, food webs are a simplification of the ecosystem showing broad relationships limited to trophic transfer. At a base level, some organisms prey on plants (herbivores), plants and animals (omnivores), or just animals (carnivores). Specific feeding classes exist with a particular trophic category. Considering the terrestrial environment, for example, although herbivores are pollen-feeding animals and may be relatively unimportant in terms of nutrient and energy transfer through the food web, they are important as plant pollinators. The same generalities are applicable to considerations of trophic linkages in the aquatic environment (e.g., many aquatic invertebrates consume periphyton and use this autotrophic

component of the aquatic food web as a refuge from predation). Ultimately, depiction of trophic-level relationships from a functional perspective allows for ready identification of the feeding guilds most at risk from ingestion of contaminated plant and animal materials (RCBRA Report [DOE/RL-2007-21, Draft B]).

This framework is used to describe a simplified trophic structure for the ecological community of the RCBRA (Figure 3-66). For the most part, trophic linkages among aquatic and terrestrial biota are stronger within habitats than between habitats. In recognition of this, receptors are delineated into aquatic near-shore and terrestrial food webs. Some organisms can use both aquatic and terrestrial habitat. For example, bats and kingbirds are aerial insectivores that live on land and meet their dietary demands primarily through the consumption of emergent aquatic insects. The highest trophic level consists of avian predators that can traverse all environments.



Source: DOE/RL-2007-21, *Risk Assessment Report for the 100 Area and 300 Area Component of the River Corridor Baseline Risk Assessment.*

Figure 3-66. Ecological Food Web Represented by Simplified Feeding Guilds in the River Corridor

Site-specific receptors are recommended as surrogates for the MTCA, "Terrestrial Ecological Evaluation Procedures" (WAC 173-340-7490), feeding guilds because they represent relevant ecological and societal endpoints that also address management goals (*DQO Summary Report for the 100 Area and 300 Area Component of the RCBRA* [BHI-01757]). Receptor trophic-based guilds are representative of the upland, riparian, and near-shore environments and include decomposers, producers, and consumers (herbivores, omnivores, insectivores, and carnivores). While categories such as omnivory and herbivory are useful constructs to simplify a complex ecosystem, it is important to note that animals do not typically restrict themselves to narrow food sources. Considerable dietary overlap exists among the middle trophic levels, because all species are, to some degree, opportunists. Other species are primarily insectivorous only at times when insects are abundant (*Washington Department of Fish and Wildlife's Priority Habitat and*

Species Management Recommendations, Vol. IV: Birds – Sage Sparrow, Amphispiza belli [WDFW, 2003]). Given the dietary overlap, it would be an artificial distinction to focus on a specific category; modeling specific diets (e.g., strict herbivory) is done to set the exposure bounds in trophic-transfer analyses.

3.10 Cultural Resources

Unless noted otherwise, the following information was derived from the NEPA Characterization Report (PNNL-6415).

The 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 the "National Register of Historic Places" (36 CFR 60). In addition, other natural resources and sacred sites important to the present cultures of the regional Tribal Nations are preserved at the Hanford Site (*Data Compendium for the Columbia River Comprehensive Impact Assessment* [PNNL-9785]). 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 significant sites, as has been experienced elsewhere in the Columbia River Basin.

While rapid Site development did not accommodate protection of important Native American locations, current and future Site planners, onsite construction activity directors, and Tribal Nations leaders work together for the protection of important Native American locations. The cultural resources of the Site are important to many people interested in their historic preservation.

The National Register of Historic Places criteria (*National Register of Historic Places Multiple Property Documentation Form – Historic, Archaeological and Traditional Cultural Properties of the Hanford Site, Washington* [DOE/RL-97-02]) offer three convenient categories for chronicling historic, archaeological, and traditional cultural properties of the Site:

- Prehistoric era (10,000 years before present to 1805)
- Homestead and Townsite era (1805 to 1945)
- Manhattan Project and Cold War era (post-1945 to 1990)

DOE has undertaken an ongoing, comprehensive preservation planning effort for the Hanford Site. The results of these efforts have implemented protective programs for conserving cultural resources as documented in the following:

- *Programmatic Agreement Among the U.S. Department of Energy, Richland Operations Office, the Advisory Council on Historic Preservation, and the Washington State Historic Preservation Office for the Maintenance, Deactivation, Alteration, and Demolition of the Built Environment on the Hanford Site, Washington* (DOE/RL-96-77)
- *National Register of Historic Places Multiple Property Documentation Form – Historic, Archaeological and Traditional Cultural Properties of the Hanford Site, Washington* (DOE/RL-97-02)
- *Hanford Cultural Resources Management Plan* (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 SAPs. Additionally, the creation of HRNM (USFWS, 2008) and "Hanford Reach National Monument; Adams, Benton, Franklin and Grant Counties, WA" (73 FR 72519)

provides an additional means for the preservation and maintenance of the wide range of cultural resources present along the Columbia River.

Artifacts discovered across the Site provide evidence regarding occupational characteristics, use durations and periods, and multiple land use (for example, ceremonial and religious sites and burial grounds). 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 (*U.S. Department of Energy's Hanford Cultural Resources Laboratory Oral History and Ethnography Task Annual Report* [PNNL-14237]). 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. Data collection and remedy selection in the RI/FS process were guided by preserving these locations for exercising customary cultural resource rights. Similar to other areas across the Site, disturbance maps and reports have been prepared for the 300 Area. The locations and potential impacts to these resources are reviewed by Tribal Nations leaders before Site activities begin (*Hanford Cultural Resources Management Plan* [DOE/RL-98-10]).

3.10.1 300 Area

Much of the 300 Area has been used for industrial activities associated with the Manhattan Project and Cold War cultural landscape. Prior to the Manhattan Project, the 300 Area was used by Native Americans as a camp location and by early settlers who developed a farming community known as Fruitvale. Due to its proximity to the Columbia River, many archaeological resources associated with these landscapes are located along the river shore outside of the 300 Area operational zone. Subsurface archaeological deposits are likely located beneath existing 300 Area facilities within 400 m (1,300 ft) of the Columbia River in pockets of undisturbed ground.

3.10.1.1 Archaeological Resources

Pre-contact campsites, house pits, and a historic trash scatter are located within the 300 Area. Many more resources may be located in subsurface deposits.

Twenty-three archaeological sites and 10 isolated artifacts have been recorded within 1 km (0.6 mi) of the 300 Area operational zone. Several archaeological sites, including 45BN162, are in the Hanford South Archaeological District, which is listed in the Washington Heritage Register. Archaeological sites associated with the early setters/farming cultural landscape are comprised mainly of domestic debris scatters and roadbeds associated with farmsteads.

3.10.1.2 Traditional Cultural Places

A documented historic Wanapum cemetery is located near the 300 Area operational zone.

3.10.1.3 Buildings and Structures.

The 300 Area operational zone was the location of the uranium fuel fabrication plants that manufactured fuel rods to be irradiated in the Site reactors. It was also the location of most of the Site R&D laboratories. In this zone, 159 buildings/structures have been documented on historic property inventory forms. Of that number, 47 were selected as representative buildings and structures eligible for the National Register as properties within the Historic District recommended for individual documentation.

Assessments/walkthroughs of the former fuel manufacturing and reactor operations facilities identified and tagged 27 Manhattan Project/Cold War era artifacts (mainly industrial) that were associated with the fuel manufacturing processes and reactor operations. The walkthroughs also identified 12 additional

artifacts that included a selection of safety signs/posters, a control panel, a safety shower, protective worker clothes, and a sample uranium fuel element. Other 300 Area building assessments identified and tagged 75 to 80 additional Manhattan Project/Cold War era artifacts.

3.10.2 400 Area

The 400 Area consists of the FFTF complex, which is a 400-megawatt, thermal, liquid-metal (sodium) cooled nuclear research and test reactor owned by DOE. The facility, which operated for about 10 years, was shut down in 1993 and is currently being deactivated.

3.10.2.1 Archaeological Resources

The 400 Area has been so altered by construction that archaeologists surveying it in 1978 were able to find only 0.12 km^2 (0.047 mi^2) of undisturbed land (*An Archaeological and Historic Survey of the 400 Area, Hanford Reservation* [Rice et al., 1978]). No cultural resources were found during the surveys conducted and no archaeological sites are known to be located within 1 km (0.6 mi) of the 400 Area.

3.10.2.2 Buildings and Structures

All the buildings and structures in the 400 Area were built during the Cold War era and 21 have been recorded on historic property inventory forms. Of these, six (405 Reactor Containment Building, 436 Training Facility, 4621-W Auxiliary Equipment Facility, 4703 FFTF Control Building, 4710 Operation Support Building, and the 4790 Patrol Headquarters) were selected as representative of buildings and structures eligible for the National Register as properties within the Historic District recommended for individual documentation (*Hanford Site Manhattan Project and Cold War Era Historic District Treatment Plan* [DOE/RL-97-56]).

In response to the "Curation Plan for the Deactivation and Decommissioning of Historic Buildings at FFTF, 400 Area, HCRC 2002-400-004" (Griffith, 2003), walkthroughs were conducted of the properties requiring mitigation (except for the 4790 Patrol Headquarters). In addition, walkthroughs were conducted at 16 FFTF properties where no individual documentation was required. Operations carried out in these facilities were closely related to the work conducted in the five contributing buildings that required mitigation. During the walkthroughs, 30 artifacts were identified and tagged. The types of artifacts included industrial equipment and machinery, photographs, publications, control room panels, and models. A Building 427 assessment was also conducted and four artifacts with Cold War era interpretive or educational value (including fuel assembly components) were identified and tagged.

3.10.3 600 Area

The 600 Area portion of the greater 300 Decision Area includes the area not occupied by the 300 Area Industrial Complex and 400 Area. Project-driven surveys have been conducted throughout the area, but much of the 600 Area has not been surveyed. Based on what is known, the 600 Area contains cultural resources associated with all three cultural landscapes that exist on the Site. Representing a full range of human activity across the Site, the activities are best characterized for the Native American cultural landscape by the utilization of inland and riverine resources. Evidence of cultural resources associated with the Manhattan Project and Cold War Era consist primarily of roads.

3.10.3.1 Archaeological Resources

A National Register District is associated with the Native American landscape is located within the 600 Area includes the Wooded Island Archaeological District.

3.10.3.2 Traditional Cultural Places

The Columbia River is the primary area of traditional cultural importance.

3.10.3.3 Buildings and Structures

There are no remaining structures associated with the early settlers/farming landscape located in the 600 Area.

3.11 Summary of Physical Characteristics

As discussed in Chapter 1, the 300 Area is located in the southeastern portion of the Site and occupies approximately 145.9 km^2 (56.35 mi^2) of the Site. The 300 Area extends from north of Energy Northwest to south of the 300 Area and from the west bank of the Columbia River to the west to Horn Road. The topography of the 300 Area is relatively flat away from the Columbia River, with the greatest changes in elevation occurring near the Columbia River where the riverbank slopes steeply. Annual precipitation varies from approximately 7.6 to 31.3 cm/year (3.0 to 12.3 in./year) since 1947, with an average of 17.2 cm/year (6.8 in./year). The following points summarize the physical characteristics of the 300 Area:

- The Columbia River is a gaining stream as it crosses the Site (i.e., the Hanford Reach). The flow volume and river stage within the 300 Area are controlled by releases from Priest Rapids Dam. Discharges from the dam vary seasonally, with typical flows between a low of 1,100 m^3 (40,000 ft^3)/s to a high of 7,000 m^3 (250,000 ft^3)/s.

- The stratigraphic sequence overlying basalt bedrock beneath the 300 Area comprises, from top to bottom, backfill materials, the Hanford formation, and the Ringold Formation (primarily unit E and the lower mud). The stratigraphy underlying the 400 Area is similar to that of the 300 Area, but also includes a surficial layer of windblown sediments referred to as the Touchet Beds.

- In the 300 Area, the vadose zone comprises unconsolidated gravel and sand of the Hanford formation and ranges in thickness from 15 m (49 ft) inland to less than 1 m (3 ft) near the Columbia River.

- The uppermost aquifer is unconfined and comprises the gravel-dominated Hanford formation and the sands and gravels of Ringold unit E. A low-permeability aquitard, the Ringold Formation lower mud unit, forms the base of the unconfined aquifer.

- Hydrogeologic conditions within the 300 Area are unique to the Site. Very high groundwater flow velocities (e.g., 18 m [59 ft]/day]) have been observed within the 300 Area using tracers. In addition, hydraulic gradients change rapidly in steepness and orientation as the river stage fluctuates on daily, weekly, seasonal, and multiyear cycles due to Columbia River stage fluctuations.

- In general, regional groundwater flow converges into the 300 Area from the northwest, west, and southwest, causing a generally southeasterly or easterly flow direction beneath the 300 Area. During the seasonal period of high Columbia River flow in the spring months, movement beneath the 300 Area becomes more southerly, and during the seasonal period of low Columbia River flow, movement becomes more easterly.

- Changes in geochemical environment in saturated Hanford formation sediment are most pronounced near the Columbia River, where river water intrudes into the aquifer. River water is lower in bicarbonate content than groundwater, resulting in lower ionic strength, which can influence the transport of certain contaminants. Lower bicarbonate content enhances the tendency for certain contaminants, such as uranium, to adsorb onto sediment.

- When the Columbia River rises, pressure increases in the aquifer beneath the 300 Area causing the water table to move upward; when the river falls, the water table also moves back downward. The

water table rises with the river stage because of a lessening or actual reversal of the hydraulic gradient between the aquifer and the river.

- At the 300 Area, the river channel incises the several stratigraphic intervals of interest within the unconfined aquifer system. The saturated sediment of the Hanford formation is completely incised by the channel, so groundwater discharge from that sediment is potentially exposed over a broad area of riverbed on the Hanford Site side of the thalweg (deepest part of the channel). Sites of potential exposure of contaminants carried by groundwater include the riverbed substrate and riverbank springs that appear during periods of low river stage.

- The unconfined aquifer adjacent to the Columbia River channel at the 300 Area is exposed to highly variable hydraulic gradients and groundwater geochemistry. Daily, weekly, seasonal, and multi-year cycles in river stage fluctuations are the principal drivers, which results in either layering or mixing of groundwater and river water. The principal impact is dilution when the two water types mix.

- The 300 Area will continue to be used by DOE during the near future for activities involving PNNL and other DOE-related activities. The 300 Area is also of interest to the city of Richland, and has a high potential for economic development by private industry.

This chapter has described the setting and provided information regarding the area of interest, 300 Decision Area, the makeup of vadose materials the groundwater, and the Columbia River. Chapter 4 describes the contaminants resulting from Hanford Site operations, how and where they have interacted, and are now present in the setting. Contaminants can be harmful to HHE if there is contact with sufficient concentrations, mass, and/or radioactive activity. Chapter 5 describes and predicts how quickly or slowly these contaminants will migrate through the setting, called fate and transport and, most importantly, the potential to enter the Columbia River. The potential to be harmful depends on specific human and environmental receptors as well as exposure times and patterns that might bring receptors and contaminants into contact. The ways that the contaminants could meet and impact HHE are called pathways. Chapter 6 addresses the human health pathway. Scenarios of how humans might encounter contaminants in the setting with resultant health impacts are evaluated. Chapter 7 addresses the biological receptor pathway. Scenarios of how plant, animal, bird, or invertebrate species might encounter contaminants in the setting and be impacted are evaluated.

Chapters 3 through 7 present the setting, the contaminants, and the pathways for HHE contact and potential harm though relevant exposure scenarios. In Chapters 8 and 9, methods or technologies that could remove contaminants from the setting and/or interrupt these pathways are identified and developed. Those methods or technologies that can best address the problem are compared and evaluated. This evaluation will support a remedial decision to implement actions to protect HHE.

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4 Nature and Extent of Contamination

The nature and extent evaluation presents and discusses the contaminant levels found in the environmental media in the 300 Area. The discussion incorporates the results from implementation of the 300 Area RI/FS Work Plan (DOE/RL-2009-30), relevant data from previous field investigations, and site-specific remedial activities. This chapter focuses principally on the COPCs that were identified in the 300 Area RI/FS Work Plan (DOE/ RL-2009-30); however, other constituents are also discussed as needed. Any significant uncertainties associated with the data are noted to facilitate their consideration in the subsequent components of the RI/FS process.

This discussion focuses primarily on the vadose zone and unconfined aquifer, but also includes surface water and sediment, air, and biota.

Highlights

- Characterization data for the deep vadose zone at the high-volume process effluent sites show residual uranium levels more than ten times above background.
- Uranium contamination in groundwater is essentially contained within the saturated Hanford formation gravels hydrologic unit.
- The area of uranium plume in groundwater where the DWS is exceeded is approximately 0.5 km^2.
- VOCs are detected in groundwater in limited occurrence at a few locations above the DWS.
- The tritium plume that extends to the east of the 618-11 Burial Ground has remained relatively constant in shape since its discovery in 1999.

4.1 Background Concentrations

Background refers to substances or locations that are not influenced by the releases from a site. They are usually described as naturally occurring (present in the environment in forms that have not been influenced by human activity) or anthropogenic (natural and artificial) substances present in the environment as a result of human activities not specifically related to the Hanford Site. A number of the contaminants that are directly attributable to past Hanford Site practices have been detected in soil and groundwater samples collected in areas appreciably away from Hanford Site operations. For example, many metals and a few radionuclides are present at detectable levels in the environment because of natural processes. In addition, a number of contaminants have been introduced into the environment by non-Hanford Site activities. Examples of this would be nitrates and pesticides introduced by farming or radiological fallout from nuclear bomb testing. *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (EPA 540-R-01-003) discusses the process for identifying, documenting, and applying background concentrations. The determination of Hanford Site-specific background concentrations in soil is documented in *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes* (hereinafter called Non-Rad Soil Background document [DOE/RL-92-24]), and *Hanford Site Background: Part 2, Soil Background for Radionuclides* (hereinafter called Rad Soil Background document [DOE/RL-96-12]). In instances where Hanford Site-specific background concentrations have not been identified, the RI/FS evaluation sometimes relies on values published in *Natural Background Soil Metals Concentrations in Washington State* (Ecology Publication 94-115). Table 4-1 lists background soil concentrations used in the 300 Area RI/FS data evaluation. Groundwater background information is presented in Section 4.4.

Analyte background concentrations in both soil and groundwater have two principal uses in the CERCLA process. Initially, they are considered when determining whether Site soils or groundwater have been impacted by Site operations. An analyte found at concentrations that exceed its established background concentration is typically taken as evidence of contamination, and triggers further evaluation. If an analyte is not detected or is found only at concentrations that do not exceed its established background concentration, it suggests that related environmental impacts resulting from Site operations have not occurred, and that further evaluation of that analyte is not warranted. The second principal use for

background concentrations in the CERCLA process is for establishing remedial action cleanup levels. CERCLA typically does not require that sites be cleaned up to concentrations that are below background levels. Thus, if the risk-based remedial action cleanup level derived for a specific contaminant is less than its background concentration, RAGs are typically set at the established background concentration.

Table 4-1. Background Concentrations in Hanford Site Soil

CAS Number	Analyte	Abbreviation	90th Percentile	Reference
Radionuclides (pCi/g)				
10098-97-2	Strontium-90[a]	Sr-90	0.178	DOE/RL-96-12
14133-76-7	Technetium-99	Tc-99	—	—
10028-17-8	Tritium	H-3	—	—
14762-75-5	Carbon-14	C-14	—	—
13981-37-8	Nickel-63	Ni-63	—	—
15046-84-1	Iodine-129	I-129	—	—
10198-40-0	Cobalt-60[a]	Co-60	0.00842	DOE/RL-96-12
10045-97-3	Cesium-137[a]	Cs-137	1.05	DOE/RL-96-12
14683-23-9	Europium-152	Eu-152	—	—
15585-10-1	Europium-154[a]	Eu-154	0.0334	DOE/RL-96-12
14391-16-3	Europium-155[a]	Eu-155	0.0539	DOE/RL-96-12
14596-10-2	Americium-241	Am-241	—	—
13966-29-5	Uranium-233/234	U-233/234	1.10	DOE/RL-96-12
15117-96-1	Uranium-235	U-235	0.109	DOE/RL-96-12
7440-61-1	Uranium-238	U-238	1.06	DOE/RL-96-12
13981-16-3	Plutonium-238[a]	Pu-238	0.00378	DOE/RL-96-12
15117-48-3	Plutonium-239/240[a]	Pu-239/240	0.0248	DOE/RL-96-12
14119-32-5	Plutonium-241	Pu-241	—	—
Nonradionuclides (mg/kg)				
7440-36-0	Antimony	Sb	0.130	ECF-Hanford-11-0038
7440-38-2	Arsenic	As	6.47	DOE/RL-92-24
7440-39-3	Barium	Ba	132	DOE/RL-92-24
7440-41-7	Beryllium	Be	1.51	DOE/RL-92-24
7440-69-9	Bismuth	Bi	—	—
7440-43-9	Cadmium	Cd	0.563	ECF-Hanford-11-0038

Table 4-1. Background Concentrations in Hanford Site Soil

CAS Number	Analyte	Abbreviation	90th Percentile	Reference
7440-47-3	Chromium (total)	Cr	18.5	DOE/RL-92-24
18540-29-9	Chromium (hexavalent)	Cr-VI	—	—
7440-50-8	Copper	Cu	22	DOE/RL-92-24
7439-92-1	Lead	Pb	10.2	DOE/RL-92-24
7439-93-2	Lithium	Li	13.3	ECF-Hanford-11-0038
7439-96-5	Manganese	Mn	512	DOE/RL-92-24
7439-97-6	Mercury	Hg	0.0131	ECF-Hanford-11-0038
7440-02-0	Nickel	Ni	19.1	DOE/RL-92-24
7782-49-2	Selenium[b]	Se	0.78	ECF-Hanford-11-0038
7440-22-4	Silver	Ag	0.167	ECF-Hanford-11-0038
82115-62-6	Sodium	Na	690	DOE/RL-92-24
7440-24-6	Strontium	Sr	—	—
7440-28-0	Thallium	Tl	0.185	ECF-Hanford-11-0038
7440-31-5	Tin	Sn	—	—
7440-62-2	Vanadium	V	85.1	DOE/RL-92-24
7440-66-6	Zinc	Zn	67.8	DOE/RL-92-24
16887-00-6	Chloride	Cl^-	100	DOE/RL-92-24
16984-48-8	Fluoride	F^-	2.81	DOE/RL-92-24
14797-55-8	Nitrate	NO_3^-	52	DOE/RL-92-24
14797-65-0	Nitrite	NO_2^-	Note[c]	DOE/RL-92-24
74-90-8	Cyanide	CN^-	—	—
12674-11-2	Aroclor 1016	—	—	—
11104-28-2	Aroclor 1221	—	—	—
11141-16-5	Aroclor 1232	—	—	—
53469-21-9	Aroclor 1242	—	—	—
12672-29-6	Aroclor 1248	—	—	—
11097-69-1	Aroclor 1254	—	—	—
11096-82-5	Aroclor 1260	—	—	—
540-59-0	1,2-Dichloroethene (total)	—	—	—
156-59-2	cis-1,2-Dichloroethene	—	—	—
71-55-6	1,1,1-Trichloroethane	—	—	—
71-43-2	Benzene	—	—	—
56-23-5	Carbon tetrachloride	CCl_4	—	—
67-66-3	Chloroform	$CHCl_3$	—	—
78-93-3	Methyl ethyl ketone	MEK	—	—

Table 4-1. Background Concentrations in Hanford Site Soil

CAS Number	Analyte	Abbreviation	90th Percentile	Reference
108-10-1	Methyl isobutyl ketone	MIBK	—	—
98-95-3	Nitrobenzene	—	—	—
108-88-3	Toluene	—	—	—
127-18-4	Tetrachloroethene	—	—	—
79-01-6	Trichloroethene	—	—	—
75-01-4	Vinyl chloride	—	—	—
1330-20-7	Xylenes (total)	—	—	—
117-81-7	Bis(2-ethylhexyl)phthalate	—	—	—
85-68-7	Butylbenzyl phthalate	—	—	—
87-68-3	Hexachlorobutadiene	—	—	—
126-73-8	Tributyl phosphate	—	—	—
50-32-8	Benzo(a)pyrene	—	—	—
218-01-9	Chrysene	—	—	—
85-01-8	Phenanthrene	—	—	—
141-78-6	Ethyl acetate	—	—	—
107-21-1	Ethylene glycol	—	—	—
1332-21-4	Asbestos	—	—	—
68334-30-5	Total petroleum hydrocarbons	NWTPH-Dx	—	—
8008-20-6	Normal paraffin hydrocarbon (kerosene)	NWTPH-Dx	—	—
7440-61-1	Uranium (total)	U-tot	3.21	Calculated[d]

Sources:

DOE/RL-92-24, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes.*

DOE/RL-96-12, *Hanford Site Background: Part 2, Soil Background for Radionuclides.*

Ecology Publication 94-115, *Natural Background Soil Metals Concentrations in Washington State.*

a. Cesium-137, cobalt-60, europium-154, europium-155, plutonium-238, plutonium-239/240, and strontium-90 are anthropogenic radionuclides whose background values only apply to surface soil samples.

b. The 90th percentile value for Se is estimated because the majority of detections were below the minimum quantitation limit.

c. Insufficient data above the reporting limit to provide for a distribution fit.

d. Calculated from U-238 isotope based on 99.7% abundance in the environment.

— = Either a background study has not been performed for this analyte (e.g., strontium, tin) or the constituent does not occur naturally in the environment (e.g., the organic constituents)

CAS = Chemical Abstract Service

4.2 Sources

The primary sources of contamination within the 300 Area geographical area are the liquid and solid wastes that were generated and managed during 300 Area fuel manufacturing or R&D operations, and disposed (or released) into FF-1 and FF-2 waste sites. Secondary sources consist of the residual contamination in the vadose zone (including the PRZ) and the unconfined aquifer, which resulted when primary sources of contamination were introduced into the environment at effluent discharge ponds and trenches, waste disposal sites, solid waste burial grounds, subsurface process and waste piping, waste storage and treatment areas, research facilities, and through UPRs. This section discusses what distinguishes primary and secondary sources, and highlights certain contaminants because of their extent or persistence.

4.2.1 Primary Sources

As discussed in Chapter 1, primary sources within the 300 Area were comprised of the process facilities, laboratories, support facilities, waste handling facilities, and associated piping within the FF-1 and FF-2 OUs. Within the context of the work completed under the 300 Area RI/FS Work Plan (DOE/RL-2009-30), many of the data needs were focused on the FF-1 OU high-volume liquid waste facilities. Appendix B contains a list of the primary source facilities and describes their status with regard to D4 activities, facility history, and contaminants associated with their operations.

Liquid Effluent Waste Sources. As described in Chapter 1, large volumes of radiologically and chemically contaminated wastewater from the 300 Area process facilities, laboratories, and support facilities were discharged to FF-1 and FF-2 OU waste sites. The primary contaminants in these liquid wastes included uranium and VOCs (notably TCE and cis-1,2-dichloroethene [cis-1,2-DCE]).

Solid Waste Primary Sources. The primary solid waste source area types were also process facilities, laboratories, and support facilities. As described in Chapter 1, the primary source solid waste were disposed to burial grounds that consisted of numerous trenches, caissons, and VPUs that contain radioactive and nonradioactive solid wastes from the 300 Area industrial complex.

4.2.2 Secondary Sources

The releases of primary contaminant sources to the environment resulted in contaminated vadose zone material beneath facilities and waste sites. The contaminated vadose zone impacted by disposal practices and release forms the secondary sources, and has the potential to spread contaminants further through the environment. Other potential secondary sources evaluated for the current investigation included contaminated material in the PRZ, which is discussed later in this chapter.

Chapter 1 presents the operational periods of the facilities. The 300 Area fuel-manufacturing processes responsible for generating and releasing the primary sources to the environment have all been discontinued. Contaminants remaining in the vadose zone or groundwater as secondary sources may continue to migrate through the environment, depending on the individual contaminant properties (i.e., K_d value) and the physical and geochemical characteristics of the vadose zone materials.

Chapters 6 and 7 evaluate the risks posed by the identified secondary sources to HHE through direct exposure. The potential for secondary sources to provide a significant ongoing source of contamination to groundwater is evaluated through the comparison of contaminant concentrations in vadose zone material to the screening levels for groundwater and surface water protection in Chapter 5.

4.2.2.1 Uranium

The principal secondary sources of uranium in the vadose zone within the 300 Area industrial complex are as follows:

- The vadose zone directly beneath the principal liquid waste disposal sites
- A more widespread portion of the vadose zone bounded laterally by the extent of the groundwater uranium plume and vertically by the range in elevation of the current water table
- A similar widespread zone that extends vertically higher than the current high-water-table limit

The latter zone is included because during the fuels production years, the historical water-table elevation extended much higher than the current range. The uranium stored in these subsurface regions has the potential to act as a source for resupplying the groundwater plume.

An additional secondary source in the 300 Area is the 307 Disposal Trenches (WIDS Site 316-3), a 300-FF-2 OU waste site. Moderate levels of uranium contamination are known to exist in the material used to backfill the trenches (sludge from the South Process Pond). Uranium concentrations also exceed background levels in the vadose zone beneath the trenches, extending to the water table.

Three sites in the 600 Area constitute secondary sources of uranium contamination. Two sites, the 618-10 and 618-11 Burial Grounds, both received substantial volumes of radiological and mixed waste. Recent intrusive characterization efforts at the 618-10 Burial Ground to support remedial action planning have identified extensive evidence of soil contamination. Non-intrusive characterization is pending at the 618-11 Burial Ground. The third site, located immediately adjacent to the 618-10 Burial Ground, was known as the 321 Cribs (WIDS Site 316-4). It was used to discharge process effluent trucked from the 300 Area directly into the vadose zone. The subsurface 316-4 Crib structure has been removed, but substantial contamination remains. Further 316-4 Crib remedial action is planned, but on hold pending actions at the 618-10 Burial Ground.

4.2.2.2 Tritium

Based on groundwater monitoring results and minimally intrusive characterization efforts, solid waste buried in the 618-11 Burial Ground appears to be a source of tritium contamination. No other substantive tritium sources have been identified in the 300 Decision Area.

4.2.2.3 Volatile Organic Compounds

Primarily, TCE and PCE were used as part of the fuels fabrication process and in various fuels-related research activities and were sometimes disposed to the ground. Dissolved-phase VOCs discharged through the process sewer to liquid effluent disposal facilities would have been quickly transported to the unconfined aquifer.

Inadvertent discharge events occurred in 1982 and 1984 at the 300 Area Process Trenches with relatively small quantities of PCE; however, they reached groundwater and migrated to downgradient wells and riverbank springs (summarized in 300 Area VOC Investigation Results [PNNL-17666]). An unexplained "spike" in PCE was observed in 1998 in three wells located downgradient of the former 300 Area Process Trenches. The elevated water table conditions of 1996 and 1997 are implicated as remobilizing contamination in the lower vadose zone (300-FF-5 LFI [PNNL-16435]).

The origin for TCE observed in an interval of fine-grained sediment in the unconfined aquifer remains uncertain, although the known extent places it proximal to the South Process Pond, a disposal location for fuels fabrication effluent.

4.2.2.4 Other Contaminants

No substantive nitrate source areas are identified in the 300 Area. Nitrate likely was introduced to groundwater during fuels fabrication; however, it has been essentially removed from environmental pathways by natural processes.

4.3 Vadose Zone

This section describes the nature (i.e., type and concentration) and extent (i.e., distribution) of vadose zone contamination present in the 300 Area industrial complex, the 400 Area, and the two subregions of the 600 Area, which together comprise the 300 Decision Area. As discussed in Chapter 1, the FF-1 high-volume process effluent discharge waste sites (i.e., the South Process Pond [WIDS Site 316-1], the North Process Pond [WIDS Site 316-2], and the 300 Area Process Trenches [316-5]) were closed out under a final ROD (300-FF-1 and 300-FF-5 ROD [EPA/ROD/R10-96/143]). However, the residual uranium mass present in the vadose zone from these waste sites is an integral component of the CSM, and was the only vadose zone information specifically pursued with new boreholes in this RI process. These residual FF-1 soil data along with the historical LFI data, CVP data from the interim-closed FF-2 OU waste sites, and newly collected RI data from the 11 new groundwater monitoring wells and 5 new temporary wells comprise the 300 Decision Area vadose zone data set.

Analytical data from the new RI boreholes and the historical LFI boreholes and test pits at the large process effluent disposal facilities are summarized in tables and depicted in vertical profile figures incorporated into this discussion. Analytical data from the previous remedial excavations are integrated into the data summary tables. A summary evaluation, in tabular form, is also presented to identify the occurrence of analytes detected above background levels at the FF-2 OU interim closed out waste sites. Historical data are from sampling events documented in the following reports:

- *Cleanup Verification Package for the South Process Pond (WIDS Site 316-1), the Retired Filter Backwash Pond (WIDS Site 300 RFBP), 300-262 Contaminated Soil, and Unplanned Release Sites UPR-300-32, UPR-300-33, UPR-300-34, UPR-300-35, UPR-300-36, UPR-300-37, and UPR-300-FF-1* (CVP-2003-00002)
- *300-FF-1 Operable Unit, North Process Pond/Scraping Disposal Area Verification Package* (BHI-01298)
- *300 Area Process Trenches Verification Package* (BHI-01164)
- *Summary of Remedial Investigations at the 307 Retention Basins and the 307 Trenches (316-3), 300-FF-2 Operable Unit* (WHC-SD-EN-TI-279)
- *Phase I Remedial Investigation Report for the 300-FF-1 Operable Unit* (DOE/RL-92-43)
- *Limited Field Investigation Report for the 300-FF-2 Operable Unit* (DOE/RL-96-42)
- *Limited Field Investigation Report for Uranium Contamination in the 300-FF-5 Operable Unit at the 300 Area, Hanford Site, Washington* (PNNL-16435)
- *Uranium Geochemistry in Vadose Zone and Aquifer Sediments from the 300 Area Uranium Plume* (PNNL-15121)

Vertical profiles of vadose zone data were plotted for each of the 11 RI boreholes as well as for historical boreholes and test pits. The profiles present results for analytes that exceeded background concentrations and are depicted relative to depth, stratigraphy, the PRZ (as defined in Chapter 3), the water table, and

when applicable, structural features of the waste site and the maximum depth of remedial excavation. The maximum depth of remedial action, represented by a horizontal dashed line, is relevant in that contaminated materials above this horizon were removed. Radiological values shown in the vertical profiles have been decayed to 2012.

4.3.1 Analytes Excluded from Consideration

Soil analytical data sets applicable to RI waste sites often include analytes that can be characterized as (1) radionuclides with short half-lives (e.g., less than 3 years), (2) common laboratory contaminants, (3) essential nutrients, or (4) nontoxic substances. A number of these analytes are commonly not carried forward in the CERCLA process, as they can be shown to be either inconsequential or inappropriate for use in the evaluation of risk per the *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A): Interim Final* (EPA/540/1-89/002). Determination of target analytes that could be excluded from consideration in the 300 Area soils is documented in *Identification of 300-Area Contaminants of Potential Concern for Soil* (WCH-333). Tables 4-2 and 4-3 are from *Identification of 300-Area Contaminants of Potential Concern for Soil* (WCH-333), with updates made for the RI/FS, including:

- Nitrate was inadvertently included on the exclusion list provided in *Identification of 300-Area Contaminants of Potential Concern for Soil* (WCH-333). It has subsequently been removed from Table 4-2 below and is discussed as appropriate in the individual site sections that follow.
- Fluoride was excluded in *Identification of 300-Area Contaminants of Potential Concern for Soil* (WCH-333), but was included in the 300 Area SAP (DOE/RL-2009-45). Therefore, detections greater than background have been presented in the profiles, and are called out in the text.
- Sulfate is addressed in the secondary DWS, and has been excluded from consideration.
- Bismuth was included as a COPC in *Identification of 300-Area Contaminants of Potential Concern for Soil* (WCH-333), but only nominal hits were measured in borehole samples and therefore it is not considered further. The maximum value detected was 30.9 mg/kg at Borehole C7658 (Well 399-6-3).
- Bis(2-ethylhexyl)phthalate was included as a COPC in *Identification of 300-Area Contaminants of Potential Concern for Soil* (WCH-333), with the maximum concentration detected being 1.14 mg/kg at Borehole C7653 (Well 399-1-54, associated with WIDS Site 316-2). Phthalates are common laboratory contaminants with the levels observed consistent with laboratory sample contamination; therefore, bis(2-ethylhexyl)phthalate will not be further considered.
- Butylbenzylphthalate was also included in *Identification of 300-Area Contaminants of Potential Concern for Soil* (WCH-333), with a maximum concentration of 0.399 mg/kg found in Borehole C7655 (Well 399-1-56, associated with WIDS Site 316-5). Similar to bis(2-ethylhexyl)phthalate, butylbenzylphthalate will not be further considered.

Table 4-2 lists analytes that are excluded from consideration in the vadose zone, and the associated rationale. Table 4-3 provides analytes excluded from soil characterization in the 300 Area vadose zone OUs based on process knowledge.

Table 4-2. 300 Area Soil Analytes Excluded from Further Consideration

Analyte	Exclusion Rationale (Half-Life)	Daughters (Half-Life)
Radionuclides		
Antimony-125	Half-life less than 3 years (2.76 years)	Te-125m (58 days) Te-125 (stable)
Beryllium-7	Naturally occurring background radiation/half-life less than 3 years (53.4 days)	Li-7 (stable)
Carbon-14a	Activation product contained in the FFTF structure	N-14 (stable)
Cerium-144	Half-life less than 3 years (284.6 days)	Pr-144m (1.2 minutes), Pr-144 (17.28 minutes), Nd-144 (stable)
Cesium-134	Half-life less than 3 years (2.065 years)	Ba-134 (stable)
Iron-55a	Activation product contained in the FFTF structure/half-life less than 3 years (2.73 years)	Mn-55 (stable)
Manganese-54	Half-life less than 3 years (612.2 days)	Fe-54 (stable)
Molybdenum-93a	Activation product contained in the FFTF structure	Nb-93 (stable)
Nickel-59a	Activation product contained in the FFTF structure	Co-59 (stable)
Nickel-63a	Activation product contained in the FFTF structure	Cu-63 (stable)
Niobium-94a	Activation product contained in the FFTF structure	Mo-94 (stable)
Ruthenium-106	Half-life less than 3 years (1.020 years)	Rh-106 (29.9 seconds) and Pd-106 (stable)
Sodium-22	Half-life less than 3 years (2.6 years)	Ne-22 (stable)
Promethium-147	Half-life less than 3 years (2.6 years)	Sm-147 (stable, natural occurring)
Zinc-65	Half-life less than 3 years (244 days)	Cm-65 (stable)
Iodine-131	Half-life less than 3 years (8.02 days)	Xe-131m (11.8 days) Xe-131 (stable)
Iodine-133	Half-life less than 3 years (20.8 hours)	Xe-133m (2.19 days) Xe-133 (5.25 days) Cs-133 (stable)
Analyte	**Exclusion Rationale**	**Half-Life**
Potassium-40	Naturally occurring background radiation	1.28 billion years
Radium-226	Only potential source is natural background radiation (insufficient in-growth time for Hanford-introduced uranium as decay daughter of U-234/Th-230)	1,600 years
Thorium-228	Daughter of Th-232/Ra-228; in equilibrium with parent	1.91 years
Thorium-232	Naturally occurring background radiation	14 billion years
Lead-212	Daughter of Th-232/Ra-228; in equilibrium with parent	10.6 hours
Nonradionuclides		
Acetone	Laboratory contaminant	
Aluminum	Essential nutrient (minerals)	
Phosphate	Essential nutrient (minerals)	
Potassium	Essential nutrient	
Ammonia	No soil toxicity information available	
Chloride	No soil toxicity information available	
Graphite	No soil toxicity information available	

Table 4-2. 300 Area Soil Analytes Excluded from Further Consideration

Analyte	Exclusion Rationale (Half-Life)	Daughters (Half-Life)
Nitrite	No soil toxicity information available	
Sulfate	No soil toxicity information available	
Sulfide	No soil toxicity information available	
Zirconium	No soil toxicity information available	
Methanol	Naturally occurring, readily biodegradable organic compound	

FFTF = fast flux test facility

Table 4-3. Other 300 Area Soil Analytes Excluded from Characterization

Analyte	Exclusion Basis
Methyl isobutyl ketone (hexone)	No known discharges of these volatile/semivolatile organic compounds to 300 Area locations proposed for characterization.
Methyl ethyl ketone	
Ethylene glycol	
Normal paraffin hydrocarbon (kerosene)	These organics are potentially present only in association with oils and solid bituminous materials used in construction. These compounds do not represent a significant potential contributor to cumulative risk in the quantities in which they would be present relative to other total petroleum hydrocarbons.
Total petroleum hydrocarbons	
Cyanide	Not associated with 300 Area processes.
Chromium (hexavalent)	
Asbestos	Potentially present in mastic coatings and facilities but would not have an impact to remaining soils.

4.3.2 Potential Stainless Steel Contamination in 300 Area RI Samples

Upon review of the analytical data from the vadose zone soil samples, some of the total chromium and nickel results appear anomalous when compared to other results from neighboring intervals in the same boring and duplicate sample results. This trend of elevated total chromium and nickel results occur primarily within a ratio of 1.5 to 2.2, total chromium to nickel. The ratio between the metals generally decreases as the analytical result approaches background values of total chromium (18.5 mg/kg) and nickel (19.1 mg/kg). Table 4-4 presents data for the corresponding wells and intervals in 300 Area boreholes that show the elevated total chromium and nickel results potentially attributable to stainless steel contamination and the relative ratios of total chromium to nickel in these samples.

Table 4-4. Borehole Samples with Suspected Stainless Steel Contamination

Borehole ID	Interval	Sample	Chromium (total) (mg/kg)	Nickel (mg/kg)	Ratio of Chromium (total) to Nickel
C7657	I-006	B27JP2	86.2	49.9	1.73
C7659	I-007	B27R46	53.2	28.5	1.87
C7660	I-007	B27PH7	48.9	29.5	1.66

The discussion of elevated concentrations of the other metals in the presence of total chromium is predicated on the fact that these metals are all components of various alloys of steel. The shoes that are used on the split spoons are made of 4140 alloy steel, the split spoons are DOM 520 steel, and the periodically used stainless steel liners are 304 stainless. The use of steel to drill and collect subsurface soils is the only method available to obtain analytical samples, and with it, comes the potential of introducing some contamination attributable to the sampling approach.

Given that the DOM 520 steel does not contain any total chromium, molybdenum, or nickel, it can be discounted as a source of the elevated concentrations. The 4140 alloy steel contains between 0.80 and 1.10 percent by weight of total chromium and 0.15 to 0.25 percent molybdenum. For the 304 stainless, total chromium is much more prevalent, ranging from 18 to 20 percent. The 304 stainless also contains nickel at 8 to 12 percent.

Results from C7660, Interval I-007 (Sample B27PH7), serve as an example of the potential stainless steel signature observed in selected samples. Elevated total chromium (48.9 mg/kg) and nickel (29.5 mg/kg) were measured potentially due to stainless steel contamination (Table 4-5). Results in this sample, collected above the water table, are more than three times those measured for total chromium and nickel in sample intervals both above and below this interval (Table 4-5). Given that both analytes are elevated in a ratio within the bounds of stainless steel and samples collected above or below this interval do not show elevated metals, it is likely that stainless steel is causing elevated total chromium and nickel results in this sample result from Interval I-007.

Table 4-5. Borehole C7660, Interval I-007 (Sample B27PH7) Chromium (total) and Nickel Results Relative to Neighboring Interval Sample Results

Interval	Sample	Sample Depth (ft)	Chromium (total) (mg/kg)	Nickel (mg/kg)
C7660; I-005	B27PH5	25.5	10.4	7.68
C7660; I-006	B27PH6	28.0	16.0	8.96
C7660; I-007	B27PH7	30.5	48.9	29.5
C7660; I-008	B27PJ1	33.0	11.2	6.00
C7660; I-009	B27PH8	35.5	7.75	5.60

4.3.3 300 Area Industrial Complex Nature and Extent

This section presents the nature and extent of vadose zone contamination organized by the following:

- Residual soil contamination beneath the closed out FF-1 OU high-volume liquid discharge waste sites, including historical verification sample results, historical LFI sampling results, and new RI sample results
- Residual soil contamination beneath the interim-closed FF-2 OU waste sites
- Soil sample results collected from the newly installed RI wells

Table 4-6 lists new RI boreholes, historical LFI sampling locations, and associated waste sites. Figure 4-1 illustrates the waste sites and associated sampling locations discussed in this chapter. The following subsections present and interpret analytical data compiled from the vadose zone characterization samples. The discussion follows the order of presentation in Table 4-6.

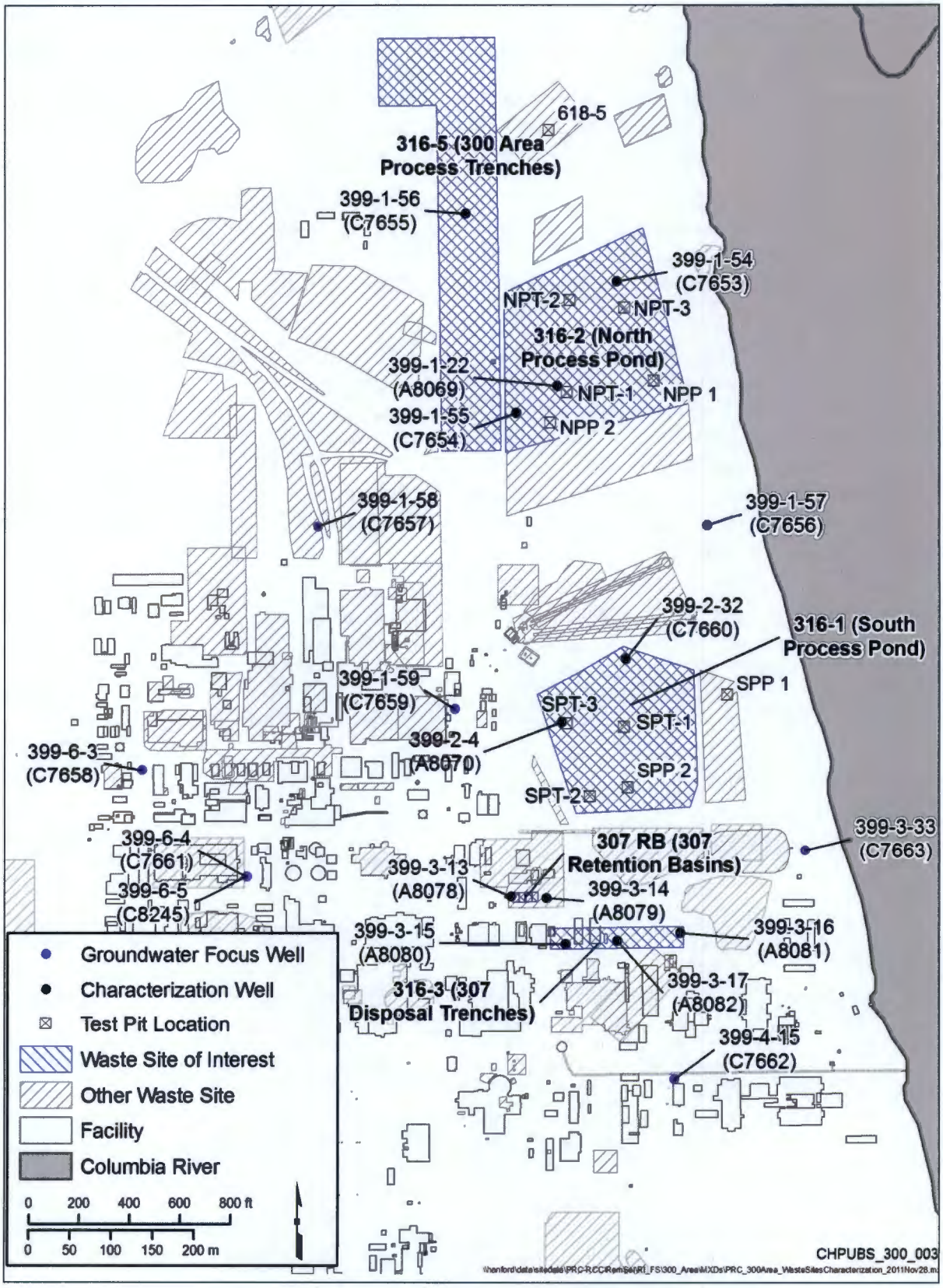


Figure 4-1. Location Map for Waste Sites of Interest

Table 4-6. Summary Table of Characterization Boreholes and Test Pits

Waste Site Name (WIDS CODE)	SAP/RI Well ID	HEIS Borehole ID	HEIS Well ID	Sample Date
South Process Pond (WIDS Site316-1)	300-DU-11	C7660	399-2-32	Nov-2010
	NA (LFI 1991)	A8070	399-2-4	Sep-1991
		Test Pits SPT-1, SPT-2, SPT-3		
North Process Pond (WIDS Site 316-2)	300-DU-8	C7653	399-1-54	Sep-2010
	300-DU-9	C7654	399-1-55	Aug-2010
	NA (LFI 1991)	A8069	399-1-22	Oct-1991
		Test Pits NPT-1, NPT-2, NPT-3		
300 Area Process Trenches (WIDS Site 316-5)	300-DU-10	C7655	399-1-56	Sep-2010
307 Disposal Trenches (WIDS Site 316-3)	NA (LFI 1991)	A8080	399-3-15	Jan-1992
		A8081	399-3-16	Dec-1991
		A8082	399-3-17	Jan-1992
307 Retention Basins	NA (LFI 1991)	A8078	399-3-13	Oct-1991
		A8079	399-3-14	Nov-1991
Non-Specific (Groundwater Focus)	300-DU-1	C7657	399-1-58	Aug-2010
	300-DU-2	C7658	399-6-3	Dec-2010
	300-DU-3	C7659	399-1-59	Dec-2010
	300-DU-4	C7661	399-6-4*	Dec-2010
		C8245	399-6-5	Jan-2011
	300-DU-5	C7662	399-4-15	Jan-2011
	300-DU-6	C7656	399-1-57	Aug-2010
	300-DU-7	C7663	399-3-33	Nov-2010

Sources:

DOE/RL-92-43, *Phase I Remedial Investigation Report for the 300-FF-1 Operable Unit.*

DOE/RL-2009-45, *300 Area Remedial Investigation/Feasibility Study Sampling and Analysis Plan for the 300-FF-1, 300-FF-2 and 300-FF-5 Operable Units.*

WHC-SD-EN-TI-038, *Summary of Drilling and Test Pit Activities for the 300-FF-1 Operable Unit Phase I Soil Sampling Investigation.*

* Obstruction at roughly 13.1 m (43 ft) bgs below-grade prevented installation of well.

SAP = Sampling and Analysis Plan

R = remedial investigation

HEIS = Hanford Environmental Information System

NA = not applicable

LFI = limited field investigation

4.3.3.1 Residual Contamination beneath the South Process Pond (WIDS No. 316-1); 1991 LFI; Borehole C7660; Well 300-DU-11

The South Process Pond (WIDS Site 316-1) was constructed in 1943 as the first process liquid waste disposal facility for the 300 Area. It was initially a single infiltration basin roughly 45,500 m^2 (490,000 ft^2) in area and 1.5 m (5 ft) deep, with its inlet at the southwest corner (*Compilation of Historical Information of 300 Area Facilities and Activities* [WHC-MR-0388]). Subsequent modifications reduced its size slightly and altered its configuration, moving the inlet to the northwest corner and using earthen dikes to form three small settling ponds on the west, and a single larger infiltration pond to the east, all separated by earthen dikes. A subsequent modification split the larger infiltration pond into two separate ponds. Early waste streams were organic wastes containing uranium in small quantities, water from the fuels processing floor drains, and aqueous wastes containing unirradiated uranium from the 3706 and 321 Laboratories. The South Process Pond was taken out of service in 1975, although the easternmost infiltration pond received filter backwash effluent from the 300 Area water treatment plant until late 1986. This easternmost pond was subsequently assigned WIDS site code 300 RFBP.

The WIDS Site 316-1 waste site was remediated and reclassified in 2003 as closed out in conjunction with the adjacent 300 RFBP and 300-262 Contaminated Soil West of South Process Pond waste sites, and the collocated UPR-300-32, UPR-300-33, UPR-300-34, UPR-300-35, UPR-300-36, and UPR-300-37 waste sites under the 300-FF-1 and 300-FF-5 ROD (EPA/ROD/R10-96/143). Remediation of the site was completed in 2000 and extended to a maximum depth of 5.5 m (18 ft) bgs. It was selected for characterization under the RI to provide additional information on the concentration and distribution of contaminant uranium in the subsurface beneath major liquid waste disposal sites (RI data needs 2 and 7).

Discussion of the nature and extent of residual contamination in the vadose zone at the 316-1 waste site is based on data from the following:

- RI Borehole C7660 (RI Well 300-DU-11/HEIS Well 399-2-32)
- Cleanup verification sampling, documented in *Cleanup Verification Package for the South Process Pond (WIDS Site 316-1), the Retired Filter Backwash Pond (WIDS Site 300 RFBP), 300-262 Contaminated Soil, and Unplanned Release Sites UPR-300-32, UPR-300-33, UPR-300-34, UPR-300-35, UPR-300-36, UPR-300-37, and UPR-300-FF-1* (CVP-2003-00002)
- A 1991 LFI, documented in *Phase I Remedial Investigation Report for the 300-FF-1 Operable Unit* (DOE/RL-92-43) (Borehole A8070 [Well 399-2-4] and test pits SPT-1, SPT-2, and SPT-3)

1991 Limited Field Investigation at WIDS Site 316-1. In 1991, an LFI was conducted to characterize the South Process Pond. Borehole A8070 (Well 399-2-4) and test pits SPT-1, SPT-2, and SPT-3 all generated samples from the vadose zone and the shallow portion of the unconfined aquifer. Figure 4-2 shows the site and the sampling locations.

LFI Borehole A8070 (Well 399-2-4). Borehole A8070 was drilled in September 1991 (prior to remedial action [RTD] to 5.7 m [19 ft] bgs) in the northwest quadrant of the South Process Pond to a total depth of 10.7 m (35 ft) bgs, encountering the water table at 7.6 m (25 ft) bgs. Samples were collected across nine discrete depth intervals located within the vadose zone, the PRZ, near the water table, and within the upper portion of the unconfined aquifer. Analytical results are summarized in Tables 4-7 and 4-8 and presented in Figure 4-3.

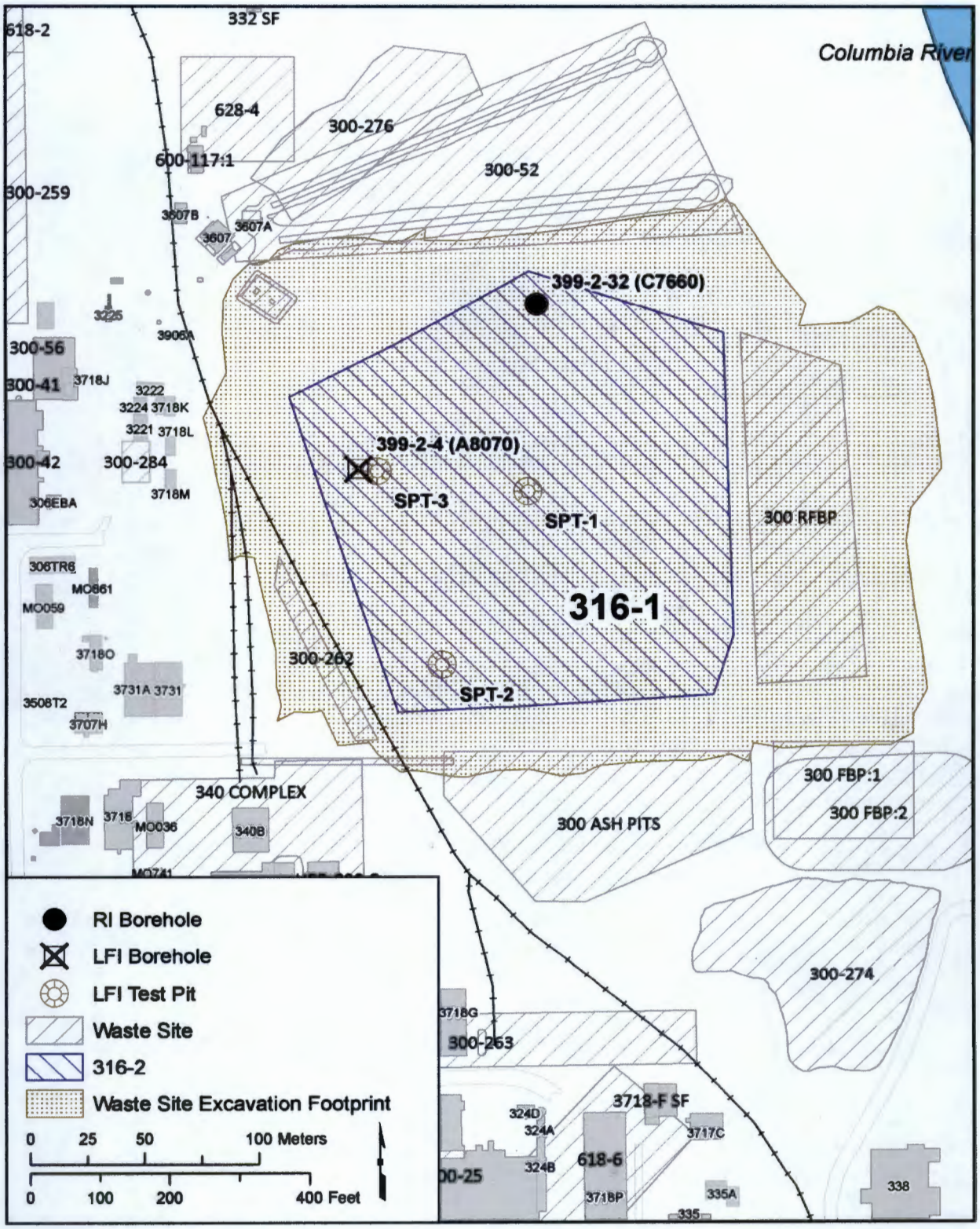


Figure 4-2. Sampling Location Map for Waste Site 316-1

Cobalt-60 (Co-60) and the three targeted uranium isotopes were the only radionuclides detected, all with maximum activity at 1.8 m (6 ft) bgs. The maximum Co-60 activity was very low (0.388 pCi/g [decayed to 2012]) at that depth; its only other detection was more than 1.5 m (5 ft) below the water table (0.006 [decayed to 2012] at 9.8 m [32 ft] bgs). Maximum detected activities for uranium-234 (U-234), uranium-235 (U-235), and uranium-238 (U-238) were 40, 2.00, and 36 pCi/g, respectively. Activities decreased substantially in the subsequent two samples, and stayed relatively low for the remainder of the borehole. Uranium-234 and U-238 activities were detected at approximately 2.6 pCi/g in the samples collected at 5.2 and 6.7 m (17 and 22 ft) bgs, and approximately 1.2 pCi/g in the sample collected at 8.2 m (27 ft) bgs, just below the water table. Uranium-235 was detected at 0.2 pCi/g at 5.2 and 6.7 m (17 and 22 ft) bgs, but was not detected in the sample collected just below the water table. These results suggest a minor residual contaminant mass in the deep vadose zone at this location.

The maximum total uranium concentration, as calculated from the isotopic values, was 108 mg/kg at 1.8 m (6 ft) bgs. Concentrations in the deep vadose zone were 8.1 mg/kg at 6.7 m (22 ft) bgs, and 3.3 mg/kg at 8.2 m (27 ft) bgs.

Antimony, chromium, copper, lead, mercury, nickel, silver, and zinc were all detected above background levels. Antimony was detected only at 1.4 m (4.5 ft) bgs, where it exceeded background at a concentration of 15.4 mg/kg. Mercury was detected at 1.8 and 2.3 m (6 and 7.5 ft) bgs, exceeding background in both samples, with a maximum concentration of 0.220 mg/kg at 1.8 m (6 ft) bgs. Silver was detected only at 1.8 m (6 ft) bgs, where it exceeded background at a concentration of 5.00 mg/kg. Concentrations of chromium, nickel, and zinc were highest at about 1.8 m (6 ft) bgs, with maximums of 36.4, 68.3, and 98.5 mg/kg, respectively, but were below background levels in samples collected at 3 m (10 ft) bgs or deeper. Copper and lead also had maximum concentrations at about 1.8 m (6 ft) bgs, but were also detected slightly above their background levels in the deep vadose zone. Copper was detected above background in the samples collected at 5.2 and 6.7 m (17 and 22 ft) bgs, with a maximum concentration of 29.6 mg/kg at 5.2 m (17 ft) bgs. Lead was only detected above background in the sample collected below the depth of remediation (5.7 m [19 ft] bgs), in the water table, showing a concentration of 12.7 mg/kg at 8.2 m (27 ft) bgs. The data suggest no substantive residual contaminant mass for metals, including uranium, in the deep vadose zone.

Fluoride was the only anion detected above its background level. It exceeded its background level in all samples collected above or at the water table, with a maximum of 5.23 mg/kg at 6.7 m (22 ft) bgs.

Aroclor 1254, the only organic compound detected, was found only at shallow depths, with a maximum concentration of 0.210 mg/kg in the sample collected at 1.8 m (6 ft) bgs. The very low concentration and limited vertical extent suggest essentially no residual mass.

LFI Test Pit SPT-1. Test Pit SPT-2 was excavated in November 1991 (prior to remedial action [RTD] to 5.7 m [19 ft] bgs) near the center of the South Process Pond. It was excavated to a total depth of 10.7 m (35 ft) bgs, encountering the water table at 9.1 m (30 ft) bgs. Samples were collected at 10 depth intervals, incorporating the vadose zone, including the PRZ, as well as the water table, and the upper portion of the unconfined aquifer. Vertical profiles of the analytical results are presented in Figure 4-4 (the radionuclide results in Figure 4-4 have been decayed to 2012 values). The analytical results (original 1991 and decayed radionuclides results) are summarized in Table 4-7.

Table 4-7. Waste Site 316-1 LFI Test—Summary of Contaminant Soil Data Pits (SPT-1, SPT-2, and SPT-3)

Constituent	Background	Concentration and Distribution														
		LFI Test Pit SPT-1[a]					LFI Test Pit SPT-2[b]					LFI Test Pit SPT-3[c]				
		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (10.7 m/35 ft bgs)		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (12.5 m/41 ft bgs)		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (12.2 m/40 ft bgs)	
Radionuclides (Original and Decayed Concentrations) (pCi/g)[d]																
		Original	Decayed		Original	Decayed	Original	Decayed		Original	Decayed	Original	Decayed		Original	Decayed
Cesium-137	NA	0.350 (0.5/1.5)	0.252	0.5/1.5	U	NA	0.353 (1.4/4.5)	0.254	1.8/6	U	NA	0.628 (0.5/1.5)	0.452	0.9/3)	U	NA
Cobalt-60	NA	4.18 (0.5/1.5)	0.264	6.4/21.0	U	NA	20.3 (1.4/4.5)	1.28	12.5/41	0.101	0.00600	81 (0.5/1.5)	5.11	12.2/40	0.0400	0.00300
Strontium-90	NA	0.600 (0.5/1.5)	0.400	0.5/1.5	U	NA	0.800 (0.9/3 and 1.4/4.5)	0.5	12.5/41	0.0500	0.0300	3.00 (3.4/11)	1.80	9.5/31	U	NA
Uranium-234	1.1	20 (0.5/1.5)	20.0	10.7/35.0	3.00	3.00	62 (0.5/1.5)	62.0	11.0/36	0.900 (<BG)	0.900 (<BG)	1230 (0.5/1.5)	1230	12.2/40	1.00 (<BG)	1.00 (<BG)
Uranium-235	0.109	1.80 (0.5/1.5)	1.80	10.7/35.0	0.300	0.300	2.4 (0.5/1.5)	2.40	11.0/36	0.0500 (<BG)	0.0500 (<BG)	75 (0.5/1.5)	75.0	12.2/40	7.20	7.20
Uranium-238	1.06	20.5 (0.5/1.5)	20.5	10.7/35.0	3.10	3.10	56 (0.5/1.5)	56.0	11.0/36	1.00 (<BG)	1.00 (<BG)	980 (0.5/1.5)	980	12.2/40	1.10	1.10
Nonradionuclides (mg/kg)																
Barium	132	152 (0.2/0.5)		7.9/26.0	85.5 (<BG)		158 (1.4/4.5)		1.4/4.5	107 (<BG)		245 (0.5/1.5)		0.5/1.5	85.2 (<BG)	
Beryllium	1.51	U		NA	0.70 (<BG)		U		NA	U		3.2 (0.5/1.5)		0.5/1.5	0.39 (<BG)	
Cadmium	0.563	0.760 (0.2/0.5)		0.2/0.5	U		0.990 (1.4/4.5)		1.4/4.5	U		13.2 (0.5/1.5)		0.5/1.5	U	
Chromium	18.2	171 (0.2/0.5)		0.5/1.5	8.4 (<BG)		110 (1.4/4.5)		1.4/4.5	8.2 (<BG)		604 (0.5/1.5)		0.5/1.5	4.1 (<BG)	
Copper	22	2750 (0.2/0.5)		7.9/26.0	18.4 (<BG)		2820 (1.4/4.5)		12.5/41	65.8		95300 (0.5/1.5)		9.5/31	17.4 (<BG)	
Lead	10.2	29.5 (0.2/0.5)		10.7/35.0	10.5		34.4 (1.4/4.5)		1.4/4.5	6.10 (<BG)		351 (0.5/1.5)		0.5/1.5	3.20 (<BG)	
Mercury	0.0131	1.10 (0.2/0.5)		10.7/35.0	0.340		4.80 (1.4/4.5)		12.5/41	0.130		9.30 (0.5/1.5)		12.2/40	0.120 (<BG)	
Nickel	19.1	217 (0.2/0.5)		1.8/6.0	7.7 (<BG)		329 (1.4/4.5)		1.8/6	U		1750 (0.5/1.5)		0.5/1.5	5.6 (<BG)	
Selenium[e]	0.78	4.50 (0.2/0.5)		3.4/11.0	U		4.30 (0.2/0.5)		12.5/41	1.00		4.20(4.9/16)		12.2/40	0.87	
Silver	0.167	18.4 (0.2/0.5)		6.4/21	U		47.1 (1.4/4.5)		1.4/4.5	U		362 (0.5/1.5)		0.5/1.5	U	
Thallium	0.185	0.250 (0.5/1.5)		0.5/1.5	U		U		NA	U		0.270 (4.9/16)		7.9/26.0	U	
Vanadium	85.1	59.4 (0.2/0.5) (<BG)		NA	26.8 (<BG)		64.8 (1.4/4.5) (<BG)		1.4/4.5	55.8 <BG		239 (0.5/1.5)		0.5/1.5	40.6 (<BG)	
Zinc	67.8	90.4 (0.2/0.5)		0.2/0.5	40 (<BG)		151 (1.4/4.5)		1.4/4.5	46.6 (<BG)		759 (0.5/1.5)		0.5/1.5	32.9 (<BG)	
Fluoride	2.81	12.4 (3.4/11)		10.7/35.0	3.10		11.4 (1.4/4.5)		12.5/41	4.86		21.5 (0.5/1.5)		12.2/40	15.0	
4-Methyl-2-pentanone	NA	U		NA	U		U		NA	U		0.00800 (9.5/31.0)		12.2/40	0.00600	
Aroclor 1248	NA	U		NA	U		U		NA	U		5.50 (0.5/1.5)		4.9/16	U	
Aroclor 1254	NA	0.150 (0.2/0.5)		0.5/1.5	U		0.260 (1.4/4.5)		1.4/4.5	U		9.00 (0.5/1.5)		4.9/16	U	

a. Test Pit data obtained from HEIS. Water table encountered at 9.1 m (30 ft) bgs. Test pit was dug to a total depth of 10.7 m (35 ft) (1991).
b. Test Pit data obtained from HEIS. Water table encountered at 10.7 m (35 ft) bgs. Test pit was dug to a total depth of 12.5 m (41 ft) (1991).
c. Test Pit data obtained from HEIS. Water table encountered at 10.7 m (35 ft) bgs. Test pit was dug to a total depth of 12.2 m (40 ft) (1991).
d. Original radiological data presented in the left column with decay corrected value to year 2012 in right column.
e. All analytical results for selenium in Test Pits SPT-1, SPT-2, and SPT-3 are flagged with a U and/or an R in DOE-RL-92-43, *Phase I Remedial Investigation Report for the 300-FF-1 Operable Unit*. These qualifiers were likely assigned during data validation but the validation package is not available. Data is not presented in profiles.

BG = background
NA = not applicable
ND = no data, not a contaminant of concern/contaminant of potential concern
U = undetected

Table 4-8. Waste Site 316-1 CVP and Boreholes—Summary of Contaminant Soil Data (399-2-4 and C7660)

Constituent	Concentration and Distribution												
	Background	Cleanup Verification Data[a]		LFI Borehole 399-2-4[b]					Remedial Investigation Borehole C7660[c]				
				Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (10.8 m/35 ft bgs)		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (10.8 m/35.5 ft bgs unless otherwise noted)	
Radionuclides (Original and Decayed Concentrations) (pCi/g)[d]													
		Original	Decayed	Original	Decayed		Original	Decayed	Original	Decayed		Original	Decayed
Cesium-137	NA	ND	ND	0.219 (2.3/7.5)	0.170	10.7/35.0	0.0390	0.0300	U	NA	NA	U	NA
Cobalt-60	NA	2.03	0.419	6.14 (1.8/6)	1.27	9.8/32.0	U	NA	U	NA	NA	U	NA
Uranium-233/234	1.1	21.2	21.2	40 (1.8/6)	4	8.2/27.0	0.900 (<BG)	0.900 (<BG)	9.68 (5.5/18)	9.68	10.8/35.5	1.41	1.41
Uranium-235	0.109	2.11	2.11	2.00 (1.8/6)	2.00	6.7/22.0	U	NA	0.574 (4.7/15.5)	0.574	5.5/18.0	U	NA
Uranium-238	1.06	19.6	19.6	36 (1.8/6)	36	8.2/27.0	0.800 (<BG)	0.800 (<BG)	9.09 (5.5/18)	9.09	10.8/35.5	1.41	1.41
Nonradionuclides (mg/kg)													
Antimony	0.13	ND		15.4 (1.4/4.5)		1.4/4.5	U		0.342 (5.5/18.0)		5.5/18.0	U	
Chromium	18.5	ND		36.4 (1.8/6)		1.8/6.0	4.6 (<BG)		48.5 (9.3/30.5)[e]		9.3/30.5	7.75 (<BG)	
Copper	22	ND		1280 (1.8/6)		6.7/22.0	15.5 (<BG)		30.6 (4.7/15.5)		5.5/18.0	11 (<BG)	
Lead	10.2	ND		15.7 (1.8/6)		8.2/27.0	3.3 (<BG)		4.19 (5.5/18.0) (<BG)		NA	2.21 (<BG)	
Mercury	0.0131	ND		0.22 (1.8/6)		2.3/7.5	U		0.055 (5.5/18.0)		5.5/18.0	U	
Molybdenum	0.47	ND		ND		ND	ND		2.33 (8.5/28)		10.8/35.5	1.15	
Nickel	19.1	ND		68.3 (1.8/6)		2.3/7.5	5.5 (<BG)		29.5 (9.3/30.5)[e]		9.3/30.5	5.60 (<BG)	
Silver	0.167	ND		5 (1.8/6)		1.8/6	U		U		NA	U	
Strontium	NA	ND		ND		ND	ND		28.7 (5.5/18)		10.8/35.5	16.9	
Thallium	0.185	ND		U		NA	U		0.202 (4.7/15.5)		4.7/15.5	U	
Tin	NA	ND		ND		ND	ND		3.83 (6.2/20.5)		10.8/35.5	2.73	
Uranium (total, calculated)[f]	3.21	ND		ND		ND	ND		27.3 (5.5/18)		10.8/35.5	4.20	
Zinc	67.8	ND		98.5 (1.8/6)		1.8/6.0	30.6 (<BG)		48.5 (7.8/25.5)		7.8/25.5	30.7 (<BG)	
Fluoride	2.81	ND		6.51 (2.3/7.5)		8.2/27.0	1.54 (<BG)		1.70 (6.2/20.5) (<BG)		NA	1.30 (<BG)	
2-Hexanone	NA	ND		U		NA	U		0.00600 (7/23)		7.0/23.0	U	
Aroclor 1248	NA	3.00		U		NA	U		U		NA	U	
Aroclor 1254	NA	0.091		0.210 (1.8/6)		2.3/7.5	U		0.00900 (4.7/15.5)		5.5/18.0	U	
Aroclor 1260	NA	ND		U		NA	U		0.00700 (4.7/15.5)		5.5/18.0	U	

a. Verification sample results represent the 95% UCL concentration from the shallow zone decision unit. Verification 95% UCL values were obtained from *Cleanup Verification Package for the South Process Pond (WIDS Site 316-1), the Retired Filter Backwash Pond (WIDS Site 300 RFBP), 300-262 Contaminated Soil, and Unplanned Release Sites UPR-300-32, UPR-300-33, UPR-300-34, UPR-300-35, UPR-300-36, UPR-300-37, and UPR-300-FF-1* (CVP-2003-00002). Maximum depth of interim remedial action was 5.5 m (18 ft) bgs.

b. Borehole data obtained from HEIS. The water table was encountered at 7.6 m (25 ft) bgs. Well was drilled to 10.7 m (35 ft) total depth (1991).

c. Borehole data obtained from HEIS. The water table was encountered at 9.9 m (32.5 ft) bgs. Well was drilled to 36.9 m (121 ft) total depth (2010).

d. Original radiological data presented in the left column with decay corrected value to year 2012 in right column. Data from closeout sampling 95% UCL values obtained using U-flagged data sets is not decayed.

e. Results of chromium and nickel in B27PH7 collected at 9.3 m (30.5 ft) bgs indicate potential stainless steel contamination in the sample. Nickel concentrations are less than background in all other borehole samples. Concentrations of chromium and nickel are less than background in the sample intervals above and below B27PH7 collected at 8.5 m (28 ft) and 10.1 m (33 ft) bgs, respectively. See stainless steel contamination discussion in Section 4.3.2.

f. Total calculated uranium value is calculated based on analytical results for uranium isotopes.

BG = background
NA = not applicable
ND = no data, not a contaminant of concern/contaminant of potential concern
U = undetected
UCL = upper confidence limit

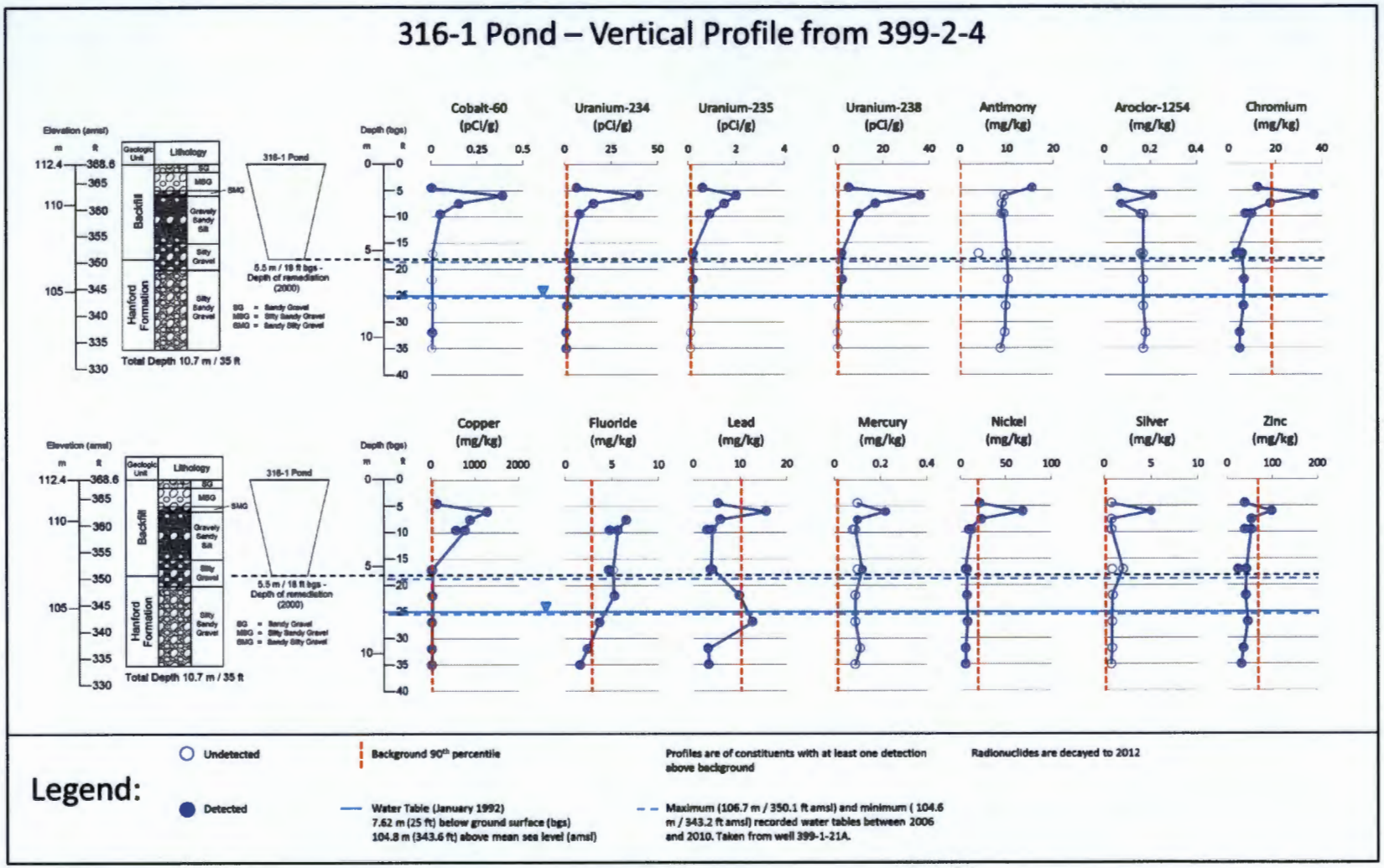


Figure 4-3. Vertical Profile from LFI Borehole A8070 (Well 399-2-4) at Waste Site 316-1

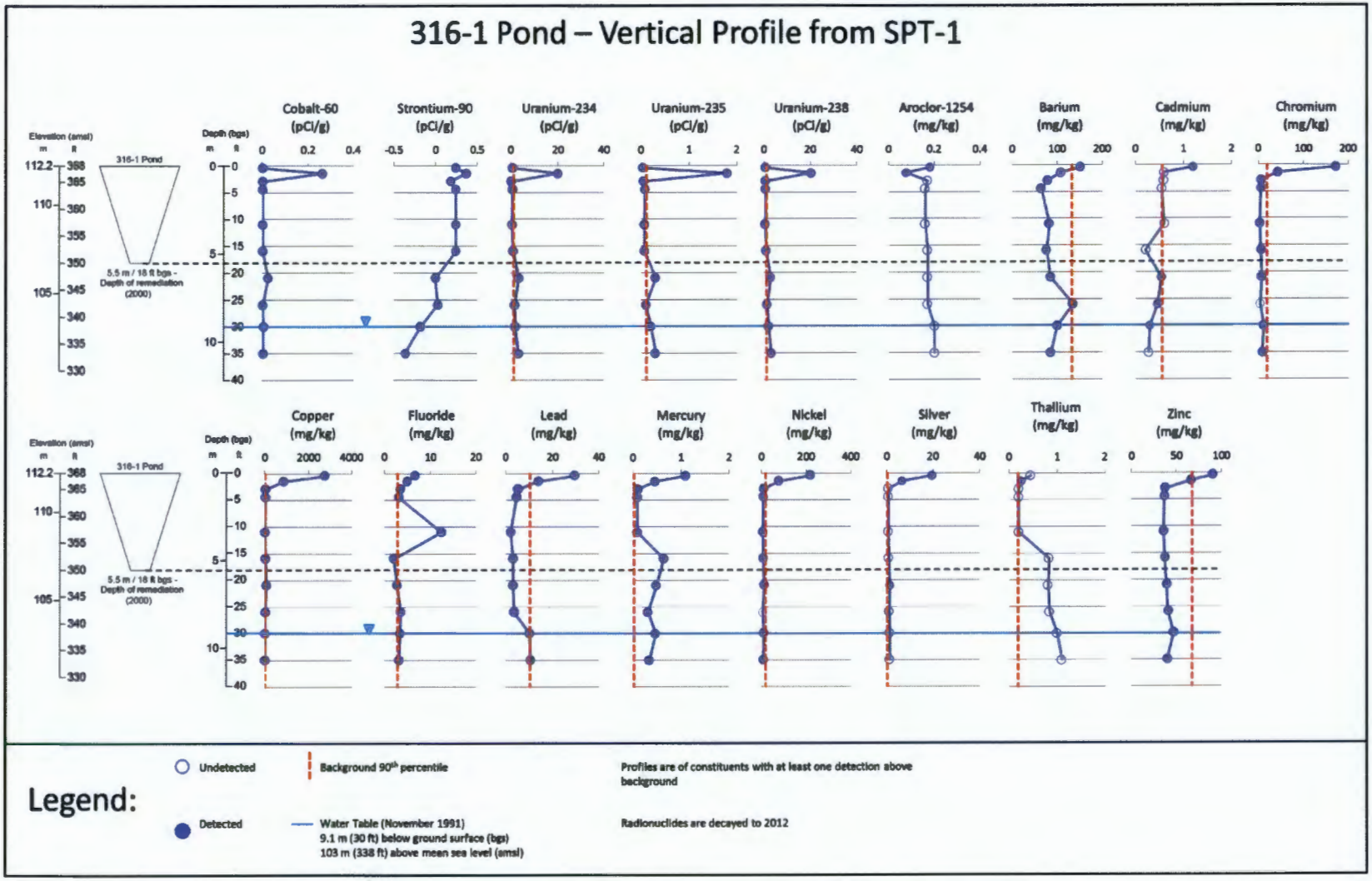


Figure 4-4. Vertical Profile from LFI Test Pit SPT-1 at Waste Site 316-1

Radionuclides detected at Test Pit SPT-1 included Co-60, strontium-90 (Sr-90), and the three uranium isotopes. The maximum activities for each of these radionuclides occurred in the sample collected at 0.5 m (1.5 ft) bgs, with all five having substantially lower values at increased depths. The original (November 1991) sample results for Co-60 and Sr-90 had maximum activities of 4.18 and 0.60 pCi/g, respectively. The original (November 1991) and decayed (2012) sample results for three uranium isotopes, U-234, U-235, and U-238, had maximum detections of 20 pCi/g, 1.8 pCi/g, and 20.5 pCi/g, respectively. In the deep vadose zone, the highest U-234 levels were 3.20 pCi/g at 6.4 m (21 ft) bgs, and 3 pCi/g at 10.7 m (35 ft) bgs (1.5 m [5 ft] below the water table). The highest U-235 level in the deep vadose zone was 0.300 pCi/g, found at both 6.4 m (21 ft) bgs and at 10.7 m (35 ft) bgs (well below the water table). The highest U-238 levels at depth were below the water table (3.1 pCi/g at 10.7 m [35 ft] bgs) (1.5 m [5 ft] below the water table). Co-60 was detected at a single depth (6.1 m [21 ft] bgs), at a concentration of 0.405 pCi/g. Strontium-90 was detected at 4.9 and 7.9 m (16 and 26 ft) bgs, with its highest concentration, 0.40 pCi/g, occurring at 7.9 m (26 ft) bgs.

The maximum total uranium concentration, as calculated from the isotopic values, was 61.8 mg/kg at 0.5 m (1.5 ft) bgs. The maximum uranium concentration detected in the deep vadose was 8.2 mg/kg at 6.4 m (21 ft) bgs.

Barium, cadmium, chromium, copper, lead, nickel, thallium, and zinc were all detected at concentrations above background levels, with all showing maximum concentrations in the sample collected at 0.5 m (1.5 ft). Concentrations decreased rapidly with depth, such that all were at or below background in the sample collected at 5 m (16 ft) bgs. Mercury was detected above background levels in most samples, including the deepest, and manifested a maximum concentration of 1.10 mg/kg at 0.2 m (0.5 ft) bgs. The data suggest no substantive residual contaminant mass for metals, including uranium, in the deep vadose zone. Silver levels exceeded background primarily in the very shallow samples, with a maximum concentration of 18.4 mg/kg at 0.2 m (0.5 ft) bgs.

Fluoride was the only anion detected above its background level. It exceeded its background concentration in three of the five samples, with a maximum of 12.4 mg/kg at 3.1 m (11 ft) bgs.

Aroclor 1254 was the only organic compound identified. It was found in the two shallowest samples only, with a maximum concentration of 0.150 mg/kg at 0.2 m (0.5 ft) bgs.

The maximum values for all of the analytes were detected in samples collected from shallow soils, which were removed during remedial excavation. The analytical data show no evidence of substantive residual contaminant mass in the deep vadose zone at the Test Pit SPT-1 location.

LFI Test Pit SPT-2. Test Pit SPT-2 was excavated in December 1991 (prior to remedial action [RTD] to 5.7 m [19 ft] bgs) in the southwest portion of the South Process Pond. It was advanced to a total depth of 12.5 m (41 ft), encountering the water table at 10.7 m (35 ft) bgs. Samples were collected at 12 depth intervals within the vadose zone, the PRZ, near the water table, and in the upper portion of the unconfined aquifer. Vertical profiles of the analytical results are presented on Figure 4-5 and the results are summarized in Table 4-7.

Cesium-137 (Cs-137), Co-60, Sr-90, and the uranium isotopes were all detected at concentrations above their respective background levels. Cesium-137, Co-60, and Sr-90 were detected at low activities in the shallow soils, each having its highest activity at 1.4 m (4.5 ft) bgs, and substantially lower levels in the remainder of the samples. Uranium-234, U-235, and U-238 also had their highest activities in shallow soils, with maximum activities (62, 2.4, and 56 pCi/g, respectively) occurring at 0.5 m (1.5 ft) bgs, and activities near background levels for the remainder of the samples. All three isotopes showed very slight activity increases in the sample collected at the water table.

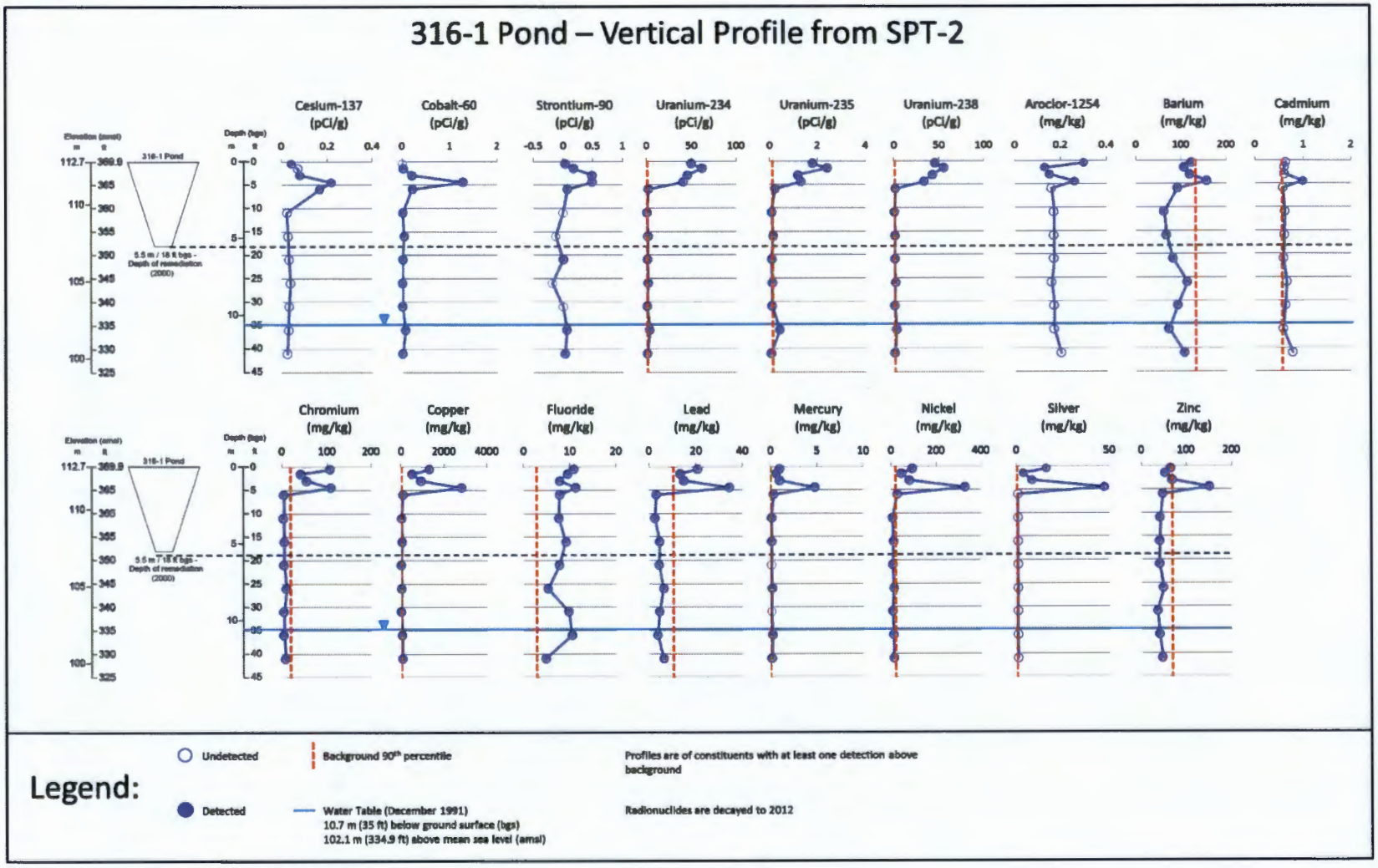


Figure 4-5. Vertical Profile from LFI Test Pit SPT-2 at Waste Site 316-1

The maximum total uranium concentration, as calculated from the isotopic values, was 138 mg/kg at 0.2 m (0.5 ft) bgs. The maximum concentration in the deep vadose zone was 8.8 mg/kg at 11 m (36 ft) bgs, in the sample collected at the water table.

A number of metals were detected at levels exceeding background levels, with all showing maximum concentrations at 1.4 m (4.5 ft) bgs. Maximum concentrations for copper (2,820 mg/kg) and silver (47.1 mg/kg) were two orders of magnitude above their respective background levels. Maximums for nickel (329 mg/kg), mercury (4.80 mg/kg), and chromium (110 mg/kg) were a single order of magnitude above background levels. The other metals with maximums at this depth were barium (158 mg/kg), cadmium (0.990 mg/kg), lead (34.4 mg/kg), and zinc (151 mg/kg). Nickel and mercury were detected above background levels at 1.8 m (6 ft) bgs, but were below background levels in all deeper samples. Copper was the only metal detected above its background level in samples collected more than 1.8 m (6 ft) bgs. In the deeper portion of the vadose zone, copper showed a maximum concentration of 55.8 mg/kg, at 11 m (36 ft) bgs.

Fluoride was the only anion detected above its background level. Concentrations exceeded its background level in all samples, with the highest being 11.4 mg/kg in the sample from 1.4 m (4.5 ft) bgs.

Aroclor 1254, the only organic compound identified, was only detected in samples at 1.5 m (5 ft) bgs or less. Its maximum concentration was 0.26 mg/kg at 1.4 m (4.5 ft) bgs.

The maximum values for all of the analytes were detected in samples collected from shallow soils, which were removed during remedial excavation.

LFI Test Pit SPT-3. Test Pit SPT-3 was excavated in December 1991 (prior to remedial action [RTD] to 5.7 m [19 ft] bgs) in the northwest quadrant of the South Process Pond, roughly 7.6 m (25 ft) east-southeast of Borehole A8070 (Well 399-2-4). It was advanced to a total depth of 12.2 m (40 ft) bgs, encountering the water table at 10.7 m (35 ft) bgs. Samples were collected at 12 depth intervals within the vadose zone, the PRZ, near the water table, and in the upper portion of the unconfined aquifer. Vertical profiles of the analytical results are presented in Figures 4-6 and 4-7. The results are summarized in Table 4-7.

Radionuclides detected in these samples included Cs-137, Co-60, Sr-90, and the three uranium isotopes. The maximum activities for Cs-137 (0.628 pCi/g) and Co-60 (81.0 pCi/g [decayed to 5.84 pCi/g by 2012]) were detected at 0.5 m (1.5 ft) bgs. The maximum activity for Sr-90 was 3.00 pCi/g at 3.4 m (11 ft) bgs. The maximum activities for the three uranium isotopes all occurred in the 0.5 m (1.5 ft) bgs sample (U-234 at 1,230 pCi/g, U-235 at 75 pCi/g, and U-238 at 980 pCi/g). Uranium isotope levels dropped significantly in the next sample and remained relatively low through the remainder of the vadose zone.

The maximum total uranium concentration, as calculated from the isotopic values, was 2,990 mg/kg at 0.5 m (1.5 ft) bgs. The maximum concentration in the deep vadose was 20.7 mg/kg at 7.9 m (26 ft) bgs. The calculated total uranium concentration in the sediment sample collected at the water table was at 4.8 mg/kg.

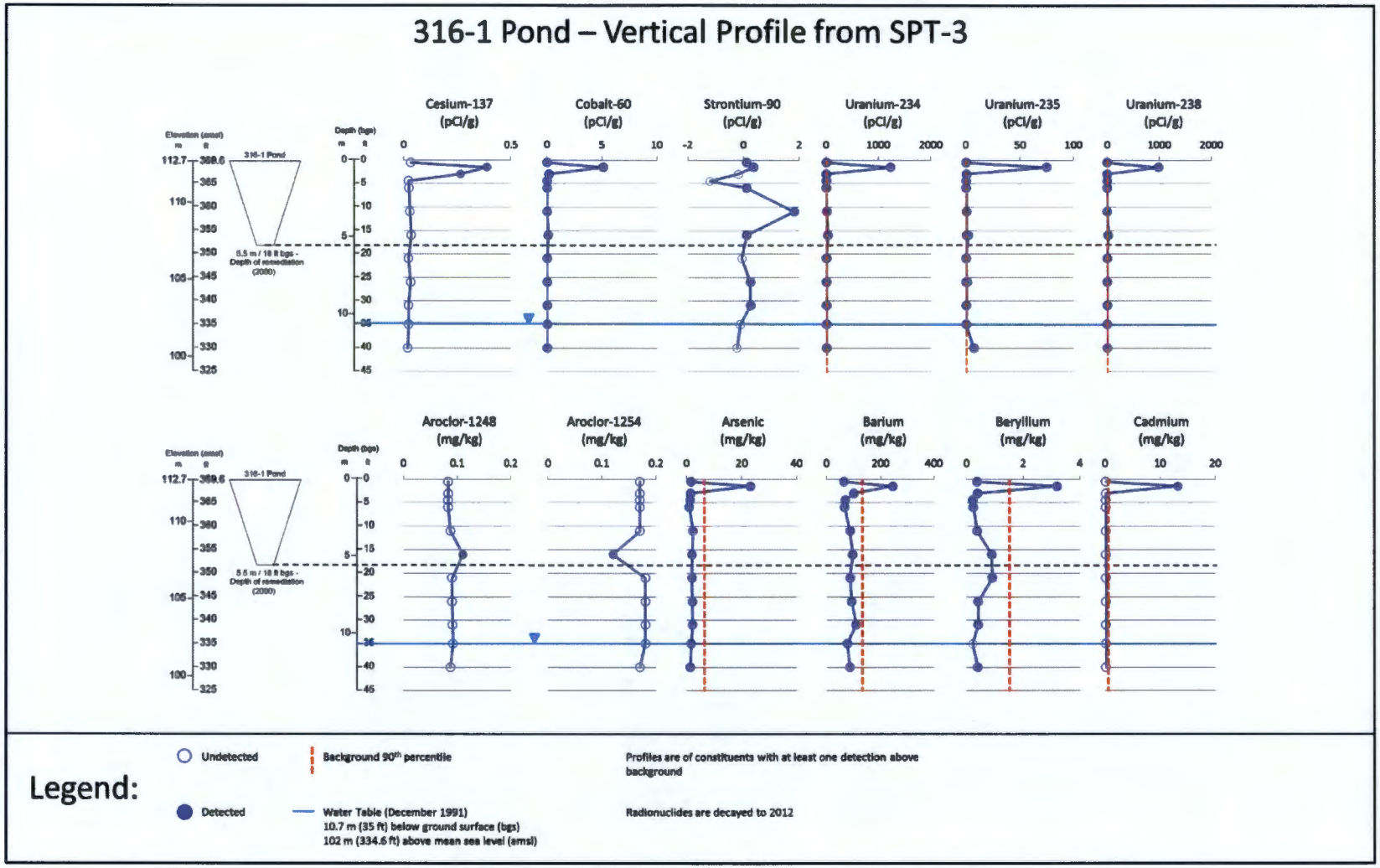


Figure 4-6. Vertical Profile from LFI Test Pit SPT-3 at Waste Site 316-1 (1 of 2)

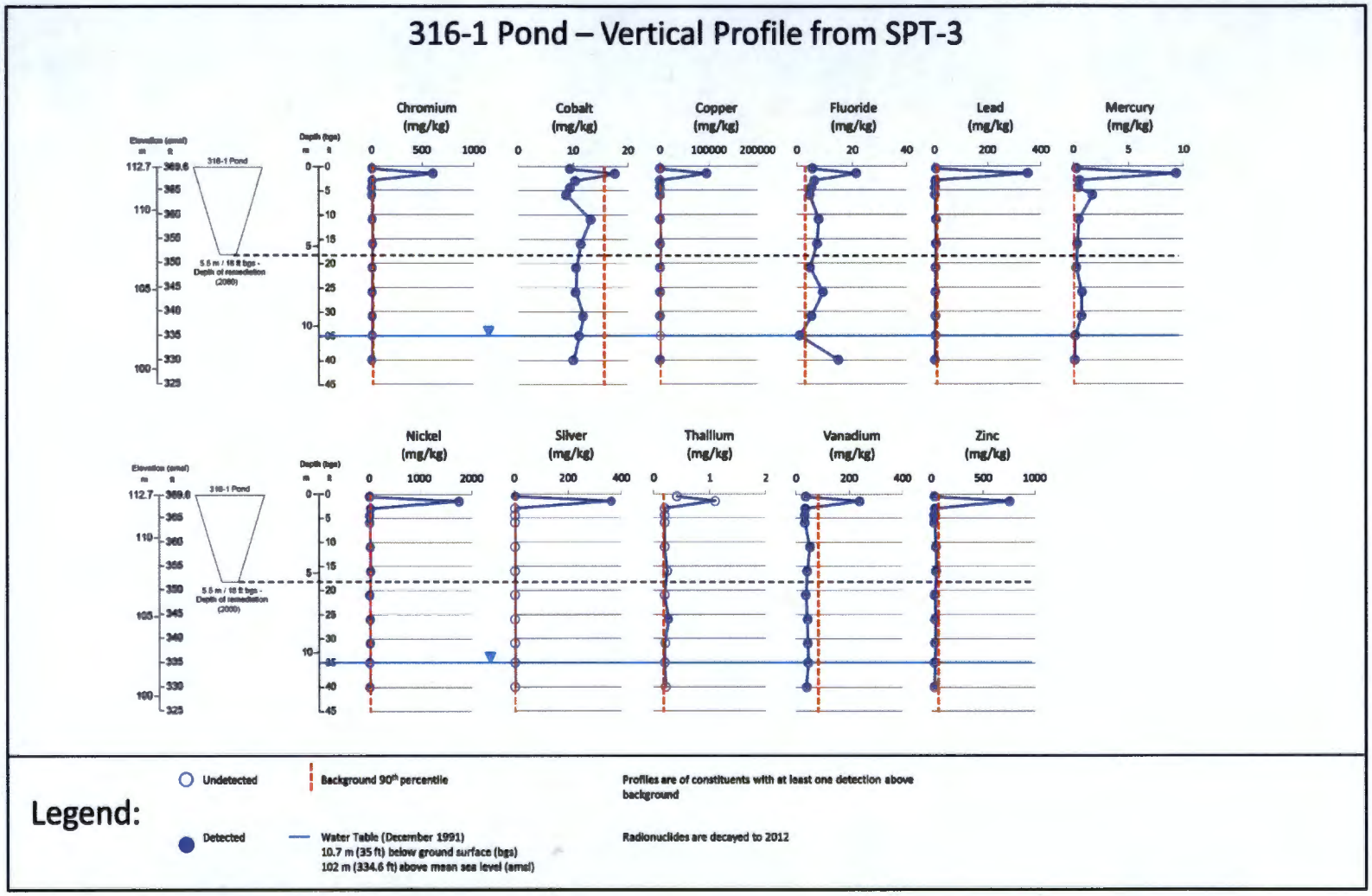


Figure 4-7. Vertical Profile from LFI Test Pit SPT-3 at Waste Site 316-1 (2 of 2)

Numerous metals were detected above background levels, including barium, cadmium, chromium, copper, lead, mercury, nickel, silver, vanadium, and zinc. All of these metals showed elevated concentrations in shallow soils, all with maximum concentrations at 0.5 m (1.5 ft) bgs. With the exception of mercury and copper, none of the metals showed substantive exceedance of its background level in the remainder of the soil column. Thallium levels exceeded background at 4.9 and 7.9 m (16 and 26 ft) bgs, with a maximum concentration of 0.270 mg/kg at 7.9 m (26 ft) bgs. In the deep vadose zone, copper and mercury showed a few detections beyond their background levels; most notably, copper was detected at 62.8 mg/kg at 7.9 m (26 ft) bgs, and mercury was detected slightly above 0.700 mg/kg at 7.9 m (26 ft) and 9.4 m (31 ft) bgs.

Fluoride was detected above its background level in all samples. Its maximum concentration of 21.5 mg/kg was detected at 0.5 m (1.5 ft) bgs.

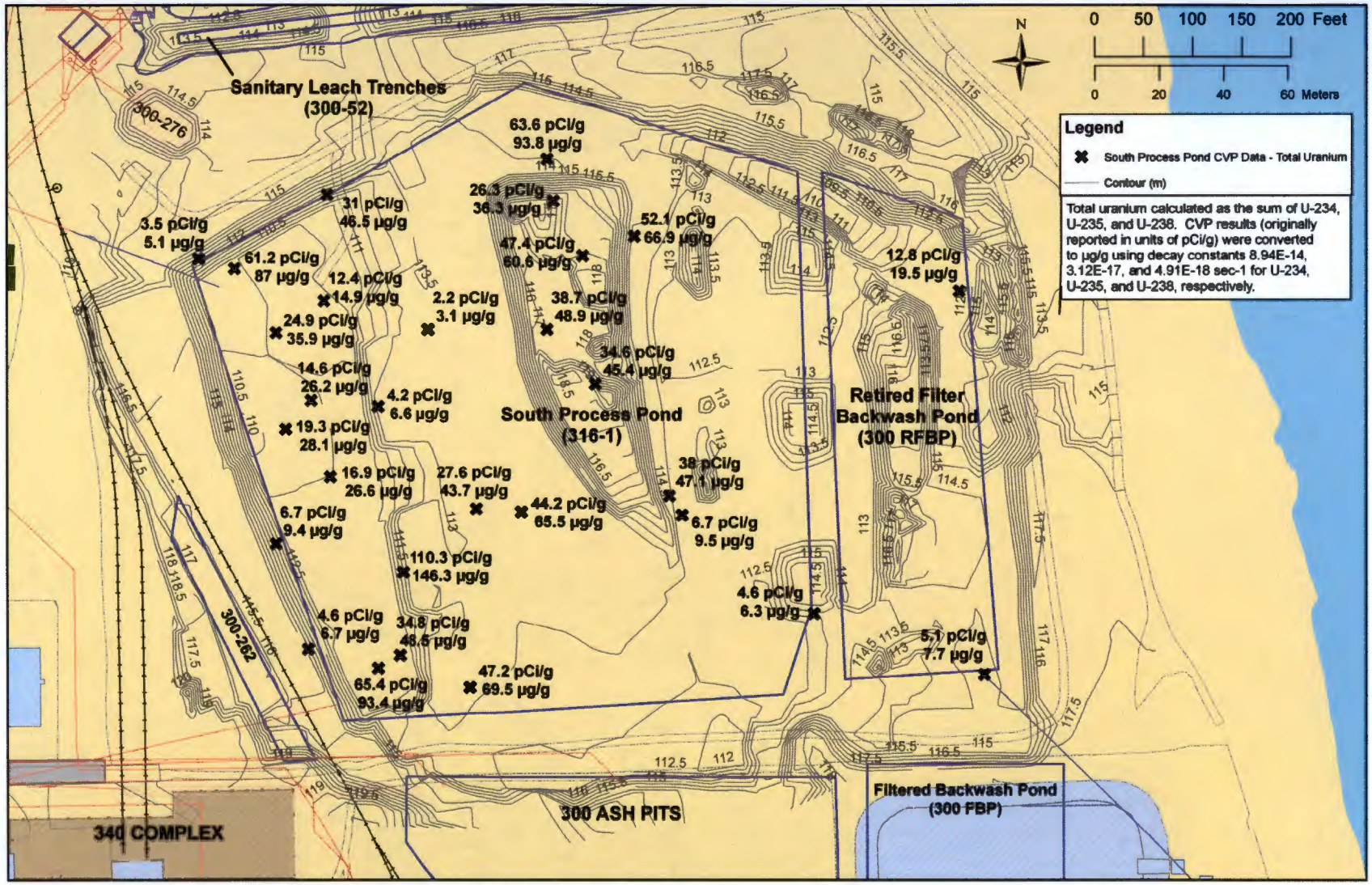
Three organic compounds were identified. 4-methyl-2-pentanone (methyl isobutyl ketone) was detected at 6.4 m (21 ft), 7.9 m (26 ft), 9.4 m (31 ft), and 10.7 m (35 ft) bgs, with its highest concentration of 0.008 mg/kg (below its practical quantitation limit [PQL]) at 9.4 m (31 ft) bgs. Aroclor 1248 and Aroclor 1254 were detected only in the sample from 4.9 m (16 ft) bgs, at concentrations of 0.11 and 0.12 mg/kg, respectively.

The maximum values for all of the analytes were detected in samples collected from shallow soils, which were removed during remedial excavation.

Cleanup Verification Sampling at WIDS Site 316-1. CERCLA closure of WIDS Site 316-1 was based on the remedial activities and verification sampling documented in *Cleanup Verification Package for the South Process Pond (WIDS Site 316-1), the Retired Filter Backwash Pond (WIDS Site 300 RFBP), 300-262 Contaminated Soil, and Unplanned Release Sites UPR-300-32, UPR-300-33, UPR-300-34, UPR-300-35, UPR-300-36, UPR-300-37, and UPR-300-FF-*1 (CVP-2003-00002). Remedial excavation extended to a maximum depth of about 5.5 m (18 ft) bgs. Approximately 234,000 metric tons (257,000 tons) of contaminated material were removed from the waste site and transported to the ERDF for disposition. After completion of the excavation activities, verification samples were collected at the lateral and vertical boundaries of the excavation and analyzed for cobalt-60, U-233/234, U-235, U-238 and PCBs. Table 4-8 summarizes the verification sampling analytical results. Site-specific modeling of the radionuclide and PCB verification results showed the site achieved applicable RAGs and the site was reclassified as closed out (*Cleanup Verification Package for the South Process Pond (WIDS Site 316-1), the Retired Filter Backwash Pond (WIDS Site 300 RFBP), 300-262 Contaminated Soil, and Unplanned Release Sites UPR-300-32, UPR-300-33, UPR-300-34, UPR-300-35, UPR-300-36, UPR-300-37, and UPR-300-FF-*1 [CVP-2003-00002]).

Figure 4-8 presents the uranium results for verification samples collected at 28 locations. The results are presented as both totaled uranium isotope activities (pCi/g) and total uranium (mg/kg). A total of 27 of the 28 verification samples exceeded the uranium background concentration of 3.21 mg/kg. Uranium concentrations ranged from 2.2 pCi/g (3.1 mg/kg total uranium) to 110.3 pCi/g (146.3 mg/kg total uranium). The maximum value was measured near the southwest corner of WIDS Site 316-1, South Process Pond, which was the primary inlet point of the 300 Area Process Sewer to the pond.

Additional soil samples were and analyzed for uranium from two trenches within the South Process Pond. The results were documented in *Uranium Geochemistry in Vadose Zone and Aquifer Sediments from the 300 Area Uranium Plume* (PNNL-15121). The trenches were dug with a backhoe through the bottom of the excavated (remediated) soil in the South Process Pond. In general, uranium concentrations tended to decrease with increasing depth.



Note: Total uranium results are presented as µg/g, which is the equivalent of mg/kg.

Figure 4-8. Uranium Results for Verification Samples at the South Process (WIDS 316-1) and Associated Site

RI Borehole C7660 (Well 399-2-32). Borehole C7660 was drilled in the north-central portion of the 316-1 waste site. It was advanced to a total depth of 36.9 m (121 ft) bgs, encountering the water table at about 9.9 m (32.5 ft) bgs. The upper 5.5 m (18 ft) bgs of the vadose zone is likely backfill material that was placed and graded following remedial excavation. Soil samples were collected at nine discrete intervals between 4 m (13 ft) and 9.9 m (32.5 ft) bgs within the vadose zone and the shallow portion of the unconfined aquifer. Analytical results for these samples are summarized in Table 4-8 and depicted in Figure 4-9.

The three uranium isotopes were the only radionuclides detected. All three exceeded background levels, with maximum activities occurring near the base of remedial excavation at 4.7 m (15.5 ft) or 5.5 m (18 ft) bgs. The maximum activities for U-233/234 and U-238 were 9.68 and 9.09 pCi/g, respectively, and both occurred at 5.5 m (18 ft) bgs. Both isotopes were detected at or slightly above background levels through the remainder of the vadose zone and into the upper portion of the unconfined aquifer. Uranium-235 activity levels were roughly 0.5 pCi/g at 4.7 and 5.5 m (15.5 and 18 ft) bgs; however, this isotope was not detected in the remainder of the vadose zone or in the shallow portion of the unconfined aquifer. Although elevated uranium activities were noted in the shallowest samples, the data suggest little residual uranium contaminant mass in the deep vadose zone.

Maximum total calculated uranium concentration was 22.5 mg/kg at 5.5 m (18 ft) bgs. Copper exceeded its background level in the two shallowest samples (30.6 mg/kg at 4.7 m [15.5 ft] bgs and 30.2 mg/kg at 5.5 m [18 ft] bgs). Chromium exceeded its background level in two samples, one at the base of remedial excavation (31 mg/kg at 5.5 m [18 ft] bgs) and one collected near the water table (48.9 mg/kg at 9.3 m [30.5 ft] bgs). Nickel also exceeded its background level in this same sample interval (29.5 mg/kg at 9.3 m [30.5 ft] bgs). Data from this sample suggests potential stainless steel contamination from sampling equipment, evidenced by increased concentrations of chromium and nickel (see Section 4.3.2 for discussion). Concentrations of chromium and nickel concentrations from intervals both above and below at 8.5 m (28 ft) and 10.1 m (33 ft) bgs, respectively, are less than background levels.

Thallium levels exceeded background only in the shallowest sample, collected at 4.7 m (15.5 ft) bgs, where its concentration was 0.202 mg/kg. Antimony and mercury exceeded background only in the two shallowest samples. Maximum concentrations for antimony (0.342 mg/kg) and mercury (0.055 mg/kg) were both found at 5.5 m (18 ft) bgs. Molybdenum levels exceeded background in all samples, with a maximum concentration of 2.33 mg/kg occurring at 8.5 m (28 ft) bgs. Concentrations of metals for which a background value is not available (strontium and tin) are consistent with concentrations measured in other 300 Area RI samples.

Three organic compounds were detected at very low concentrations. Aroclor 1254 and Aroclor 1260 were detected in only two samples, both at concentrations of less than 0.0100 mg/kg (below the PQL) in the samples collected at 4.7 and 5.5 m (15.5 and 18 ft) bgs. The third organic compound, 2-hexanone, was also detected at a concentration of less than 0.01 mg/kg (also below its PQL), with the qualifier that the analyte was also detected in the associated QC blank.

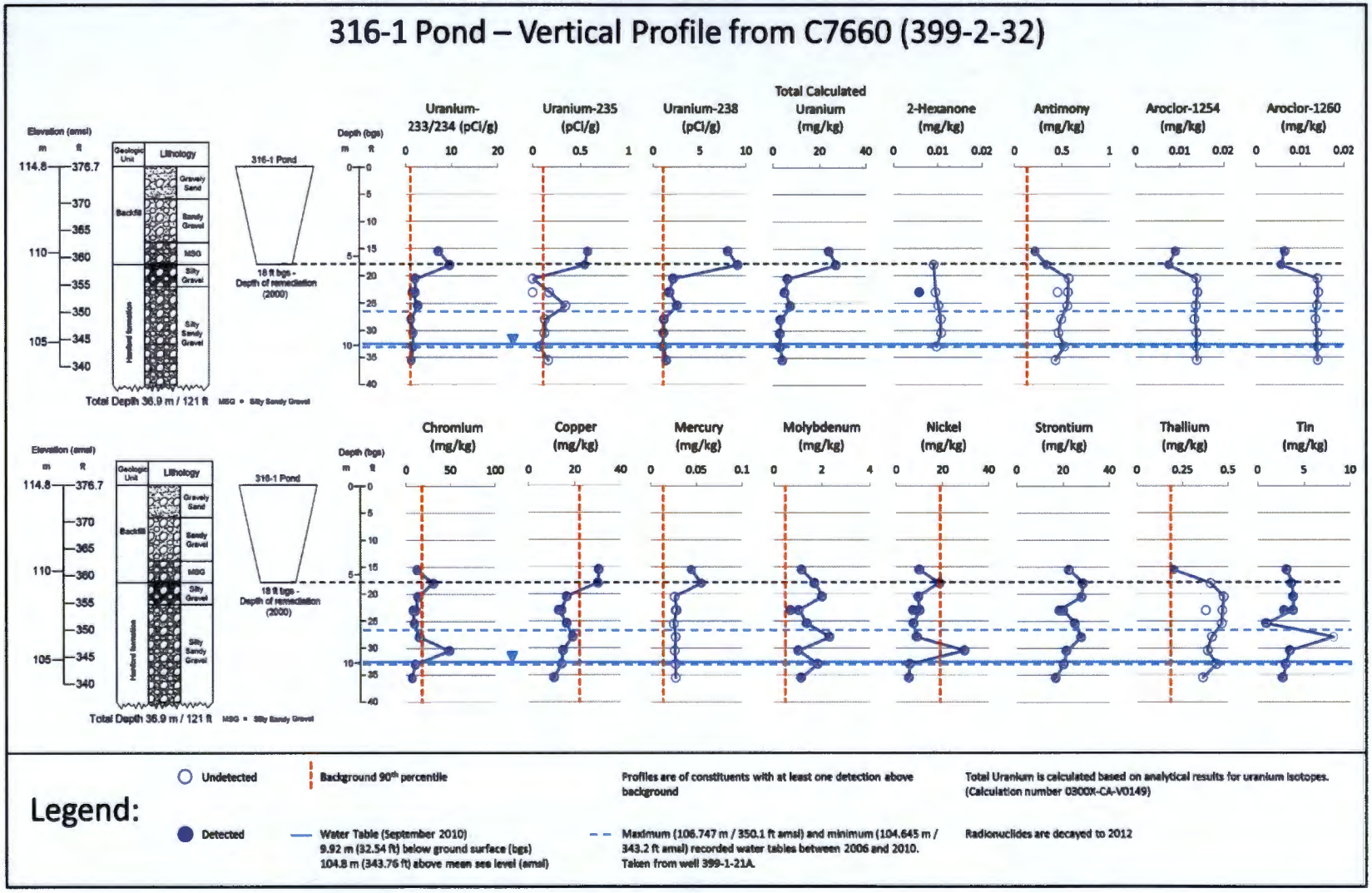


Figure 4-9. Vertical Profile from RI Borehole C7660 (Well 399-2-32) at Waste Site 316-1

4.3.3.2 5.5 m (18 ft)Residual Contamination beneath the North Process Pond (WIDS Site 316-2); Borehole C7653 (Well 300-DU-8) and Borehole C7654 (Well 300-DU-9)

The North Process Pond (WIDS Site 316-2) was located approximately 91 m (300 ft) west of the Columbia River and 274 m (900 ft) north of the South Process Pond. It was constructed and activated in 1948, following a dike failure at the South Process Pond (WIDS Site 316-1), and remained in operation until 1975. Originally a single, unlined infiltration basin, it was later subdivided using earthen dikes into six small settling ponds and one large infiltration basin, covering an area of approximately 40,600 m^2 (437,000 ft^2). The inlet for the pond was in the southwest corner. There was no outlet; all effluent either infiltrated into the soil column or evaporated. Early waste streams consisted of cooling water and low-level liquid process waste from 300 Area fuel fabrication facilities and the early laboratory facilities in the 313, 314, 3706, and 321 Buildings. From 1963 to 1975, laboratory facility waste was routed through the 307 RB, to ensure that the site did not receive waste streams with substantive radionuclide inventory. During its operational period, several UPRs to the North Process Pond occurred, with most being releases of uranium-bearing acidic wastes.

WIDS Site 316-2 was remediated and reclassified as closed out in conjunction with the adjacent Scraping Disposal Area (WIDS Site 618-12) and the co-located UPRs UPR-300-7, UPR-300-34, UPR-300-35, UPR-300-36, and UPR-300-37, under the 300-FF-1 and 300-FF-5 ROD (EPA/ROD/R10-96/143). Remediation of the site was completed in 1999 and extended to a maximum depth of 7.5 m (25 ft) bgs. The location was selected for additional characterization in the 300 Area RI/FS Work Plan (DOE/RL-2009-30) to provide additional information on the concentration and distribution of contaminant uranium in the subsurface beneath major liquid waste disposal sites (RI data needs 2 and 7).

Discussion of the nature and extent of residual contamination in the vadose zone at WIDS Site 316-2 is based on data from the following.

- A 1991 LFI documented in *Phase I Remedial Investigation Report for the 300-FF-1 Operable Unit* (DOE/RL-92-43) (LFI borehole A8069 [Well 399-1-22] and test pits NPT-1, NPT-2 and NPT-3)
- Cleanup verification sampling, documented in 300-FF-1 OU Verification Package (BHI-01298)
- RI Borehole C7653 (RI Well 300-DU-8 / HEIS Well 399-1-54)
- RI Borehole C7654 (RI Well 300-DU-9 / HEIS Well 399-1-55)

Figure 4-10 shows the locations of boreholes and test pits cited in the discussion of the 316-2 waste site.

1991 Limited Field Investigation at WIDS Site 316-2. The North Process Pond was characterized in conjunction with an LFI conducted in 1991 (prior to remedial action [RTD] to 7.5 m [25 ft] bgs). Characterization data for the North Process Pond was collected at Borehole A8069 (Well 399-1-22) and test pits NPT-1, NPT-2, and NPT-3 (Figure 4-10). Some of the samples were collected from vadose zone material that was subsequently removed during the RI, but all available data are considered.

LFI Borehole A8069 (Well 399-1-22). This borehole was drilled in the southwest quadrant of WIDS Site 316-2 waste site in 1991 (prior to remedial action [RTD] to 7.5 m [25 ft] bgs). It was advanced to a total depth of 9.8 m (32 ft) bgs, intersecting the water table at 6 m (22.5 ft) bgs. Sampling was conducted at nine depth intervals within the vadose zone, the PRZ, near the water table, and within the shallow portion of the unconfined aquifer. Analytical results are summarized in Table 4-9 and presented on Figures 4-11a and 4-11b.

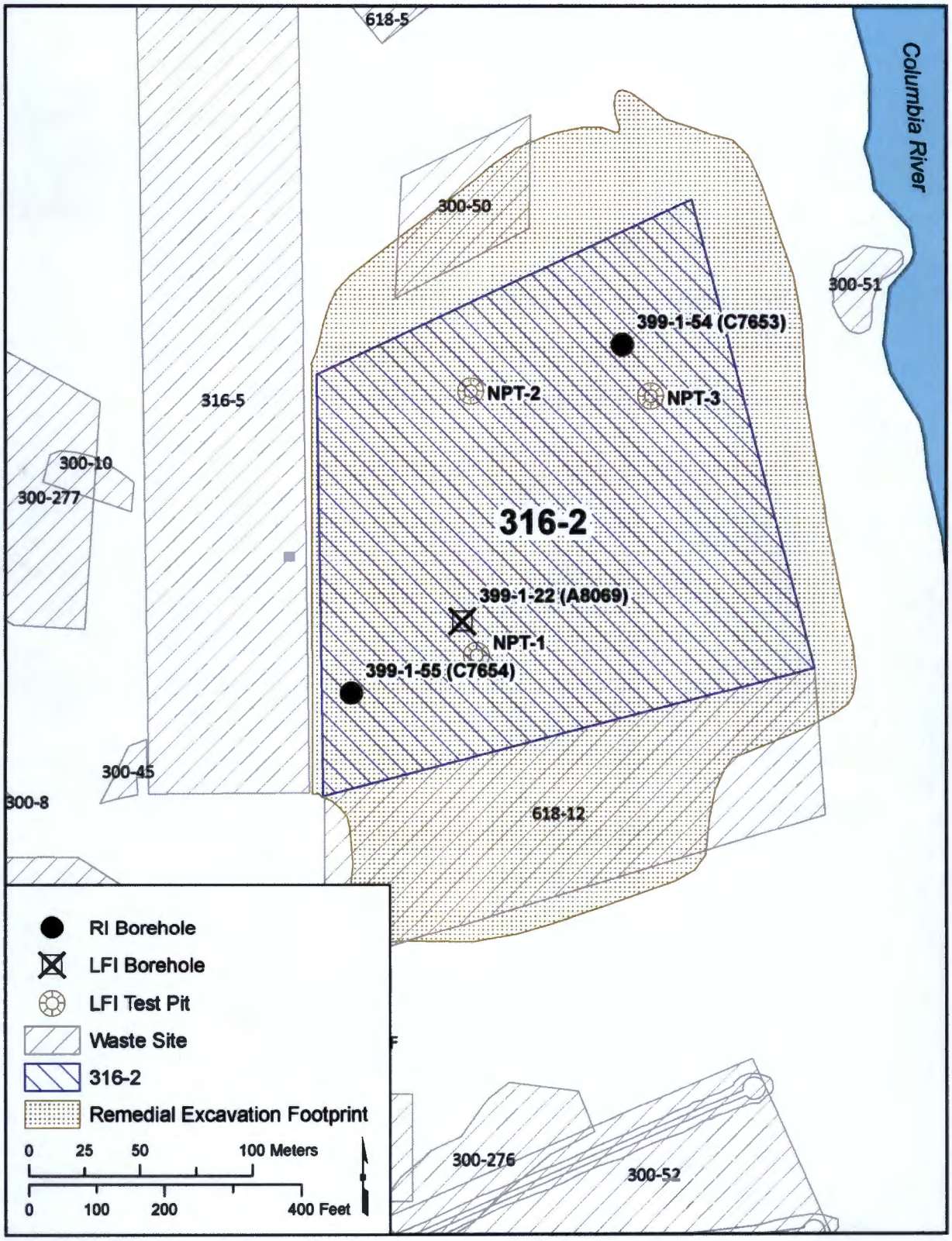


Figure 4-10. Sampling Location Map for Waste Site 316-2

Table 4-9. Waste Site 316-2 (North Process Pond)—Summary of Contaminant Soil Data (399-1-22)

Constituent	Background	Concentration and Distribution				
		LFI Borehole 399-1-22[a]				
		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (9.75/32 ft bgs Unless Otherwise Noted)	
Radionuclides (Original and Decayed Concentrations) (pCi/g)[b]						
		Original	Decayed		Original	Decayed
Cobalt-60	0.008	0.402 (2.1/7)	0.0254	7.6/25	0.0970	0.00613
Strontium-90	0.18	0.800 (3.4/11)	0.485	5.8/19	U	
Uranium-234	1.1	52.0 (3.4/11)	52	7.6/25	7.30	7.30
Uranium-235	0.109	4.90 (3.4/11)	4.90	7.6/25	0.600	0.600
Uranium-238	1.06	43.0 (3.4/11)	43	7.6/25	5.70	5.70
Nonradionuclides (mg/kg)						
Barium	132	288 (0.8/2.5)		0.8/2.5	110 (<BG)	
Beryllium	1.51	1.90 (0.8/2.5)		0.8/2.5	U	
Cadmium	0.563	1.70 (2.1/7)		3.4/11	U	
Chromium	18.5	64.0 (5.8/19)		5.8/19	12.7 (<BG)	
Cobalt	15.7	18.0 (3.4/11)		7.6/25	16	
Copper	22	2,610 (5.8/19)		7.6/25	766	
Lead	10.2	19.0 (0.8/2.5)		5.8/19	4.50 (<BG)	
Mercury	0.0131	0.620 (5.8/19)		7.6/25	U	
Nickel	19.1	41.2 (5.8/19)		7.6/25	21.8	
Silver	0.73	3.30 (5.8/19)		5.8/19	U	
Thallium	0.185	0.44 (9.1/30)		9.1/30	U	
Vanadium	85.1	87.4 (3.4/11)		3.4/11	81.2 (<BG)	
Fluoride	2.81	40.0 (3.4/11)		7.6/25	3.18	
Aroclor 1254	NA	0.140 (3.4/11)		5.8/19	U	

a. Borehole data obtained from HEIS. The water table was encountered at 6.86 m (22.5 ft) bgs. Well was drilled to 9.75 m (32 ft) total depth.

b. Original radiological data presented in the left column with decay corrected value to year 2012 in right column. Data from closeout sampling 95% upper confidence limit values obtained using U-flagged data sets is not decayed.

BG = background

U = undetected

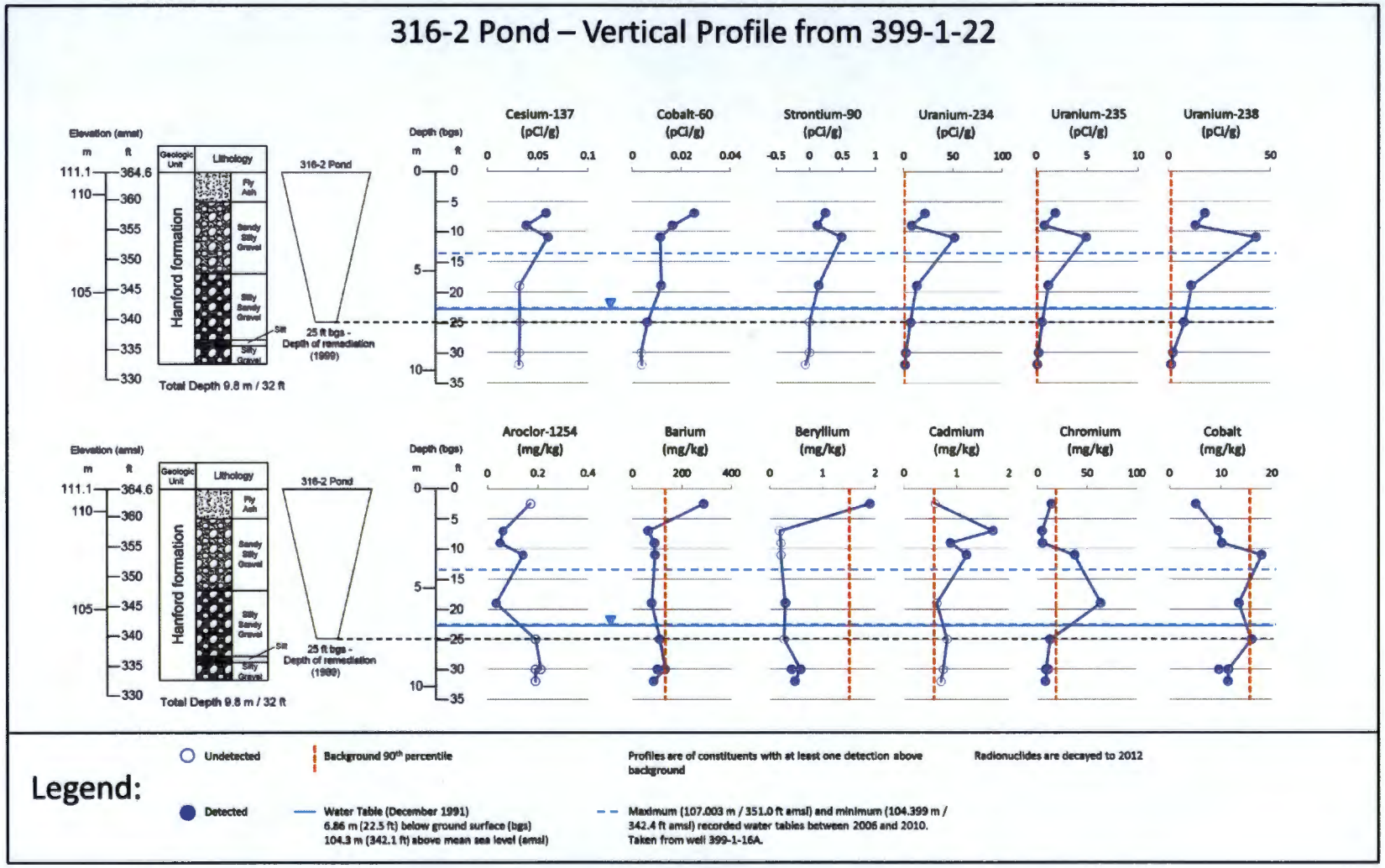


Figure 4-11a. Vertical Profile from LFI Borehole A8069 (Well 399-1-22) at Waste Site 316-2 (1 of 2)

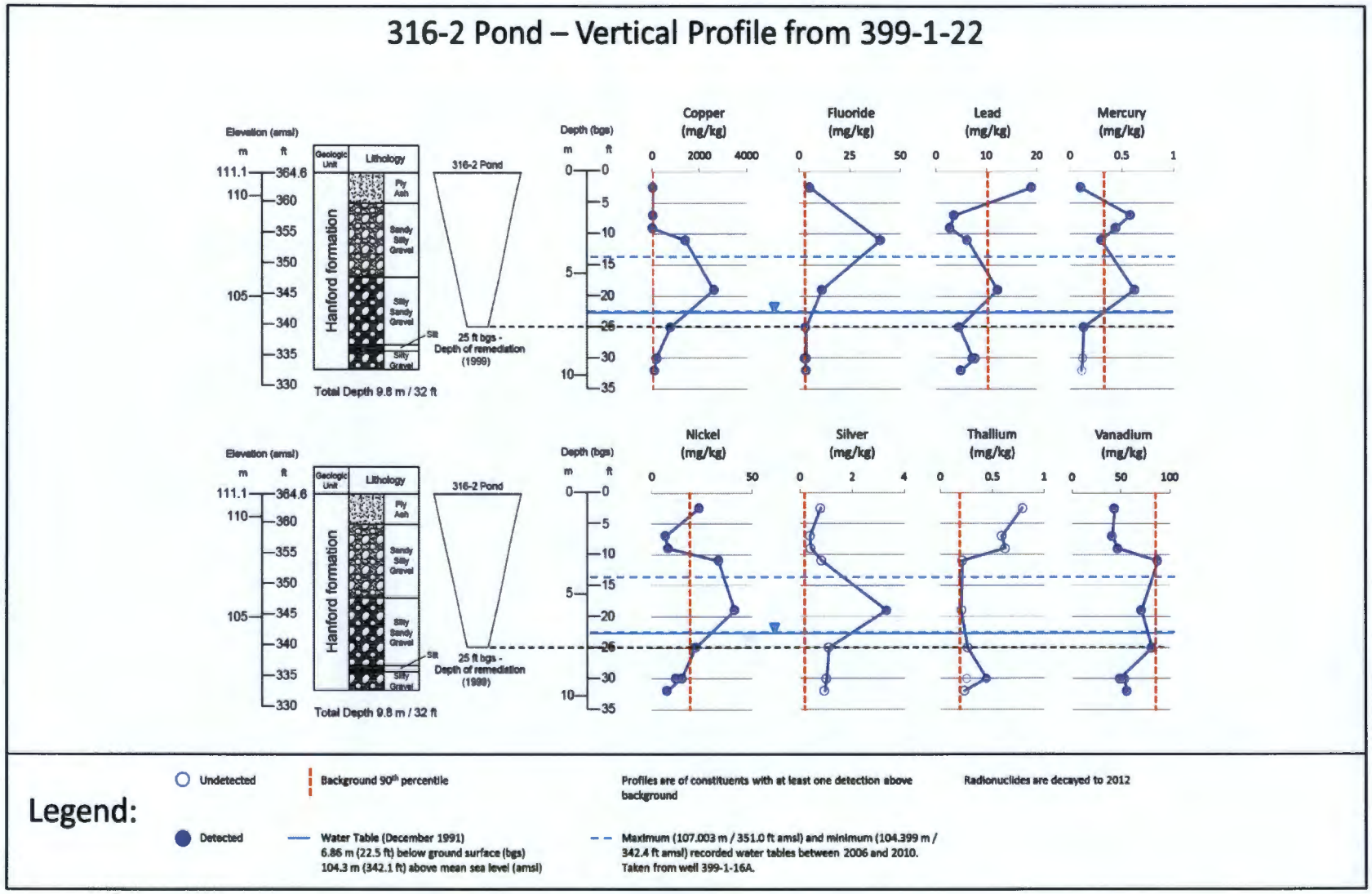


Figure 4-11b. Vertical Profile from LFI Borehole A8069 (Well 399-1-22) at Waste Site 316-2 (2 of 2)

Radionuclides detected above background levels were Cs-137, Co-60, Sr-90, and the three uranium isotopes. Cesium-137, Co-60, and Sr-90 were all found at very low activities (less than or equal to 0.8 pCi/g) that generally decreased with depth. The sample collected at 3.4 m (11 ft) bgs produced the highest activities for U-234 (52.0 pCi/g), U-235 (4.90 pCi/g), and U-238 (43.0 pCi/g). Although uranium activities decreased with depth, notable residual was present in the deep vadose zone with the highest activities for the three isotopes (13.4, 1.2, and 11.3 pCi/g, respectively) detected in the 5.8 m (19 ft) bgs sample.

A number of metals were detected within Borehole A8069 at concentrations above their respective background levels. Barium, beryllium, cadmium, and cobalt exceeded background concentrations in the shallow vadose zone (0 to 3.4 m [0 to 11 ft] bgs), but were below background levels in all deeper samples. Chromium, copper, and nickel exceeded background levels in the deeper portion of the vadose zone, with the maximum concentrations (64, 2,610, and 41.2 mg/kg, respectively) occurring in the 5.8 m (19 ft) bgs sample. Mercury was detected above background in all samples collected between 0.8 and 7.6 m (2.5 and 25 ft) bgs, with a maximum concentration of 0.620 mg/kg at 7.6 m (25 ft) bgs. Silver was detected only at 5.8 m (19 ft) bgs, where it exceeded background levels with a concentration of 3.30 mg/kg. Thallium was detected in only one sample, exceeding background with a concentration of 0.44 mg/kg at 9.1 m (30 ft) bgs. Lead exceeded its background level both at 0.8 m (2.5 ft) bgs, with a concentration of 19 mg/kg, and 5.8 m (19 ft) bgs with a concentration of 12.2 mg/kg.

Fluoride exceeded its background level in all vadose zone samples. Its maximum concentration of 40 mg/kg occurred at 3.4 m (11 ft) bgs.

Aroclor 1254 was detected in samples as deep as 5.8 m (19 ft) bgs. Its maximum concentration of 0.140 mg/kg (below the PQL) occurred at 3.4 m (11 ft) bgs.

LFI Test Pit NPT-1. Test Pit NPT-1 was excavated in December 1991 (prior to remedial action [RTD] to 7.5 m [24.6 ft] bgs) in the southwest quadrant of the North Process Pond. It was excavated to a total depth of 9.4 m (31 ft) bgs; the water table was encountered at 7.9 m (26 ft) bgs. Ten samples were collected between ground surface and the upper portion of the unconfined aquifer (9.4 m [31 ft] bgs). The upper portion of the vadose zone was removed during remediation of the North Process Pond. Therefore, the sample results within the interval from ground surface to the depth of excavation are no longer representative of existing conditions. Analytical results are shown in Figures 4-12 and 4-13 and summarized in Table 4-10.

Radionuclides detected included Cs-137, Co-60, Sr-90, and the three uranium isotopes, U-234, U-235, and U-238. All six of these radionuclides showed maximum activities in the sample collected at 1.4 m (4.5 ft) bgs. Cesium-137 was detected in two samples from the shallow zone, with a maximum of 37.5 pCi/g. Cobalt-60 and Sr-90 were detected in most samples, with maximum activities of 3.52 and 2.10 pCi/g, respectively. The uranium isotopes were detected above background levels in all samples. Maximum activities in the 1.4 m (4.5 ft) sample were 1,100, 110, and 900 pCi/g for U-234, U-235, and U-238, respectively. In the sample interval that intersected the water table, values for these three isotopes were 24.5, 2.4, and 20.4 pCi/g, respectively, constituting a potential secondary source for continued groundwater impacts, which is consistent with the CSM. Substantial uranium and metals contamination existed at this location, predominantly in the shallow portion of the vadose zone. However, subsequent remediation of WIDS Site 316-2 removed contaminated vadose zone soil to 7.5 m (25 ft) in this area.

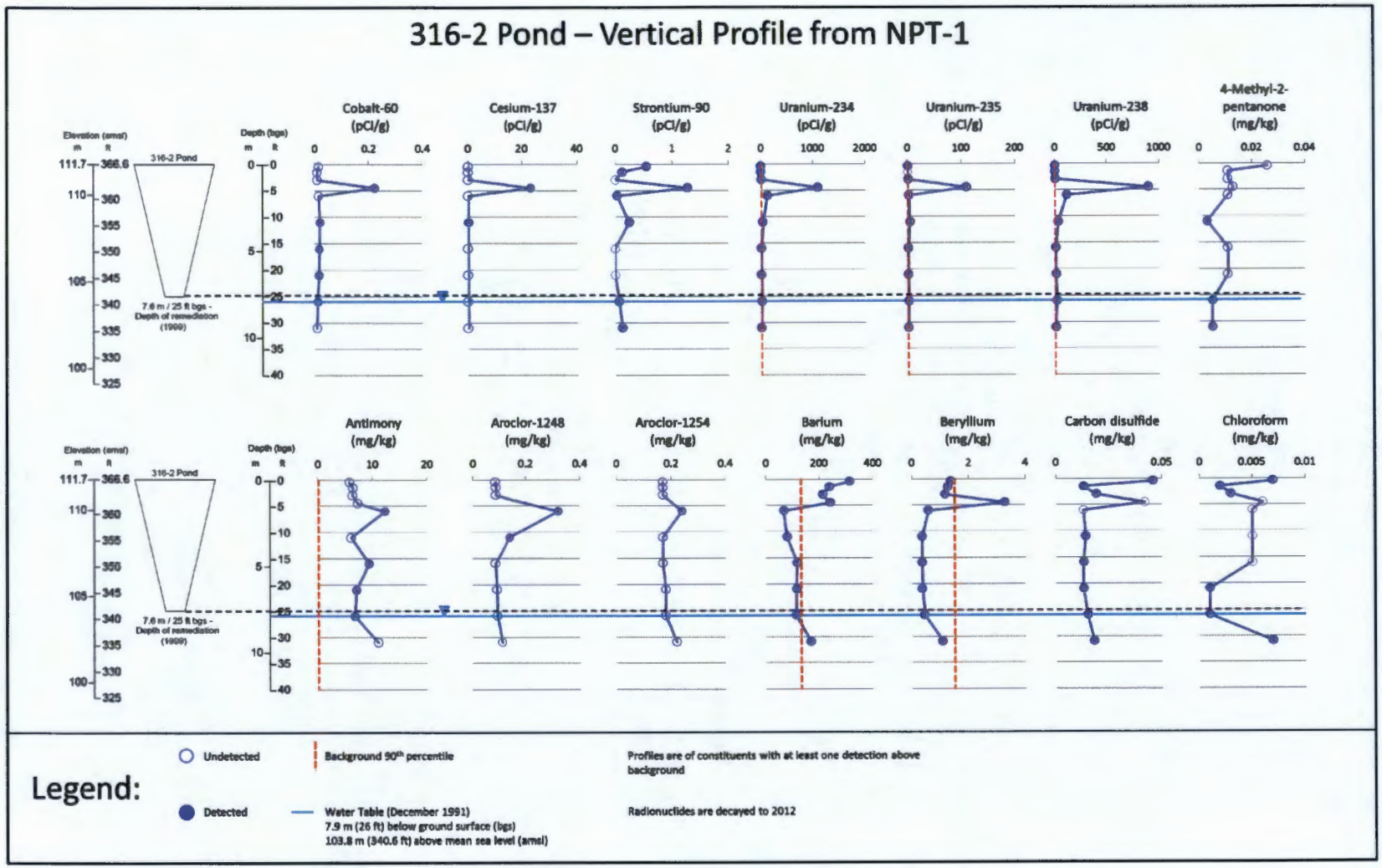


Figure 4-12. Vertical Profile from LFI Test Pit NPT-1 at Waste Site 316-2 (1 of 2)

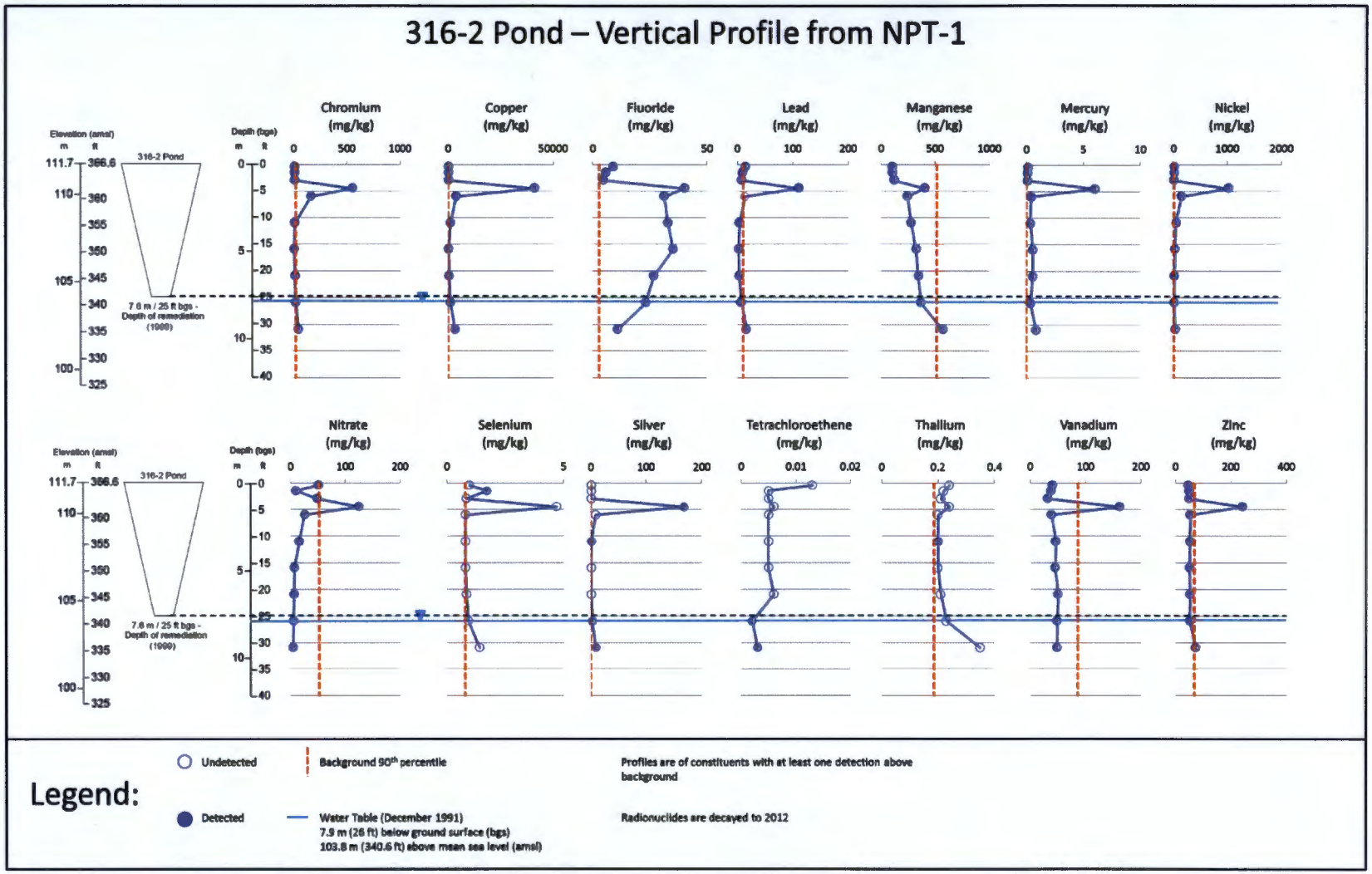


Figure 4-13. Vertical Profile from LFI Test Pit NPT-1 at Waste Site 316-2 (2 of 2)

A number of metals were detected above background levels in shallow soil, with the most prominent being copper. Others metals exceeding background levels included antimony, barium, chromium, lead, nickel, mercury, selenium, silver, and thallium. Most of the metals had maximum concentrations in the sample collected at 1.4 m (4.5 ft) bgs. These included beryllium (3.30 mg/kg), chromium (553 mg/kg), copper (41,100 mg/kg), lead (111 mg/kg), manganese (572 mg/kg), mercury (6.00 mg/kg), nickel (1,020 mg/kg), silver (168 mg/kg), vanadium (161 mg/kg), and zinc (241 mg/kg). Those metals with maximum concentrations at other depths were antimony (12.3 mg/kg at 1.8 m [6 ft] bgs), barium (315 mg/kg at 0.2 m [0.5 ft] bgs), manganese (572 mg/kg at 9.4 m [31 ft] bgs), selenium (1.7 mg/kg at 0.5 m [1.5 ft] bgs), and thallium (0.200 mg/kg at 3.4 m [11 ft] bgs). In general, metal concentrations were highest at 1.4 m (4.5 ft) bgs, but had dropped substantially by the next sample interval, remaining relatively low through the remainder of the soil column to the water table. Most metals exceeded background concentrations at and below the water table. This held true for total uranium, which was 61.9 mg/kg at the water table, as calculated from the isotopic values, and most notably for copper, at concentrations of 1,060 mg/kg at the water table and 3,350 mg/kg below the water table.

Fluoride exceeded its background level in all samples, with a maximum of 40.3 mg/kg in the 1.4 m (4.5 ft) bgs sample. Nitrate also exceeded its background level in that same sample with a concentration of 125 mg/kg, but was below background in all other samples. Sulfate exceeded its background level in the 0.2 m (0.5 ft), 0.9 m (3 ft), and 1.4 m (4.5 ft) bgs samples, with the maximum concentration of 1,660 mg/kg occurring in the 0.9 m bgs sample. Only fluoride exceeded its background level in the deep vadose zone.

Organic compounds 4-methyl-2-pentanone, carbon disulfide, chloroform, PCE, and TCE were reported in several samples at levels below the PQL. In all instances, they were also detected in the QC blank. However, all data from these analytes received a "U" flag in the LFI data summary (*Phase I Remedial Investigation Report for the 300-FF-1 Operable Unit* [DOE/RL-92-43]) based on data validation. Other organics detected included Aroclor 1248 and Aroclor 1254, with maximums of 0.320 and 0.240 mg/kg, respectively, at 1.8 m (6 ft) bgs.

LFI Test Pit NPT-2. Test Pit NPT-2 was excavated in December 1991 (prior to remedial action [RTD] to 7.5 m [24.6-ft] bgs) in the north central portion of the North Process Pond. It was excavated to a total depth of 9.4 m (31 ft) bgs, with groundwater first encountered at 7.9 m (26 ft) bgs. A total of 10 samples were collected between the ground surface and the upper portion of the unconfined aquifer (9.4 m [31 ft] bgs). The upper portion of the vadose zone was removed during remediation of the North Process Pond. Therefore, the sample results within the interval from ground surface to depth of excavation are no longer representative of existing conditions. Available analytical results are depicted in Figures 4-14a and 4-14b and summarized in Table 4-10.

Radionuclides detected included Cs-137, Co-60, Sr-90, and the three uranium isotopes. Cesium-137 was only detected in the very shallow samples, at levels below 1 pCi/g. Cobalt-60 was detected in most samples, including those at the water table, but all were at concentrations below 1.3 pCi/g. Sr-90 was detected at activities of 0.600 pCi/g or less in samples to 1.8 m (6 ft) bgs. Below 1.8 m, it was only detected once at an activity of 2.00 pCi/g in the sample collected from the shallow portion of the aquifer. Uranium-234, -235, and -238 all had maximum activities (55, 2.29, and 54.2 pCi/g, respectively) in the sample collected at 0.5 m (1.5 ft) bgs. Below that depth, each of the isotopes showed substantial decreases in activity levels, with very low activities detected in the deep vadose zone and shallow portion of the aquifer. This supports the CSM, showing that the distribution of uranium mass in the deep vadose zone varies at different locations beneath the former high-volume liquid waste disposal sites.

Table 4-10. Waste Site 316-2 (North Process Pond) Summary of Contaminant Soil Data (NPT-1, NPT-2, and NPT-3)

Constituent	Background	Concentration and Distribution														
		LFI Test Pit NPT-1[a]					LFI Test Pit NPT-2[b]					LFI Test Pit NPT-3[c]				
		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (9.5 m/31 ft bgs)		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (9.5 m/31 ft bgs)		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (9.5 m/31 ft bgs)	
Radionuclides (Original and Decayed Concentrations) (pCi/g)[d]																
		Original	Decayed		Original	Decayed	Original	Decayed		Original	Decayed	Original	Decayed		Original	Decayed
Cobalt-60	NA	3.52 (1.4/4.5)	0.22	7.9/26	U	NA	1.21 (0.5/1.5)	0.08	0.9/3	U	NA	0.133 (0.2/0.5)	0.008	0.2/0.5	U	NA
Cesium-137	NA	37.5 (1.4/4.5)	23.2	3.4/11	U	NA	0.689 (0.5/1.5)	0.425	0.5/1.5	U	NA	0.443 (0.2/0.5)	0.274	0.2/0.5	U	NA
Strontium-90	NA	2.1 (1.4/4.5)	1.3	9.5/31	0.2	0.1	2.0 (9.5/31)	1.2	9.5/31	2.0	1.2	0.1 (3.4/11)	0.06	6.4/21	U	NA
Uranium-234	1.1	1100 (1.4/4.5)	1100	9.5/31	10.5	10.5	55 (0.5/1.5)	55	9.5/31	1.4	1.4	8.6 (0.2/0.5)	8.6	9.5/31	1.7	1.7
Uranium-235	0.109	110 (1.4/4.5)	110	9.5/31	1.0	1.0	2.1 (0.5/1.5)	2.1	6.4/21	0.1 (<BG)	0.1 (<BG)	0.7 (0.2/0.5)	0.7	7.9/26	0.1	0.1
Uranium-238	1.06	900 (1.4/4.5)	900	9.5/31	9.4	9.4	49 (0.5/1.5)	49	9.5/31	1.2	1.2	7.4 (0.2/0.5)	7.4	9.5/31	1.6	1.6
Nonradionuclides (mg/kg)																
2-Hexanone	NA	U		NA	U		0.013 (0.9/3)[e]		0.9/3	U		U		NA	U	
4-Methyl-2-pentanone	NA	0.005 (9.5/31.0)[f]		9.5/31	0.005		0.008 (9.5/31)[e]		9.5/31	0.008		0.007 (7.9/26)[g]		9.5/31	0.005	
Antimony	0.13	12.3 (1.8/6)		7.9/26	U		U		NA	U		U		NA	U	
Aroclor 1248	NA	10 (1.4/4.5)		3.4/11	U		U		NA	U		U		NA	U	
Aroclor 1254	NA	6.3 (1.4/4.5)		1.8/6	U		0.23 (0.2/0.5)		0.2/0.5	U		U		NA	U	
Barium	132	315 (0.2/0.5)		9.5/31	169		189 (0.2/0.5)		0.2/0.5	61.3 (<BG)		179 (7.9/26)		7.9/26	94.4 (<BG)	
Beryllium	1.51	3.3 (1.4/4.5)		1.4/4.5	1.1 (<BG)		0.59 (<BG) (0.5/1.5)		NA	U		1.3 (<BG) (7.9/26)		NA	U	
Carbon disulfide	NA	0.046 (0.2/0.5)[f]		9.5/31	0.018		0.006 (9.5/31)[e]		9.5/31	0.006		0.004 (9.5/31)[g]		9.5/31	0.004	
Chloroform	NA	0.007 (9.5/31.0)[f]		9.5/31	0.007		0.006 (0.2/0.5)[e]		9.5/31	0.002		0.003 (7.9/26)[g]		9.5/31	0.002	
Chromium	18.5	553 (1.4/4.5)		9.5/31	45		171 (0.5/1.5)		4.9/16	U		71.1 (0.2/0.5)		0.2/0.5	U	
Copper	22	41100 (1.4/4.5)		9.5/31	3350		2600 (0.5/1.5)		0.5/1.5	16.3 (<BG)		1520 (0.2/0.5)		7.9/26	19.7 (<BG)	
Fluoride	2.81	40.3 (1.4/4.5)		9.5/31	11.1		9.7 (0.5/1.5)[h]		4.9/16	2.5		8.8 (0.2/0.5)		7.9/26	U	
Lead	10.2	111 (1.4/4.5)		9.5/31	16.7		25.1 (4.9/16)		4.9/16	4.2 (<BG)		10.1 (<BG) (0.2/0.5)		0.2/0.5	4.9 (<BG)	
Manganese	512	572 (9.5/31)		9.5/31	572		351 (<BG) (0.2/0.5)		NA	225 (<BG)		412 (<BG) (4.9/16)		0.2/0.5	272 (<BG)	
Mercury	0.0131	6.00 (1.4/4.5)		9.5/31	0.86		2.00 (0.2/0.5)		1.8/6	U		0.660 (0.2/0.5)		1.8/6	U	
Nickel	19.1	1020 (1.4/4.5)		9.5/31	37.4		322 (0.5/1.5)		0.5/1.5	U		91.1 (0.2/0.5)		0.2/0.5	U	
Nitrate	52	124.6 (1.4/4.5)		1.4/4.5	4.7 (<BG)		7.8 (<BG) (0.5/1.5)		NA	4.5		6.2 (<BG) (0.2/0.5)		NA	4.7 (<BG)	
Selenium	0.78	1.70 (0.5/1.5)		0.5/1.5	U		U		NA	U		U		NA	U	
Silver	0.167	168 (1.4/4.5)		9.5/31	9.5		33.6 (0.2/0.5)		9.5/31	0.420		U		NA	U	
Tetrachloroethene	NA	0.003 (9.5/31)[f]		9.5/31	0.003		U		NA	U		U		NA	U	
Thallium	0.185	0.200 (3.4/11)		3.4/11	U		U		NA	U		U		NA	U	

Table 4-10. Waste Site 316-2 (North Process Pond) Summary of Contaminant Soil Data (NPT-1, NPT-2, and NPT-3)

Constituent	Background	Concentration and Distribution								
		LFI Test Pit NPT-1[a]			LFI Test Pit NPT-2[b]			LFI Test Pit NPT-3[c]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (9.5 m/31 ft bgs)	Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (9.5 m/31 ft bgs)	Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (9.5 m/31 ft bgs)
Trichloroethene	NA	0.005 (0.5/1.5)[f]	0.5/1.5	U	U	NA	U	U	NA	U
Vanadium	85.1	161 (1.4/4.5)	1.4/4.5	48.4 (<BG)	68.4 (<BG) (0.5/1.5)	NA	40.2 (<BG)	61.6 (<BG) (0.9/3)	NA	44.5 (<BG)
Zinc	67.8	241 (1.4/4.5)	9.5/31	73.3	102 (0.5/1.5)	0.5/1.5	U	U	0.2/0.5[1]	U

a. Test Pit data obtained from HEIS. Water table encountered at 7.9 m (26 ft) bgs. Test pit was dug to a total depth of 9.5 m (31 ft) (1991).

b. Test Pit data obtained from HEIS. Water table encountered at 7.9 m (26 ft) bgs. Test pit was dug to a total depth of 9.5 m (31 ft) (1991).

c. Test Pit data obtained from HEIS. Water table encountered at 7.3 m (24 ft) bgs. Test pit was dug to a total depth of 9.5 m (31 ft) (1991).

d. Original radiological data presented in the left column with decay corrected value to year 2012 in right column.

e. All analytical results for carbon disulfide, chloroform, 2-hexanone, and 4-methyl-2-pentanone in Test Pit NPT-2 are flagged with a U or UJ in DOE-RL-92-43, *Phase I Remedial Investigation Report for the 300-FF-1 Operable Unit*. The U qualifier was likely assigned during data validation but the validation package is not available. Data is not presented in profiles.

f. All analytical results for 4-methyl-2-pentanone, carbon disulfide, chloroform, tetrachloroethene, and trichloroethene in Test Pit NPT-1 are flagged with a U or UJ in DOE-RL-92-43, *Phase I Remedial Investigation Report for the 300-FF-1 Operable Unit*. The U qualifier was likely assigned during data validation but the validation package is not available. Data is not presented in profiles.

g. All analytical results for 4-methyl-2-pentanone, carbon disulfide, and chloroform in Test Pit NPT-3 are flagged with a U or UJ in DOE-RL-92-43, *Phase I Remedial Investigation Report for the 300-FF-1 Operable Unit*. The U qualifier was likely assigned during data validation but the validation package is not available. Data is not presented in profiles.

h. Fluoride results from samples extending to 0.5 m (1.5 ft) in Test Pit NPT-2 are flagged with an R in DOE-RL-92-43, *Phase I Remedial Investigation Report for the 300-FF-1 Operable Unit*. The R qualifier was likely assigned during data validation but the validation package is not available. Remaining fluoride results from Test Pit NPT-2 are not qualified and are above background.

BG = background
J = estimate
NA = not applicable
R = rejected
U = undetected

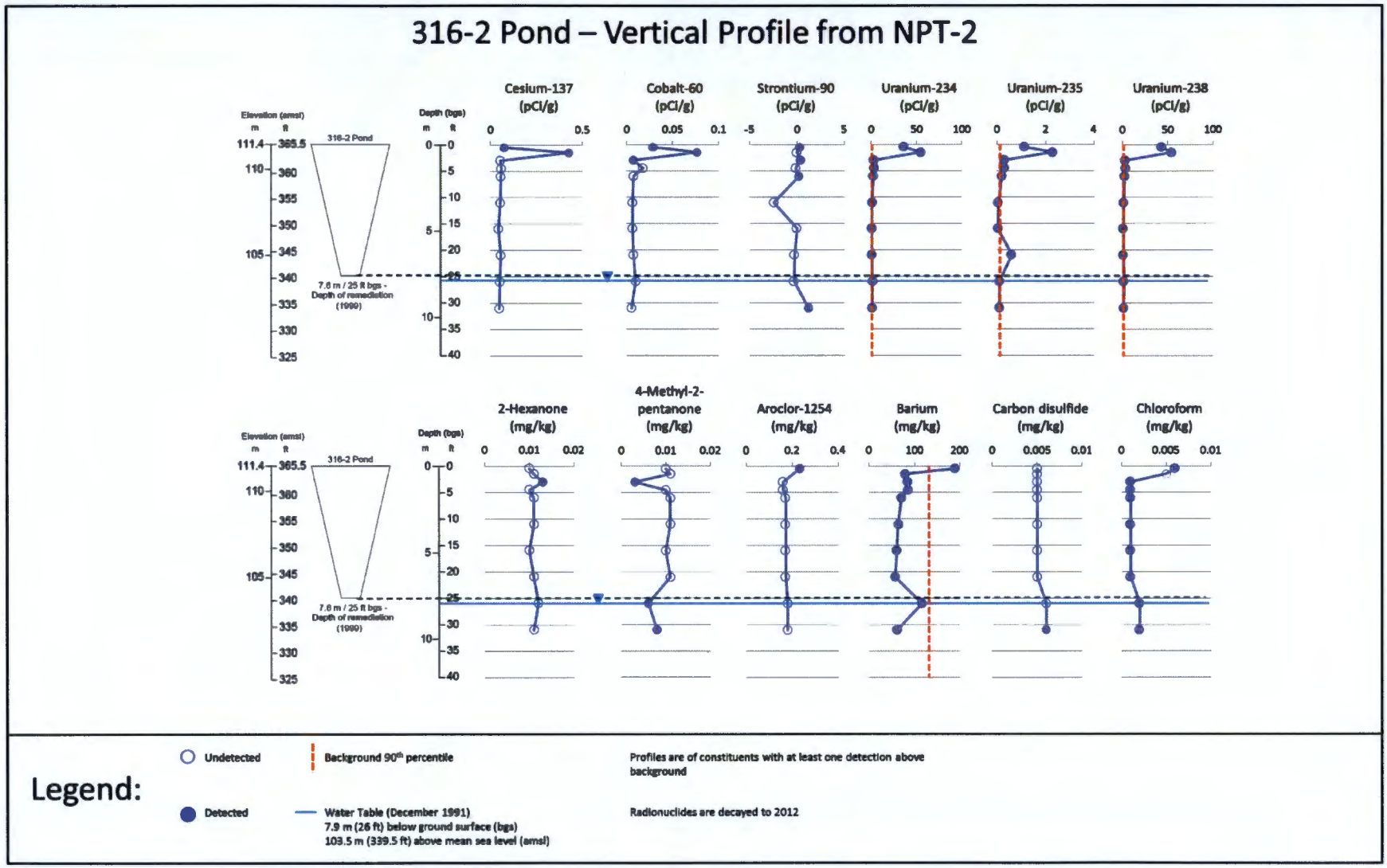


Figure 4-14a. Vertical Profile from LFI Test Pit NPT-2 at Waste Site 316-2 (1 of 2)

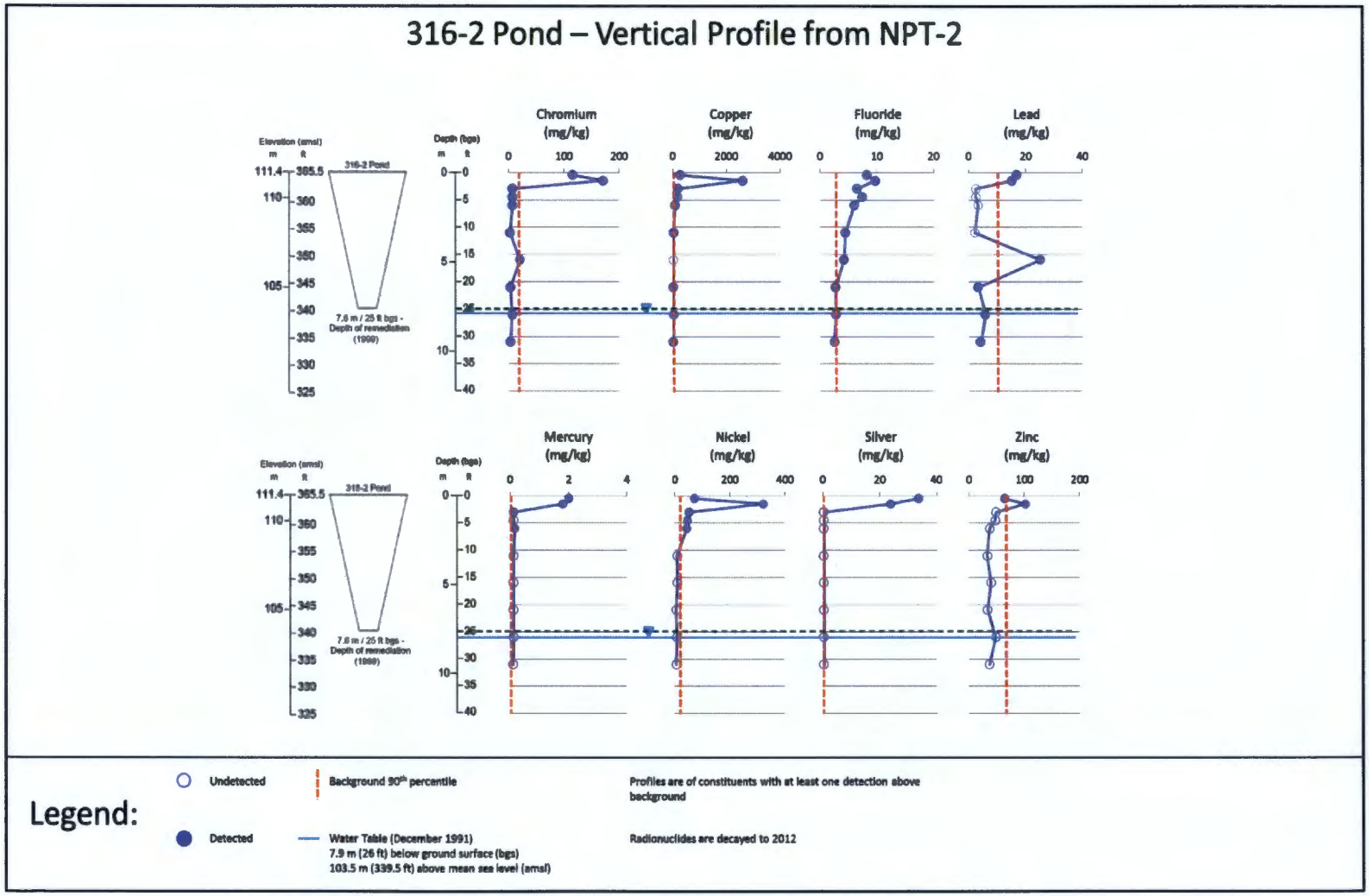


Figure 4-14b. Vertical Profile from LFI Test Pit NPT-2 at Waste Site 316-2 (2 of 2)

The maximum total uranium, calculated based on isotopic values, was 163 mg/kg at 0.5 m (1.5 ft) bgs. In the deep vadose zone, total uranium was relatively low, with a concentration of 3.3 mg/kg at 6.4 m (21 ft) bgs and 4.2 mg/kg at the water table. Barium, copper, mercury, nickel, silver, and zinc were all found at concentrations exceeding background levels in the samples collected at 1.8 m (6 ft) bgs or less, but were not detected in the sample collected at 4.9 m (16 ft) bgs. Chromium and lead exceeded their background levels in the shallow samples as well; they were also found above background levels in the samples collected at 4.9 m (16 ft) bgs. Only lead had a maximum in the deeper sample 4.9 m (16 ft) bgs, at a concentration of 25.1 mg/kg. Maximum concentrations for all metals are presented in Table 4-10.

Fluoride was the only anion detected above its background level. It had a maximum of 7.4 mg/kg at 1.4 m (4.5 ft) bgs, and decreased in concentration with increasing depth.

Organic constituents 2-hexanone, 4-methyl-2-pentanone, carbon disulfide, and chloroform were reported in several samples. However, all data from these analytes were reported with a "U" flag in the LFI data summary (Phase I Remedial Investigation Report for the 300-FF-1 Operable Unit [DOE/RL-92-43]) based on data validation. Aroclor 1254 was identified in the shallowest sample at a concentration of 0.230 mg/kg.

LFI Test Pit NPT-3. Test Pit NPT-3 was excavated in December 1991 (prior to remedial action [RTD] to 7.5 m [24.6-ft] bgs) in the northeast quadrant of the North Process Pond. It was excavated to a total depth of 9.4 m (31 ft) bgs, with groundwater being encountered at 7.3 m (24 ft) bgs. A total of 10 samples were collected between ground surface and the upper portion of the unconfined aquifer (9.4 m [31 ft] bgs). The upper portion of the vadose zone was removed during remediation of the North Process Pond; therefore, the sample results within the interval from ground surface to depth of excavation are no longer representative of existing conditions. Analytical results are depicted in Figure 4-15 and summarized in Table 4-10.

Radionuclides detected at Test Pit NPT-3 included Cs-137, Co-60, Sr-90, and the three uranium isotopes. Only Cs-137 and Co-60 were detected in the shallowest sample, at activities of 0.443 pCi/g and 0.133 pCi/g, respectively. Strontium-90 was detected as deep as 4.9 m (16 ft) bgs, but its maximum activity of 0.100 pCi/g was detected at 0.5 m (1.5 ft) and 3.4 m (11 ft) bgs. The three uranium isotopes had relatively low activities, even in the shallow vadose zone, with maximums of 8.60 pCi/g for U-234, 0.867 pCi/g for U-235, and 7.40 pCi/g U-238, all at 0.2 m (0.5 ft) bgs. In the deep vadose zone, at 6.4 m (21 ft) bgs, activities were also relatively low, at 3.00, 0.200, and 2.20 pCi/g, respectively.

The maximum total uranium concentration, calculated from isotopic values, was 22.5 mg/kg at 0.2 m (0.5 ft) bgs. In the deep vadose zone, concentrations ranged from 8.1 mg/kg in the sample interval that spanned the water table, to 6.6 mg/kg in the overlying sample interval (6.4 m [21 ft] bgs). A number of metals exceeded background levels, including barium at 179 mg/kg, cadmium at 0.98 mg/kg, chromium at 71.1 mg/kg, copper at 1,590 mg/kg, mercury at 0.66 mg/kg, and nickel at 91.1 mg/kg.

Fluoride was detected above its background level in most of the vadose zone samples, with a maximum of 4.50 mg/kg in the sample collected at the water table (7.9 m [26 ft] bgs). No other anions were detected above background levels.

Three organic compounds were detected at concentrations below their respective PQLs. Analytes 4-methyl-2-pentanone, carbon disulfide, and chloroform were reported in several samples. However, all data from these analytes are reported with a "U" flag in the LFI data summary (*Phase I Remedial Investigation Report for the 300-FF-1 Operable Unit* [DOE/RL-92-43]), based on data validation.

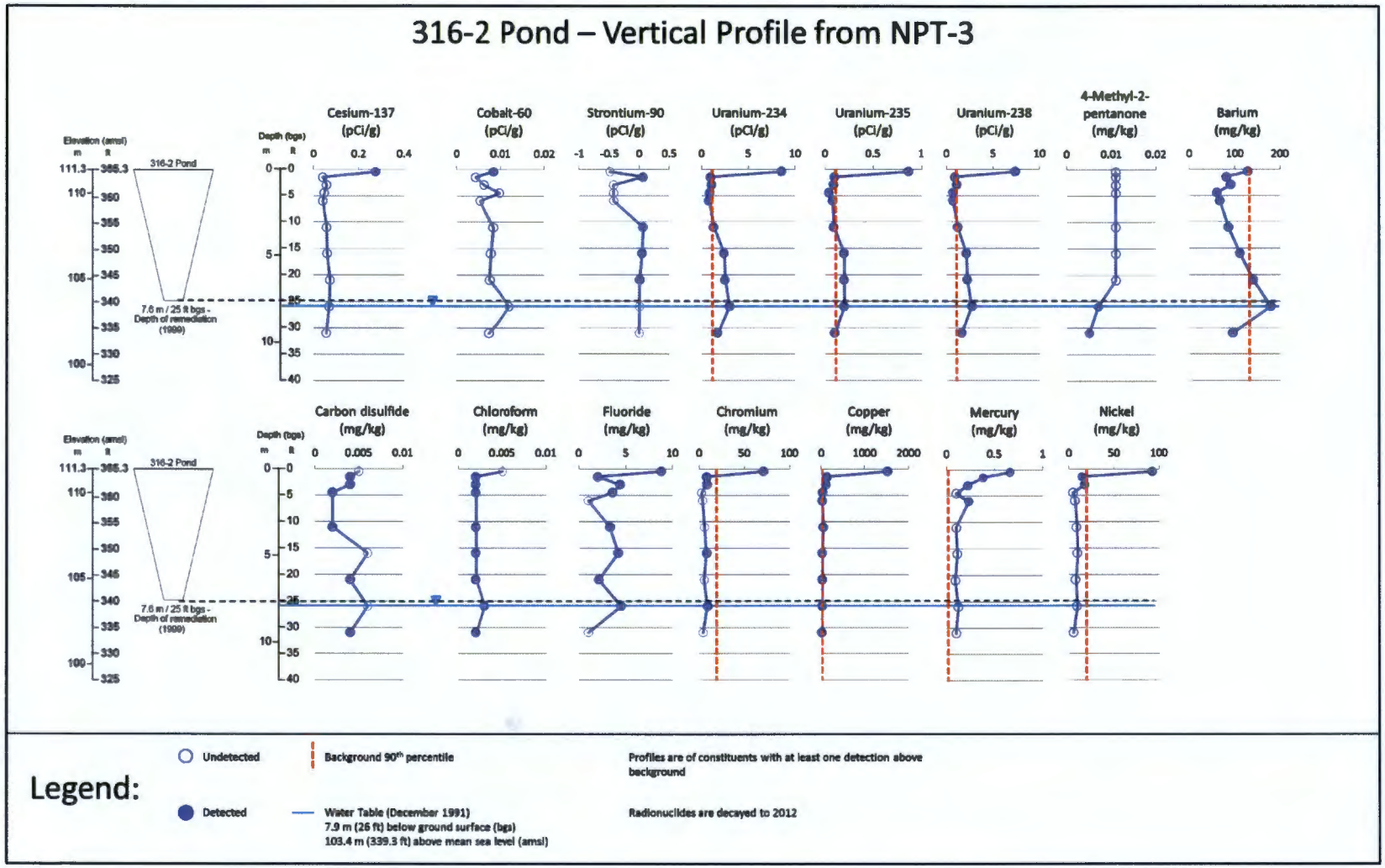
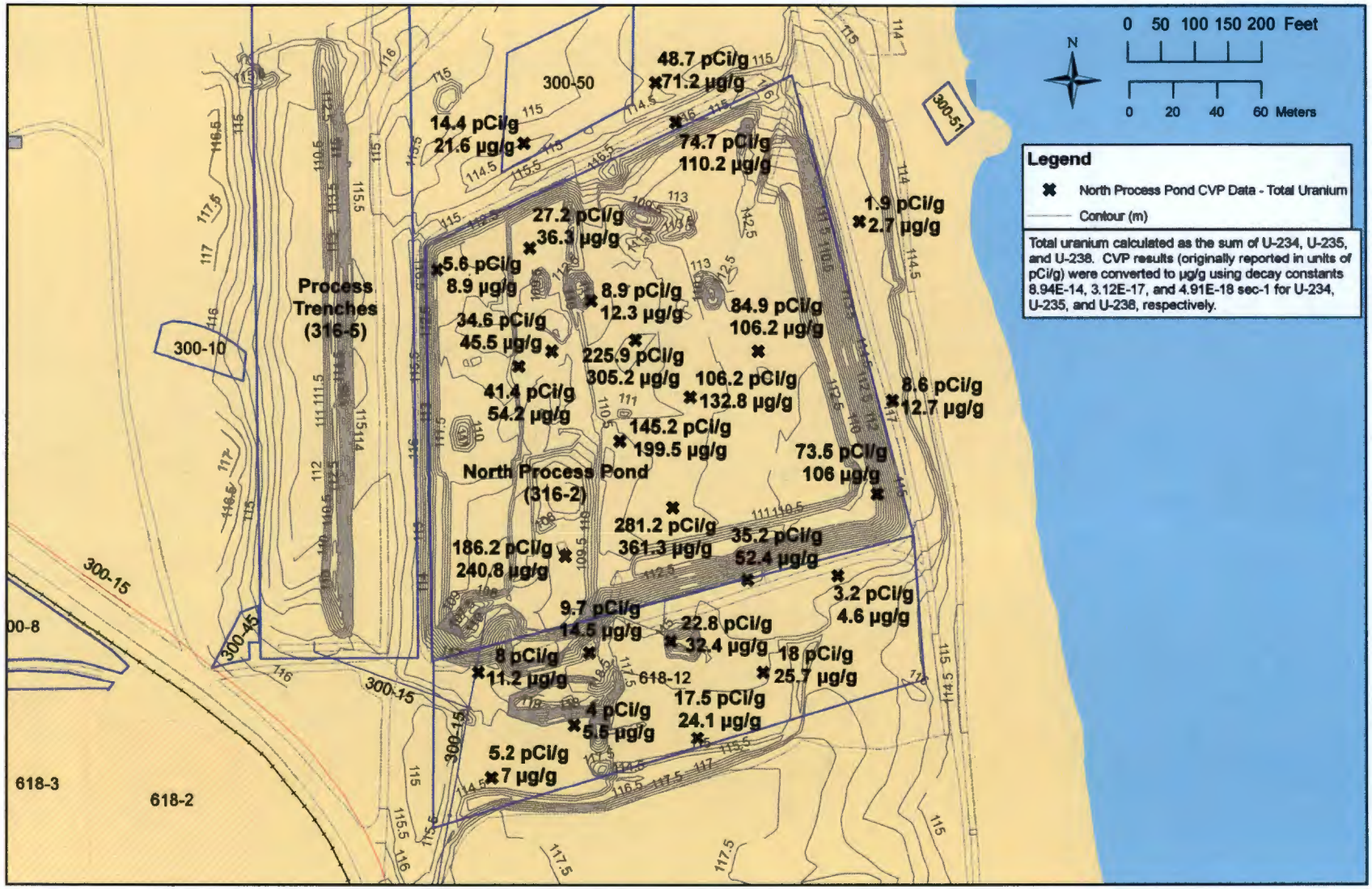


Figure 4-15. Vertical Profile from LFI Test Pit NPT-3 at Waste Site 316-2

Remedial Action Verification Sampling—316-2. CERCLA closure of 316-2 was based on the remedial activities and verification sampling documented in 300-FF-1 OU Verification Package (BHI-01298). The maximum depth of excavation was 7.5 m (24.6 ft) bgs, and approximately 139,204 metric tons (153,446 tons) of contaminated material was removed and transported to ERDF for disposal. The remedial excavation footprint is shown in Figure 4-10. The contaminants of concern for 316-2 were PCBs, Co-60, U-234, U-235, and U-238. All were detected above background concentrations in the verification samples.

Figure 4-16 shows the verification sampling locations, associated isotopic uranium activities, and total uranium concentrations calculated from those isotopic values. Also depicted in Figure 4-10 are elevation contours for the remedial excavation. As shown, the highest total uranium concentrations from individual verification samples were found in the central and southwestern portions of the site, with the highest concentration, 361.3 mg/kg, found in the south central portion of the site.

Other Uranium Studies Conducted at 316-2. Following site remediation, two additional sampling campaigns were performed in the North Process Pond, as documented in *300 Area Uranium Leach and Adsorption Project (*PNNL-14022), and *Uranium Geochemistry in Vadose Zone and Aquifer Sediments from the 300 Area Uranium Plume* (PNNL-15121). *300 Area Uranium Leach and Adsorption Project* (PNNL-14022) discusses the results of two sediment samples recovered from the northeast corner of the process pond excavation/remediation depth, and a 1.5 m (5 ft) deep trench dug below the excavation floor (7.5 m [24.6 ft] bgs) at the southern edge of the pond. The sample collected from the southwest corner yielded an average uranium concentration of 40 mg/kg (13 pCi/g U-238) and the sample collected from the south edge yielded an average uranium concentration of 540 mg/kg (180 pCi/g U-238) (*300 Area Uranium Leach and Adsorption Project* [PNNL-14022], Table 4.7). In a study reported in *Uranium Geochemistry in Vadose Zone and Aquifer Sediments from the 300 Area Uranium Plume* (PNNL-15121), two backhoe excavations were dug at the southwest and southeast corners of the North Process Pond from below the excavated (remediated) surface to groundwater. Sediment samples were collected every 0.61 m (2 ft). Sediment samples (less than 2 mm [0.08 in.] fraction) collected from the profile at the southwest corner, near the liquid-waste inlet, yielded uranium concentrations between 15 and 240 mg/kg (5 to 80 pCi/g U-238). Sediment samples (less than 2 mm [0.08 in.] fraction) collected from the southeast corner yielded uranium concentrations between 11 and 20 mg/kg (3.7 to 6.7 pCi/g U-238) (*Uranium Geochemistry in Vadose Zone and Aquifer Sediments from the 300 Area Uranium Plume* [PNNL-15121], Table 2.3). Sediment uranium concentrations tended to be higher in upper 3.66 m (12 ft) than in the lower 3.05 m (10 ft) for the samples collected in the southwest corner near the inlet. It should be noted that X-ray fluorescence (XRF) was used to measure uranium activities in these two studies. The XRF values were then converted to pCi/g of U-238 based on 99.7 percent abundance of U-238 in the environment. Because these data were collected and analyzed differently than the verification data, they are not directly comparable. However, the XRF data can be used qualitatively to demonstrate the presence of uranium mass at these locations. The verification sampling results and supplemental evaluation performed by PNNL suggest the potential for a significant residual contaminant mass in the deep vadose zone.



Note: Total uranium results are presented as µg/g, which is the equivalent of mg/kg.

Figure 4-16. Uranium Results for Verification Samples at the North Process (WIDS 316-2) and Associated Site

RI Borehole C7653 (RI Well 300-DU-8/HEIS Well 399-1-54). Borehole C7653 was drilled in the northeast corner of the 316-2 waste site. It was advanced to a total depth of 36.1 m (118.5 ft) bgs, intersecting the water table at about 9.2 m (30.2 ft) bgs. Remedial excavation at 316-2 was conducted in 1999. The excavation extended as deep as 7.5 m (24ft) bgs, although in many locations did not extend below 4.6 m (15 ft) bgs. Soil samples were collected during drilling at multiple depth intervals between 3.4 m (11.2 ft) and 8.7 m (28.6 ft) bgs within the vadose zone (including the PRZ); however, samples were not collected at or below the water table. Sampling was successful at seven other depth intervals, with the following exceptions: sample returns at 5.3 m (17.5 ft) bgs were insufficient to accommodate testing for anions, metals, PCBs, and semivolatile organic compounds (SVOCs); sample returns at 8.7 m (28.6 ft) bgs were not sufficient to accommodate testing for VOCs. Sample collection was attempted at 8.4 m (27.5 ft) bgs, but the material collected was not sufficient to constitute a sample. Analytical results are summarized in Table 4-11 and depicted in Figure 4-17.

Radionuclides detected above background levels were tritium, U-233/234, and U-238. None was detected above background level in the deepest sample, collected at 8.7 m (28.6 ft) bgs, approximately 0.5 m (1.6 ft) above the water table. Tritium was detected in the four samples collected between 3.4 and 5.6 m (11.2 and 18.5 ft) bgs, with a maximum activity of 12.9 pCi/g at 4.9 m (16 ft) bgs. It was undetected in the deep vadose zone. Both U-233/234 and U-238 were detected above background levels in all samples between 11.2 and 23 ft bgs, with maximum activities of 4.17 and 3.91 pCi/g, respectively, occurring in the 4 m (13.2 ft) bgs sample. Activity levels for both isotopes decreased consistently with depth.

Total uranium concentrations, calculated as a function of the isotopic values, exceeded background levels in the samples between 3.4 m (11.2 ft) and 5.6 m (18.5 ft) bgs, with a maximum of 11.7 mg/kg found in the shallow vadose zone at 4 m (13.2 ft) bgs. Uranium concentrations decrease consistently with depth. A number of other metals were detected at concentrations above background, primarily in shallower samples, with several having maximums at 4 m (13.2 ft) bgs. Chromium was detected above background in two shallow zone samples, with a maximum concentration of 29 mg/kg at 4 m (13.2 ft) bgs; it was not detected in any of the deeper samples. Copper was detected above its background concentration in all but the deepest sample, with a maximum of 112 mg/kg at 4 m (13.2 ft) bgs. Mercury was detected above background in all samples, with a maximum concentration of 0.104 mg/kg at 4 m (13.2 ft) bgs. Nickel was detected above its background concentration only once, with a concentration of 25.3 mg/kg at 4 m (13.2 ft) bgs. Molybdenum was detected above background in all samples, with a maximum concentration of 2.02 mg/kg at 5.6 m (18.5 ft) bgs. Vanadium was detected above background only once, with a concentration of 97.1 mg/kg at 6.5 m (21.2 ft) bgs. Concentrations of metals for which a background value is not available (strontium and tin) are consistent with concentrations measured in other 300 Area RI samples.

Fluoride exceeded its background level only at 5.6 m (18.5 ft) bgs, with a concentration of 4.2 mg/kg. No other anions were detected above background.

Aroclor 1254, the only organic compound detected, was identified in three samples, with a maximum concentration of 0.00599 mg/kg at 4 m (13.2 ft) bgs. It was not detected in the deepest sample.

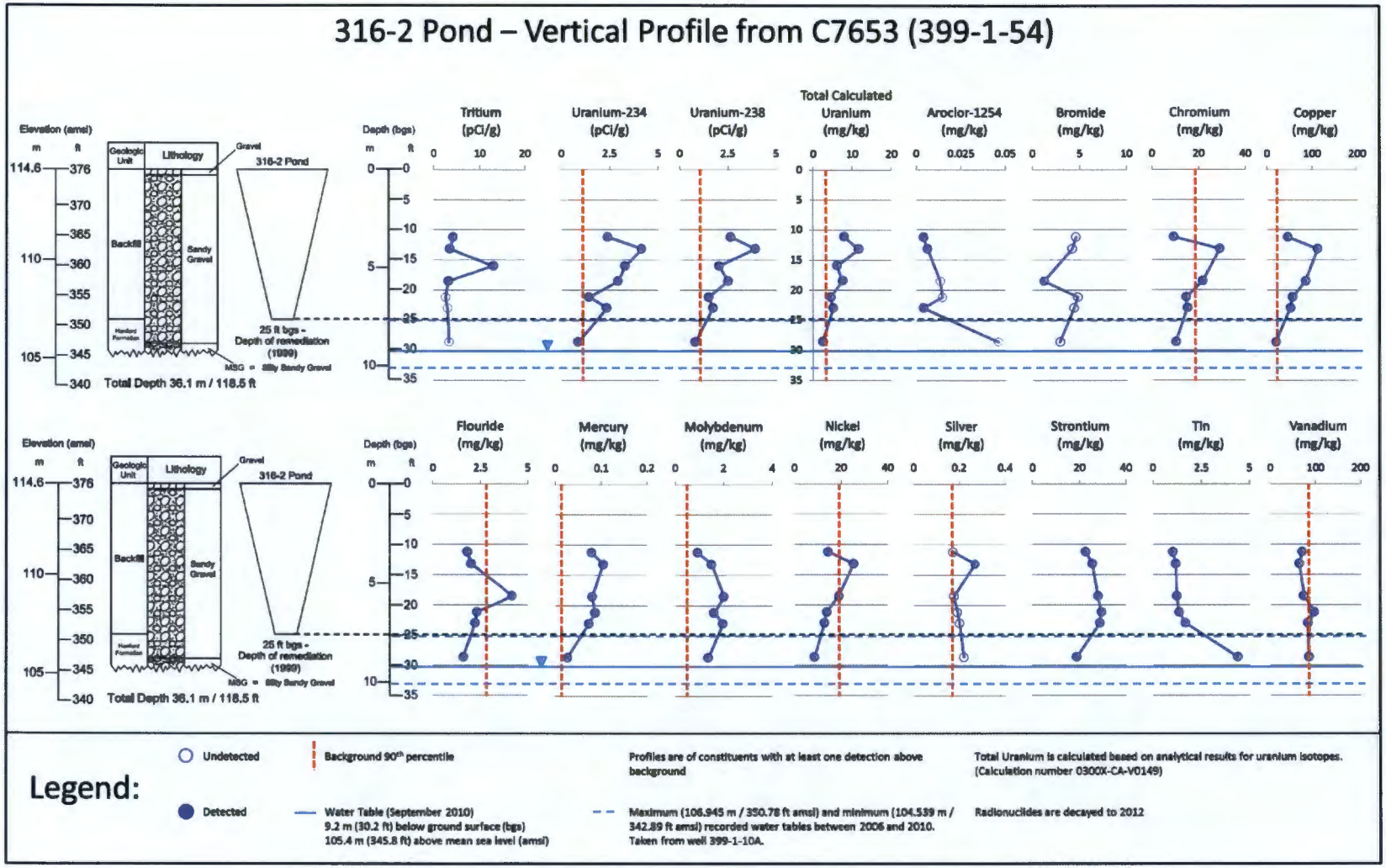


Figure 4-17. Vertical Profile from RI Borehole C7653 (Well 399-1-54) at Waste Site 316-2

Borehole C7654 (RI Well 300-DU-9/HEIS Well 399-1-55). Borehole C7654 was drilled roughly 198 m (650 ft) southwest of Borehole C7653, in the southwest corner of the 316-2 waste site near the former location of the North Process Pond inlet. It was advanced to a total depth of 34.4 m (113 ft) bgs, intersecting the water table at about 9.8 m (32.3 ft) bgs. Soil samples were collected at 11 depth intervals between 3.8 and 11.4 m (12.4 and 37.4 ft) bgs within the vadose zone (including the PRZ), near the water table and within the upper portion of the unconfined aquifer. Analytical results are summarized in Table 4-11 and depicted on Figure 4-18.

Tritium and the three uranium isotopes were the only radionuclides detected. Tritium was detected only at and below the water table, with a maximum activity of 12.8 pCi/g occurring in the 9.9 m (32.4 ft) bgs sample, the depth horizon that incorporated the capillary fringe and water table.

Each of the three uranium isotopes exceeded background in all samples collected between 4.5 and 11.4 m (14.9 and 37.4 ft) bgs. Each had relatively low activities in the shallower samples, with maximum activities occurring at the approximate remedial action depth of 7.6 m (24.9 ft) bgs, and decreasing activities with increasing depth below 7.6 m (24.9 ft) bgs. The maximum activities were U-233/234 at 35.6 pCi/g, U-235 at 2.91 pCi/g, and U-238 at 38.6 pCi/g.

Total uranium concentration, calculated as a function of the isotopic values, exceeded its background level in all samples collected between 4.5 and 11.4 m (14.9 and 37.4 ft) bgs. Consistent with the observed isotopic values, the maximum total uranium concentration was 116 mg/kg, at 7.6 m (24.9 ft) bgs.

Antimony, barium, manganese, mercury, and molybdenum were detected above background levels. Barium and manganese were detected at 6.7 m (22 ft) bgs, with concentrations of 139 mg/kg and 545 mg/kg, respectively. Antimony was detected above background only at 10.6 m (34.9 ft) bgs, at a concentration of 0.27 mg/kg. Mercury exceeded background levels in several samples, with a maximum concentration of 0.51 mg/kg at 8.4 m (27.7 ft) bgs. Molybdenum exceeded background in most samples, with a maximum concentration of 1.79 mg/kg at 3.8 m (12.4 ft) bgs. Concentrations of metals for which a background value is not available (strontium and tin) are consistent with concentrations measured in other 300 Area RI samples.

Fluoride levels exceeded its background level in several samples, with a maximum of 9.6 mg/kg at 9.2 m (30.2 ft) bgs. Nitrate exceeded its background level only in the sample collected at 7.6 m (24.9 ft) bgs, with a concentration of 54.7 mg/kg. No other anions were detected above background levels.

Aroclor 1260 was detected in most vadose zone samples, but not in samples collected from the shallow aquifer. The maximum concentration was 0.0228 mg/kg at 3.8 m (12.4 ft) bgs. Aroclor 1254 was detected in two samples, but at concentrations well below the PQL (maximum of 0.00393 mg/kg at 6.7 m [22 ft] bgs).

4.3.4 Residual Contamination beneath the 300 Area Process Trenches (WIDS Site 316-5); Borehole C7655; Well 300-DU-10

The 300 Area Process Trenches (WIDS Site 316-5) was a RCRA TSD unit that consisted of two parallel, unlined, north-south trending infiltration trenches, each 468 m (1,535 ft) long, 3 m (10 ft) wide, and 3.7 m (12 ft) deep. Placed into service in 1974 as a replacement for the North and South Process Ponds, these trenches received roughly 9,800,000 L/d (2,600,000 gal/d) of process effluent from the 300 Area uranium fuel fabrication facilities and waste effluent from the 300 Area laboratories. The trenches received dangerous waste from these processes until 1985. In 1991, an expedited response action (ERA) of the southern two-thirds of the trenches removed roughly 0.3 m (1 ft) of contaminated sludge and soil from the trench walls, and 1.3 m (4 ft) of contaminated sludge and soil from the trench bottoms. The contaminated material was placed at the north end of the trenches in the Process Trench Spoils Area, and covered with plastic and aggregate. The trenches continued to receive nonregulated liquid effluent until they were taken out of service in 1994.

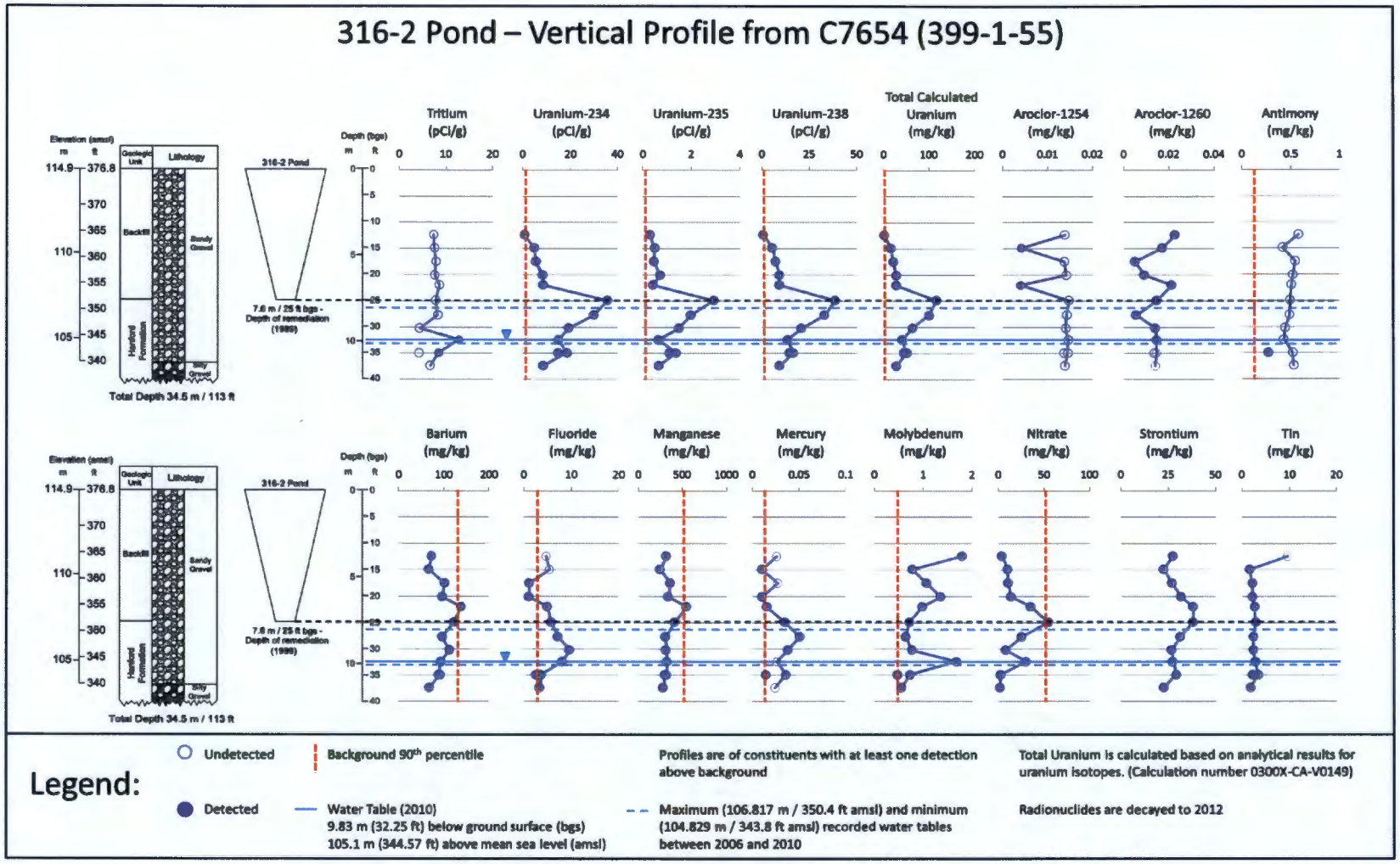


Figure 4-18. Vertical Profile from RI Borehole C7654 (Well 399-1-55) at Waste Site 316-2

Table 4-11. Waste Site 316-2 (North Process Pond) Summary of Contaminant Soil Data (C7653 and C7654)

Constituent	Concentration and Distribution													
	Background	Cleanup Verification Data[a]		Remedial Investigation Borehole C7653 (RI Well 300-DU-8)[b]					Remedial Investigation Borehole C7654 (RI Well 300-DU-9)[c]					
				Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (8.7 m/28.6 ft bgs)		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (11.3 m/37.4 ft bgs Unless Otherwise Noted)		
Radionuclides (Original and Decayed Concentrations) (pCi/g)[d]														
		Original	Decayed	Original	Decayed		Original	Decayed	Original	Decayed		Original	Decayed	
Cobalt-60	NA	0.46	0.08	U	NA	NA	U	NA	U	NA	NA	U	NA	
Tritium	NA	ND		12.9 (4.9/16.0)	11.5	5.8/18.5	U	NA	12.8 (9.8/32.4)	11.4	10.7/34.9	U	NA	
Uranium-233/234	1.1	ND		4.17 (4.0/13.2)	4.17	7.0/23.0	0.877 (<BG)	0.877 (<BG)	35.6 (7.6/24.9)	35.6	11.3/37.4	8.37	8.37	
Uranium-235	0.109	ND		U	NA	NA	U	NA	2.91 (7.6/24.9)	2.91	11.3/37.4	0.663	0.663	
Uranium-238	1.06	ND		3.91 (4.0/13.2)	3.91	7.0/23.0	0.809 (<BG)	0.809 (<BG)	38.6 (7.6/24.9)	38.6	11.3/37.4	9.25	9.25	
Uranium (total)[e]	3.21	221.6	221.6	ND	NA	NA	ND	NA	ND	NA	NA	ND	NA	
Nonradionuclides (mg/kg)														
Antimony	0.13	ND		U		NA	U		0.27 (10.6/34.9)		10.6/34.9	U		
Barium	132	ND		115 (<BG) (7/23)		NA	61.8 (<BG)		139 (6.7/22)		6.7/22	67.6 (<BG)		
Boron														
Chromium	18.5	ND		29.0 (4/13.2)		5.8/18.5	10.2 (<BG)		18.4 (<BG) (6.1/20.1)		NA	9.41 (<BG)		
Copper	22	ND		112 (4/13.2)		7/23	19 (<BG)		17.8 (<BG) (7.6/24.9 and 8.5/27.7)		NA	14.9 (<BG)		
Manganese	512	ND		428 (<BG) (6.4/21.2)		NA	400 (<BG)		545 (6.7/22)		6.7/22	279 (<BG)		
Mercury	0.0131	ND		0.104 (4/13.2)		8.7/28.6	0.026		0.051 (8.4/27.7)		10.6/34.9	U		
Molybdenum	0.47	ND		2.02 (5.6/18.5)		8.7/28.6	1.37		1.79 (3.8/12.4)		10.6/34.9	U		
Nickel	19.1	ND		25.3 (4/13.2)		4.0/13.2	8.49 (<BG)		12.8 (<BG) (4.6/14.9 and 6.7/22)		NA	8.83 (<BG)		
Silver	0.167	ND		0.267 (4/13.2)		4/13.2	U		U		NA	U		
Strontium	NA	ND		29.4 (6.4/21.2)		8.8/28.6	18.8		38.2 (6.7/22)		11.3/37.4	22.6		
Tin	NA	ND		4.39 (8.8/28.6)		8.8/28.6	4.39		3.39 (10.7/34.9)		11.3/37.4	1.78 (<BG)		
Vanadium	85.1	ND		97.1 (6.4/21.2)		6.4/21.2	85.1		74.4 (<BG) (10.7/34.9)		NA	64.1 (<BG)		
Fluoride	2.81	ND		4.20 (5.8/18.5)		5.8/18.5	1.60 (<BG)		9.60 (9.1/30.2)		11.3/37.4	3.30		
Nitrate	52	ND		28.6 (<BG) (7.0/23.0)		NA	U		54.7 (7.6/24.9)		7.6/24.9	1.70 (<BG)		
Aroclor 1254	NA	ND		0.00599 (4.0/13.2)		7/23	U		0.00411 (4.6/14.9)		6.7/22	U		
Aroclor 1260	NA	ND		U		NA	U		0.0228 (3.7/12.4)		8.5/27.7	U		
Total PCBs[f]	NA	1.87		ND		NA	ND		ND		NA	ND		
Toluene	NA	ND		U		NA	U		0.000967 (8.5/27.7)		8.5/27.7	U		

Table 4-11. Waste Site 316-2 (North Process Pond) Summary of Contaminant Soil Data (C7653 and C7654)

Constituent	Concentration and Distribution							
			Remedial Investigation Borehole C7653 (RI Well 300-DU-8)[b]			Remedial Investigation Borehole C7654 (RI Well 300-DU-9)[c]		
	Background	Cleanup Verification Data[a]	Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (8.7 m/28.6 ft bgs)	Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (11.3 m/37.4 ft bgs Unless Otherwise Noted)

Source: DOE/RL-96-70, *300-FF-1 Remedial Design Report/Remedial Action Work Plan.*

a. Verification sample results represent the single highest 95% UCL concentration from among the decision units, including the 618-12 Scraping Disposal Area. Verification results were compared to the cleanup levels established in *300-FF-1 Remedial Design Report/Remedial Action Work Plan* (DOE/RL-96-70) for radionuclides, and WAC 173-340, "Model Toxics Control Act," Method C, cleanup standards for nonradionuclides. Verification 95% UCL values were obtained from *300-FF-1 Operable Unit, North Process Pond/Scraping Disposal Area Verification Package* (BHI-01298). Maximum depth of interim remedial action was 7.6 m (25 ft) bgs.

b. Borehole data obtained from HEIS. The water table was encountered at 9.2 m (30.2 ft) bgs. Borehole was drilled to 36.1 m (118.5 ft) bgs total depth.

c. Borehole data obtained from HEIS. The water table was encountered at 9.8 m (32.3 ft) bgs. Borehole was drilled to 34.4 m (113 ft) bgs total depth.

d. Original radiological data presented in the left column with decay corrected value to year 2012 in right column.

e. Verification sample results for total uranium presented as the sum of U-234, U-235, and U-238 values per *300-FF-1 Operable Unit, North Process Pond/Scraping Disposal Area Verification Package* (BHI-01298).

f. Verification sample results for total PCB reported as sum of Aroclors 1016, 1221, 1232, 1242, 1248, 1254, and 1260 per *300-FF-1 Operable Unit, North Process Pond/Scraping Disposal Area Verification Package* (BHI-01298).

BG = background
J = estimate
NA = not applicable
ND = no data, not a contaminant of concern/contaminant of potential concern
R = rejected
U = undetected
UCL = upper confidence limit

The 316-5 waste site, along with 16 co-located UPR waste sites, was remediated in 1997 and 1998. Remedial excavation of the trenches extended to a maximum depth of about 5.5 m (18 ft) bgs. Approximately 34,000 metric tons (37,500 tons) of contaminated material and six 208-L (55-gal) drums of sediment were transported to the ERDF. Contaminants of concern were arsenic, thallium, benzo(a)pyrene, chrysene, PCBs, Co-60, U-234, U-235, and U-238 (*300 Area Process Trenches Verification Package* [BHI-01164]). Based on evaluation of the analytical results for closure verification samples, summarized in Table 4-12, the site was determined to meet industrial land-use closure requirements and was reclassified as closed out. The vadose zone portion of the site was approved for clean closure under RCRA.

The 316-5 waste site was selected for further characterization in the 300 Area RI/FS Work Plan (DOE/RL-2009-30) to provide additional information on the concentration and distribution of contaminant uranium in the subsurface beneath major liquid waste disposal sites (RI data needs 2 and 7). Figure 4-19 shows the 316-5 waste site and the location of the RI borehole.

Remedial Action Verification Sampling – 316-5. An ERA was performed in 1991 to reduce the potential for migration of the trench contaminants to the soil column, groundwater, and Columbia River. The east and west trenches were excavated to a depth of approximately 1.2 m (4 ft) below the former trench bottom. Approximately 5,400 m^3 (7,000 yd^3) of material was removed from each trench. Because the facility was still active during this action, the contaminated sediments from the southern three-quarters of the trench were moved to the northern end, to prevent continued infiltration of water from mobilizing contaminants. Post-remediation samples were collected from four locations in the east trench and one location in the west trench. The samples from the east trench were all collected at the surface (i.e., the bottom of the excavation), whereas the samples from the west trench were collected at 0 m, 2 m (6.5 ft), 3 m (10 ft), and 5 m (16 ft) below the bottom of the excavation. The sample results indicated that the ERA successfully reduced contamination in all areas of the trenches other than the northern spoils area.

In 1997 and 1998, the remainder of the two trenches was remediated under an integrated RCRA/CERCLA process. The maximum depth of remediation was 5.5 m (18 ft) bgs. Roughly, 34,386 metric tons (37,904 tons) of excavated material was disposed of at the ERDF. After completion of the excavation activities, verification samples were collected at the lateral and vertical boundaries of the excavation and analyzed for the contaminants arsenic, benzo(a)pyrene, chrysene, PCBs, thallium, and radionuclides. Table 4-12 summarizes the verification sampling analytical results. Site-specific modeling of the radionuclide and PCB verification results demonstrated that the site achieved applicable RAGs and the site was reclassified to closed out (*300 Area Process Trenches Verification Package* [BHI-01164]). Figure 4-20 presents the total uranium isotope analytical results and corresponding calculated total uranium values from the verification sampling.

RI Borehole C7655 (SAP Well 300-DU-10/HEIS Well 399-1-56). Borehole C7655 was drilled near the center of the 316-5 waste site. It was advanced to a total depth of 37.6 m (123.5 ft) bgs, encountering the water table at about 9.7 m (31.8 ft) bgs. Vadose zone material encountered to a depth of about 5.5 m (18 ft) bgs was assumed to be fill material. Samples were collected at seven discrete intervals within the vadose zone to a depth of 8.2 m (27 ft). Sample collection at and above the water table was attempted at 9.1 and 9.9 m (30 and 32.5 ft) bgs, however insufficient volume was obtained. Analytical results for the C7655 vadose zone samples are summarized in Table 4-12 and depicted on Figure 4-21.

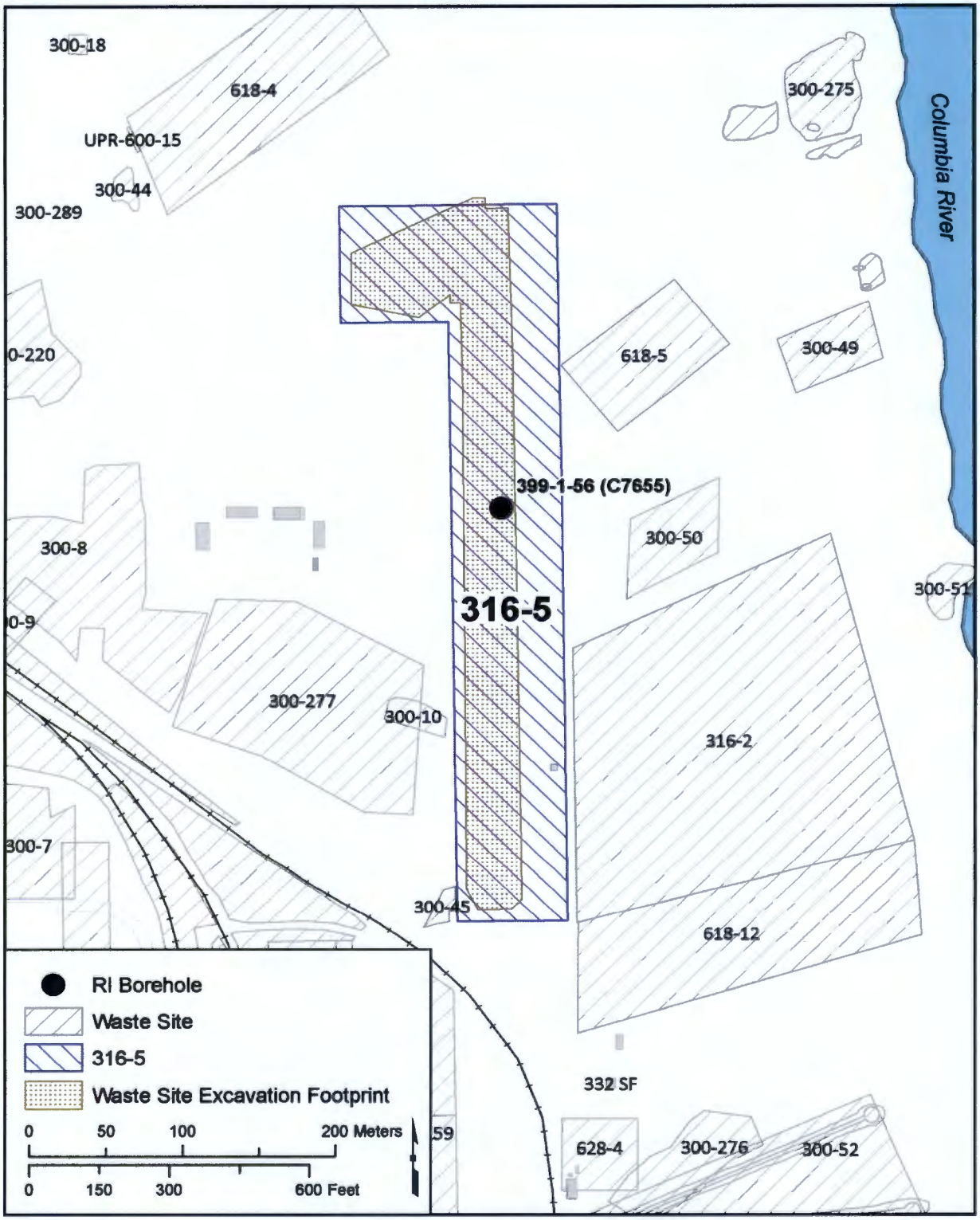
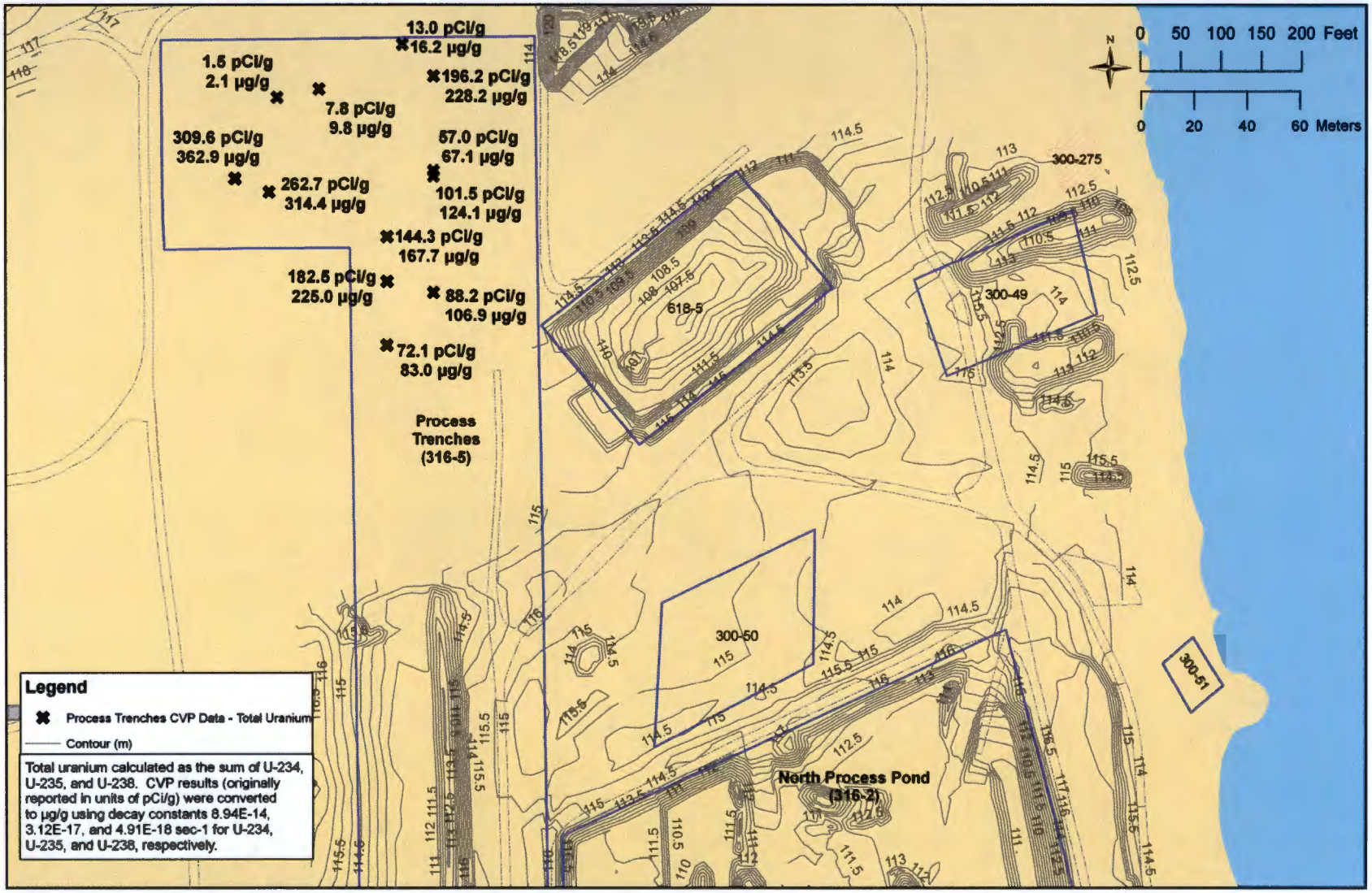


Figure 4-19. Sampling Location Map for Waste Site 316-5



Note: Total uranium results are presented as µg/g, which is the equivalent of mg/kg.

Figure 4-20. Uranium Results for Verification Samples at the 300 Area Process Trenches (WIDS 316-5)

Table 4-12. 300 Area Process Trenches (316-5)—Summary of Contaminant Soil Data (C7655)

Constituent	Concentration and Distribution							
	Background	Cleanup Verification Dataa		Remedial Investigation Boreholeb C7655 (RI Well 300-DU-10)				
				Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection Above Background (m/ft bgs)	Result at Maximum Sample Depth (8.2 m/27 ft bgs unless otherwise noted)c	
Radionuclides (Original and Decayed Concentrations) (pCi/g)[d]								
		Original	Decayed	Original	Decayed		Original	Decayed
Americium-241	NA	ND	ND	0.104 (6.0/19.8)	0.104	6.0/19.8	U	NA
Cesium-137	NA	ND	ND	0.356 (6.0/19.8)	0.34	8.2/27	0.217	0.207
Tritium	NA	ND	ND	0.106 (8.2/27)	0.095	8.2/27	0.106	0.095
Uranium-234	1.1	ND	ND	5.95 (6.0/19.8)	5.95	6.0/19.8	4.49	4.49
Uranium-235	0.109	ND	ND	0.640 (6.9/22.7)	0.64	8.2/27	0.226	0.226
Uranium-238	1.06	ND	ND	4.58 (6.0/19.8)	4.58	8.2/27	3.52	3.52
Total Uranium[e]	2.27	171.8	171.8	ND	ND	ND	ND	ND
Nonradionuclides (mg/kg)								
Aroclor 1260	NA	ND		0.00491 (3.5/11.6)		3.5/11.6	U	
Arsenic	6.5	12.1		2.34 <BG (4.4/14.3)		NA	1.53 (<BG)	
Cadmium	0.563	ND		0.839 (6.0/19.8)		6.9/22.7	0.412 (<BG)	
Chromium	18.5	ND		21.9 (8.2/27)		8.2/27	21.9	
Copper	22	ND		44.1 (6.0/19.8)		8.2/27	25	
Mercury	0.0131	ND		0.096 (6/19.8)		8.2/27	0.069	
Molybdenum	0.47	ND		0.825 (8.2/27)		8.2/27	0.825	
Nitrate	52	ND		146 (3.5/11.6)		6.04/19.8	44.4 (<BG)	
Silver	0.167	ND		22.4 (6.0/19.8)		8.2/27	0.843	
Strontium	NA	ND		27.7 (6.9/22.7)		8.2/27	17.8	
Tin	NA	ND		8.46 (6.9/22.7)		8.2/27	7.04	
Total Calculated Uranium[f]	3.21	ND		13.8 (6/19.8)		8.2/27	10.6	

a. Verification sample results represent the single highest 95% UCL concentration from the 316-5 decision units. Verification 95% UCL values were obtained from *300 Area Process Trenches Verification Package* (BHI-01164). Maximum depth of interim remedial action was 5.5 m (18 ft) bgs.

b. Borehole data obtained from HEIS. The water table was encountered at 9.7 m (31.8 ft) bgs. Well was drilled to 37.7 m (123.5 ft) total depth.

c. The maximum depth from which soil samples were collected is in the rewetted zone/aquifer.

d. Original radiological data presented in the left column with decay corrected value to year 2012 in right column. Data from closeout sampling 95% UCL values obtained using U-flagged data sets is not decayed.

e. Reported result calculated as sum of U-234, U-235, and U-238 activities.

f. Total uranium value is calculated based on analytical results for uranium isotopes.

BG = background

NA = not applicable

ND = no data, not a contaminant of concern/contaminant of potential concern

U = undetected

UCL = upper confidence limit

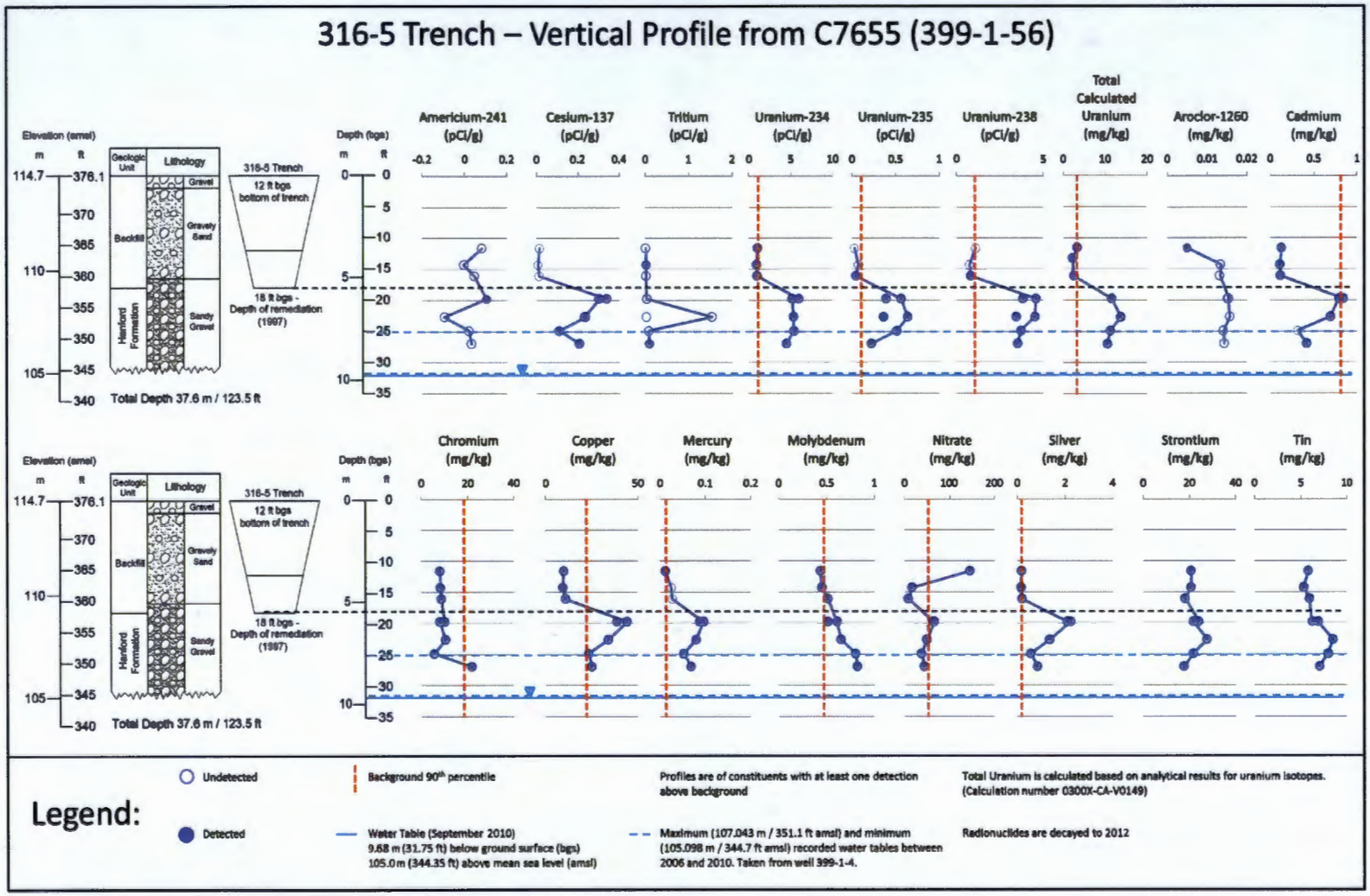


Figure 4-21. Vertical Profile from RI Borehole C7655 (Well 399-1-56) at Waste Site 316-5

Radionuclides detected in these samples included americium-241, Cs-137, tritium, and the three uranium isotopes. For all but tritium and U-235, the most elevated concentrations were measured at about 6 m (19.8 ft) bgs, which is below the depth of the remedial action. Americium-241 was detected at a very low concentration (0.104 pCi/g) in the sample collected below the remedial excavation (6 m [19.8 ft] bgs). These data suggest that americium-241 has an extremely limited vertical extent and no substantive residual mass. Cesium-137 was detected at very low levels in all samples collected below the final depth of remediation, with the maximum activity of 0.356 pCi/g occurring at 6 m (19.8 ft) bgs. The data show that Cs-137 is present from the base of the remedial excavation through the deep vadose zone, but its residual mass is most likely minimal. Tritium was detected at extremely low activities in three samples: 0.0208 pCi/g at about 4.6 m (15 ft) bgs in the backfill portion of the soil column; 0.0877 pCi/g at 7.6 m (24.9 ft) bgs; and 0.106 pCi/g at 8.2 m (27 ft) bgs. These data suggest there is no substantive tritium contamination at this location. Uranium-234, -235, and -238 were all detected at or below background concentrations in the backfill material, and at levels exceeding background at depths below the depth of remedial excavation. All showed maximum activities in samples collected below the remedial excavation at 6 m (19.8 ft) and 6.9 m (22.7 ft) bgs.

The maximum total uranium, calculated from the isotopic activities, was 13.7 mg/kg at 6.9 m (22.7 ft) bgs. The data suggest that uranium isotopes are present at levels exceeding background from the base of remedial excavation to the deep vadose zone, and suggest that concentrations of mobile uranium that exceed background may be present at or near the water table.

Several metals were detected above background concentrations. For all but total chromium, the most elevated metals concentrations were measured at 6 m (19.8 ft) bgs, the sample collected beneath the depth of remedial action. Copper showed a maximum concentration of 44.1 mg/kg at 6 m (19.8 ft) bgs, and from there, a generally decreasing trend with depth. Mercury exceeded background levels in all samples collected at depths of 6 m (19.8 ft) bgs or deeper, with a maximum concentration of 0.096 mg/kg at 6 m (19.8 ft) bgs. Molybdenum was detected above background levels in all samples from depths of 4.9 m (16.1 ft) bgs and greater, with a maximum concentration of 0.825 mg/kg at 8.2 m (27 ft) bgs. Silver was detected above its background level in most samples below the excavation depth, with the maximum concentration of 2.24 mg/kg detected below the excavation depth at 6 m (19.8 ft) bgs. Silver concentrations decrease with depth and are only slightly above background level at 0.843 mg/kg in the deepest sample collected at 8.2 m (27 ft) bgs. Cadmium slightly exceeded background only in the sample collected below the base of remedial excavation (0.839 mg/kg at 6 m [19.8 ft] bgs). Total chromium was below its background level in all but the deepest sample, which was slightly elevated at 21.9 mg/kg (8.3 m [27 ft] bgs). Concentrations of metals for which background values are not available (strontium and tin) are consistent with concentrations measured in other 300 Area RI samples.

Nitrate was the only anion detected above its background level in the RI vadose zone samples. It was detected in all samples, though it only exceeded background in samples collected at 3.5 m (11.6 ft) and 6 m (19.8 ft) bgs, with the maximum concentration of 146 mg/kg being detected in the uppermost sample interval at 3.5 m (11.6 ft) bgs.

Aroclor 1260 was the only PCB detected. It was identified at a very low concentration (0.00491 mg/kg, in a sample collected at 3.5 m (11.6 ft) bgs (within the material used to backfill the remedial excavation). No polycyclic aromatic hydrocarbons (PAHs) or VOCs were detected in the borehole samples.

4.3.4.1 Residual Contamination beneath the 300 Area 307 Disposal Trenches (WIDS Site 316-3)

The 307 Disposal Trenches site (WIDS Site 316-3) is an FF-2 waste site and is currently classified as an "Accepted" CERCLA waste site in WIDS. The RI did not include new characterization activities at this site. It is discussed here because of its history as a liquid waste disposal facility, and its subsequent use as a disposal site for uranium-bearing sludges scraped from the floor of the South Process Pond.

WIDS Site 316-3 is located approximately 226 m (740 ft) west of the Columbia River and 140 m (460 ft) south of the South Process Pond (316-1). It was constructed in 1965 to receive low-level radioactive effluent from the 300 Area Laboratory expansion facilities (329 Biophysics Laboratory, 327 Radiometallurgy Building, 324 Radiochemistry Building, 326 Pile Technology Building, and 329 Mechanical Development Building). Effluent was first routed through the 307 RB, which allowed retention of higher activity effluents for diversion to 200 Area tank farms.

The site originally consisted of two trenches, each 180 m (600 ft) long, 9.1 m (30 ft) wide at the east end, tapering to 3 m (10 ft) wide at the west end. Depth varied from 3.7 to 8.2 m (12 to 27 ft). In service from 1953 to 1963, the trenches received roughly 1,000,000,000 L (260,000,000 gal) of low-level and nonradiological effluent.

When the trenches were taken out of service in 1963, some portion of the contaminated sediments were excavated and transported to the 618-10 Burial Ground. Specifics on the depth and lateral extent of excavation were not found. In 1965, the trenches were backfilled with about 7,600 m^3 (10,000 yd^3) of uranium contaminated sludge scraped from the bottom of the South Process Pond (WIDS Site 316-1). The sludge was then covered with fly ash from the 300 Area Ash Pits (*Summary of Remedial Investigations at the 307 Retention Basins and 307 Trenches (316-3), 300-FF-2 Operable Unit* [WHC-SD-EN-TI-279]). A large portion of WIDS Site 316-3 was subsequently paved and fenced, and several buildings were constructed over a portion of the backfilled trenches.

In 1987, the west end of WIDS Site 316-3 was used to test a grout liquid waste solidification process. During related construction of a 6.1 × 6.1 × 2.7 m (20 × 20 × 9 ft) pit, contaminated materials with readings as high as 378 pCi/g beta and 234 pCi/g alpha were encountered.

In 2008, the three facilities (3718-E, 3718-G, and 3727) located on top of the backfilled trenches were demolished to slab.

Available characterization data are limited to results from LFI boreholes A8080 (399-3-15), A8081 (399-3-16), and A8082 (399-3-17), which were drilled in 1991 and 1992 (Figure 4-22). Data for these boreholes were obtained from two sources. Nonradionuclide data was obtained from HEIS; however, radionuclide data was not available in HEIS and, therefore, was obtained from the associated investigation summary report (*Summary of Remedial Investigations at the 307 Retention Basins and 307 Trenches (316-3), 300-FF-2 Operable Unit* [WHC-SD-EN-TI-279]). A cursory comparison of the HEIS data for nonradionuclides with the same data in *Summary of Remedial Investigations at the 307 Retention Basins and 307 Trenches (316-3), 300-FF-2 Operable Unit* (WHC-SD-EN-TI-279) identified several discrepancies related to laboratory qualifiers for certain analyses. The discrepancies were not resolved, but for the purposes of this document, the following analytical results are presented in the associated tables, but are excluded from analyte profiles and contaminant discussion because of the following uncertainties associated with the data:

- Analytical results for carbon disulfide, chloroform, cadmium, fluoride, selenium, and TCE in borehole A8080 (399-3-15)
- Analytical results for selenium and TCE in Borehole A8081 (399-3-16) deeper than 0.9 m (3 ft) bgs and silver deeper than 3.8 m (12.4 ft) bgs
- Analytical results for carbon disulfide and chloroform in Borehole A8081 (399 3-16)
- Analytical results for 4-methyl-2-pentanone in Borehole A8081 (399-3-16)

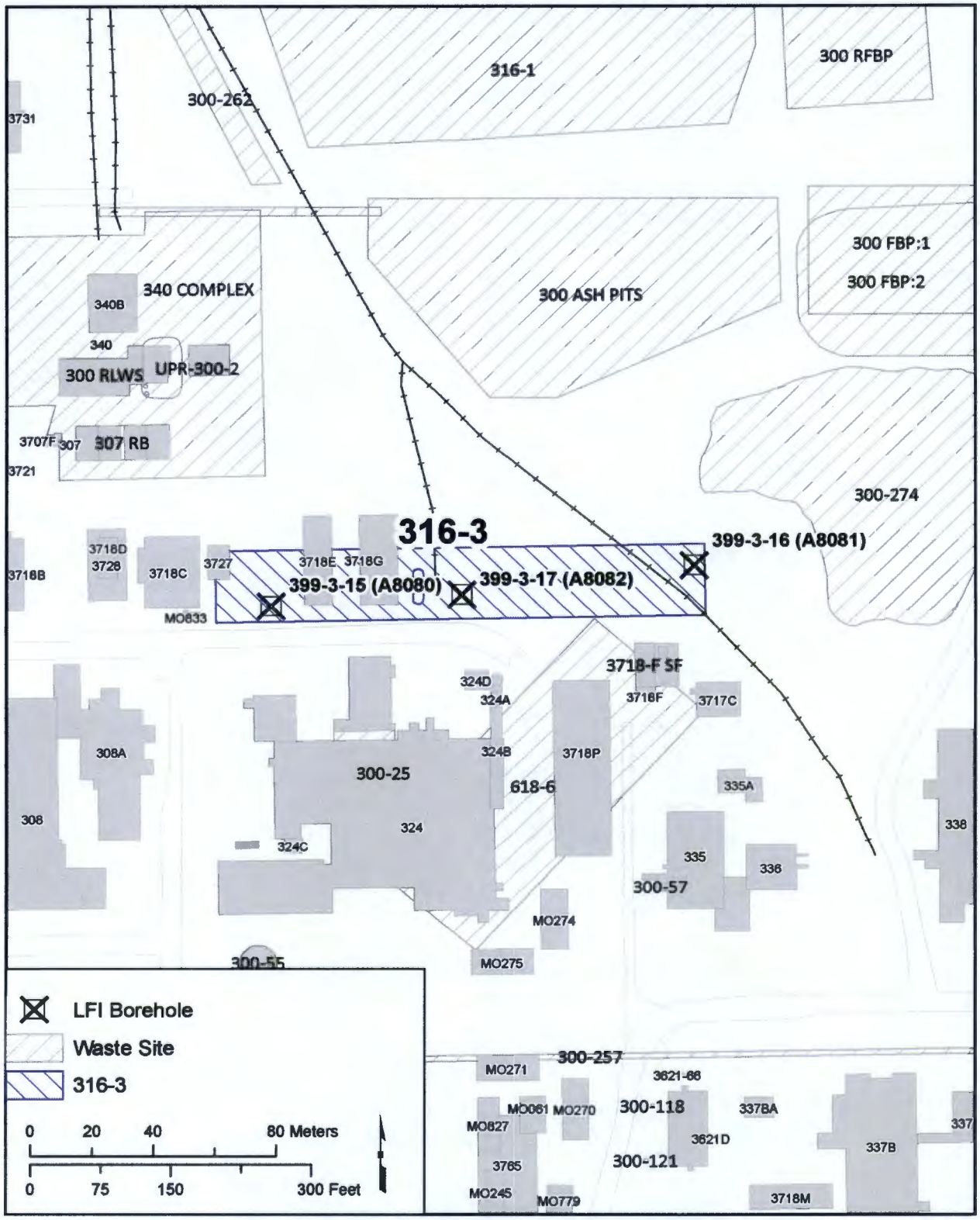


Figure 4-22. Sampling Location Map for the 307 Disposal Trenches (316-3)

LFI Borehole A8080 (HEIS Well 399-3-15). Borehole A8080 was drilled through the western end of the southern trench, near the former location of the inlet to that trench. It was advanced to a total depth of 20.7 m (68 ft) bgs, intersecting the water table at about 16.8 m (55 ft) bgs. The borehole log identifies a sudden lithology change at 6.4 m (21 ft) bgs, interpreted as the interface between disturbed material and indigenous material (i.e., the base of the original trench, or base of the excavation from the 1963 cleanup efforts).

Sampling was conducted at 15 depth intervals between 1.4 m (4.8 ft) and 20.7 m (68 ft) bgs within the vadose zone (including the PRZ) near the water table, and within the shallow portion of the unconfined aquifer. Analytical results are summarized in Table 4-13 and depicted on Figure 4-23.

Radionuclides detected above background levels included Cs-137, Sr-90, and the three uranium isotopes. Cesium-137 was detected in two samples, located slightly below the depth of the trench base, with a maximum of 3.15 pCi/g at 7.5 m (24.5 ft) bgs. Strontium-90 was detected at levels of 0.100 pCi/g or less in samples collected at or deeper than 9.1 m (30 ft) bgs. Uranium-234 and -238 exceeded background levels in most samples, with maximum activities of 8.9 pCi/g and 7.9 pCi/g, respectively, occurring at 7.5 m (24.5 ft) bgs, which is just below the former trench bottom. Both showed secondary peaks at 4.6 to 5.2 m (15 to 17 ft) bgs, just above the former trench bottom, as well as slightly elevated concentrations (2.20 to 2.6 pCi/g) in the deep vadose zone, extending to the water table. Uranium-235 was detected above its background level less frequently, and had its maximum activity of 0.500 pCi/g at 5.2 m (17 ft) bgs.

Metals detected above background included antimony, barium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc. Several of these showed maximum concentrations above the structural bottom of the trench, at either 4.6 m (15 ft) or 5.2 m (17 ft) bgs. These included antimony (10.3 mg/kg), barium (198 mg/kg), copper (62.3 mg/kg), lead (110 mg/kg), and zinc (75.1 mg/kg). Mercury and silver had maximum concentrations of 2.5 mg/kg and 10.6 mg/kg, respectively, at 7.5 m (24.5 ft) bgs, just below the bottom of the trench. The remainder of the metals had maximum concentrations at 12.8 m (42 ft) bgs, including chromium (274 mg/kg), cadmium (2.80 mg/kg), and nickel (146 mg/kg). Total uranium, calculated from the isotopic values, had a maximum concentration of 23.7 mg/kg at 7.5 m (24.5 ft) bgs, just below the bottom of the trench. Total uranium was also calculated at a concentration of 15 mg/kg for the sediment sample collected at 20.7 m (68 ft) bgs, which was roughly 4 m (13 ft) below the water table.

No anions were detected above background levels.

Three organic compounds were detected. Tetrachloroethene was detected in one sample, at 0.006 mg/kg at 7.5 m (24.5 ft) bgs. Aroclor 1254 and Aroclor 1260 were each detected at 2.7 m (9 ft) bgs, at concentrations below their respective PQLs.

LFI Borehole A8081 (HEIS Well 399-3-16). Borehole A8081 was drilled in December 1991 at the eastern end of the northern trench to a total depth of 18.3 m (60 ft) bgs, intersecting the water table at 14.9 m (49 ft) bgs. Soil samples were collected at 20 different depth intervals between 0.6 m (2 ft) and 18.3 m (60 ft) bgs within the vadose zone (including the PRZ), near the water table, and within the upper 3.4 m (11 ft) of the unconfined aquifer. The borehole log does not identify a break in lithology suggestive of an interface between disturbed and indigenous material, which was expected at roughly 6.4 m (21 ft) bgs. Analytical results for borehole A8081 are summarized in Table 4-13 and depicted in Figures 4-24 and 4-25.

Radionuclides detected included Cs-137, Co-60, Sr-90, and the three uranium isotopes. Cesium-137 was detected at a maximum activity of 3.7 pCi/g (below its PQL) at 8 m (26.4 ft) bgs. Cobalt-60 and Sr-90 were detected at very low levels, with maximums of 0.109 pCi/g and 0.800 pCi/g, respectively, both at 12.5 m (41 ft) bgs. The uranium isotopes were detected above background in most samples. Uranium-234 and U-238 had maximum activities of 58 pCi/g and 66 pCi/g, respectively, at 3.1 m (10.3 ft) bgs. Uranium-235 had a maximum activity of 1 pCi/g at 11 m (36 ft) bgs. The data suggest a moderate uranium contaminant mass in the shallow zone, roughly 2.4 to 4.6 m (8 to 15 ft) bgs, and show no substantive contaminant mass in the deep vadose zone, where maximum activities were 3 pCi/g, 1 pCi/g and 3.7 pCi/g, respectively.

Total uranium, calculated from the isotopic values, had a maximum concentration of 197 mg/kg at 3.1 m (10.3 ft) bgs. Concentrations in the deep vadose zone were much lower, with a localized maximum of 11.1 mg/kg found at 12.5 m (41 ft) bgs. Barium, lead, and selenium all had maximum concentrations at 0.6 m (2 ft) bgs. Barium and selenium exceeded background levels only at that depth, with concentrations of 1,090 mg/kg and 4.4 mg/kg, respectively. Lead exceeded its background level in several samples to depths of 7.9 m (26 ft) bgs, with a maximum concentration of 51 mg/kg occurring at 0.6 m (2 ft) bgs. Silver was detected in several samples with a maximum concentration of 23 mg/kg in the 3.1 m (10.3 ft) bgs sample. Mercury exceeded its background level in several samples to depths of 7.9 m (26 ft) bgs, with a maximum concentration of 1.70 mg/kg being detected at both 3.1 m (10.3 ft) and 3.8 m (12.4 ft) bgs. Chromium, copper, and nickel had maximum concentrations of 64.9 mg/kg, 427 mg/kg, and 12.7 mg/kg, respectively, at the 3.8 m (12.4 ft) bgs depth interval. Zinc was detected above background at two depths, with a maximum concentration of 119 mg/kg at 7.9 m (26 ft) bgs. Cadmium exceeded background at 3.8 and 9.3 m (12.4 and 30.4 ft) bgs, with its maximum concentration, 4.1 mg/kg, occurring at 9.3 m (30.4 ft) bgs.

Fluoride was detected above background in most samples, and had a maximum concentration of 109 mg/kg at 0.6 m (2 ft) bgs. Nitrate exceeded background in two samples, with a maximum concentration of 106 mg/kg at 4.4 m (14.3 ft) bgs.

Aroclor 1248 and Aroclor 1254 were detected above background, with maximums of 160 mg/kg and 180 mg/kg, respectively, at 7.9 m (26 ft) bgs. Trichloroethene and PCE were detected above background, but at levels below PQLs.

LFI Borehole A8082 (HEIS Well 399-3-17). LFI Borehole A8082 was drilled in January 1992 near the center of the 316-3 waste site. It extended to a total depth of 19.8 m (65 ft) bgs, and intersected the water table at 15.5 m (51 ft) bgs. Soil samples were collected at 13 different depth intervals between 2.6 m (8.4 ft) and 19.8 m (65 ft) bgs within the vadose zone, near the water table, and within the upper 4.3 m (14 ft) of the unconfined aquifer. It is not clear that sampling captured much material from the PRZ because no samples were collected between 11.6 m (38 ft) bgs and the water table at 15.5 m (51 ft) bgs. The borehole log identifies a sudden lithology change at 6.2 m (20.5 ft) bgs, interpreted as the interface between disturbed material and indigenous material. Analytical results for borehole A8082 are summarized in Table 4-13 and depicted in Figure 4-26.

Table 4-13. 316-3 Trench Summary of Contaminant Soil Data (399-3-15, 399-3-16, and 399-3-17)

Constituent	Background	Concentration and Distribution														
		LFI Borehole 399-3-15[a]					LFI Borehole 399-3-16[b]					LFI Borehole 399-3-17[c]				
		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (20.7 m/68 ft bgs)		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (18.3 m /60 ft bgs)		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (19.8 m/65 ft bgs unless otherwise noted)	
Radionuclides (Original and Decayed Concentrations) (pCi/g)[d]																
		Original	Decayed		Original	Decayed	Original	Decayed		Original	Decayed	Original	Decayed		Original	Decayed
Cesium-137	NA	3.148 (7.5/24.5)	1.99	7.5/24.5	U		3.71 (8.1/26.4)	2.34	9.4/30.7	U		U		NA	U	
Cobalt-60	NA	U		NA	U		0.109 (12.5/41)	0.008	12.5/41	U		U		NA	U	
Strontium-90	NA	0.100 (11.3/37)	0.062	20.7/68	0.070	0.044	0.800 (12.5/41)	0.497	18.3/60	0.01	0.006	0.40 (2.6/8.4)	0.25	10.1/33	U	
Uranium-234	1.1	8.5 (7.5/24.5)	8.5	16.2/53	0.040 (<BG)	0.040	58.0 (3.1/10.3)	58	18.3/60	2.5	2.5	29 (2.6/8.4)	29	15.9/52	2.1	2.1
Uranium-235	0.109	0.50 (5.2/17)	0.50	20.7/68	0.20	0.20	1.00 (11.0/36)	0.80	12.5/41	0.10 (<BG)	0.10	1.1 (6.1/20)	1.1	7.3/24	0.090	0.090
Uranium-238	1.06	7.9 (7.5/24.5)	7.9	20.7/68	5.0	5.0	66.0 (3.1/10.3)	66	18.3/60	3.1	3.1	32 (2.6/8.4)	32	15.9/52	2.0	2.0
Nonradionuclides (mg/kg)																
Antimony	0.13	10.3 (5.2/17)		20.7/68	8.6		U		NA	U		U		NA	U	
Barium	132	198 (4.6/15)		4.6/15	79.6 (<BG)		1090 (0.9/3)		1.5/4.9	77.5 (<BG)		199 (5.4/17.7)		5.4/17.7	83.1 (<BG) (15.9/52)	
Cadmium	0.563	2.8 (12.8/42) [e]		20.7/68	0.64		4.1 (9.3/30.4)		9.3/30.4	U		4.0 (6.1/20)		10.1/33	U	
Chromium	18.5	274 (12.8/42)		12.8/42	5.1 (<BG)		64.9 (3.8/12.4)		3.8/12.4	5.6 (<BG)		49.2 (2.6/8.4)		7.3/24	4.6 (<BG) (15.9/52)	
Copper	22	62.3 (4.6/15)		12.8/42	21 (<BG)		427 (3.8/12.4)		11.0/36	20.1 (<BG)		181 (2.6/8.4)		6.1/20	17.1 (<BG) (15.9/52)	
Fluoride	2.81	2.5 (16.2/53.0) [e] (<BG)		NA	U		109.2 (0.9/3)		17.7/58	U		8.9 (2.6/8.4)		3.2/10.4	1.0 (<BG)	
Lead	10.2	110 (4.6/15)		16.2/53	5.1 (<BG)		51 (0.9/3)		7.9/26	2.3 (<BG)		34.9 (6.1/20)		6.1/20	3.1 (<BG) (15.9/52)	
Mercury	0.0131	2.5 (7.5/24.5)		17.7/58	U		1.7 (3.8/12.4)[f]		7.9/26	U		0.58(2.6/8.4)		19.8/65	0.09	
Nickel	19.1	146 (12.8/42)		12.8/42	7.5 (<BG)		25.7 (3.8/12.4)		3.8/12.4	6.3 (<BG)		19.1 (2.6/8.4)		2.6/8.4	6.9 (<BG) (15.9/52)	
Selenium	0.78	U		NA	U		3.3 (0.9/3)		9.3/30.4 [g]	U		U		NA	U	
Silver	0.167	10.6 (7.5/24.5)		7.5/24.5	U		23 (3.1/10.3)		7.9/26 [g]	U		5.6 (2.6/8.4)		6.1/20	U	
Zinc	67.8	98.2 (4.57/15)		7.47/24.5	38.3 (<BG)		119 (7.9/26)		7.9/26	39.3 (<BG)		155 (6.1/20.0)		6.1/20.0	27.6 (<BG) (15.9/52.0)	
Nitrate	52	10.7 (<BG) (2.1/7)		NA	4.70 (<BG)		106 (4.4/14.3)		4.4/14.3	4.70 (<BG)		21.1 (<BG) (2.6/8.4)		NA	2.00 (<BG)	
Aroclor 1248	NA	U		NA	U		0.16 (7.9/26)		7.9/26	U		U		NA	U	
Aroclor 1254	NA	0.91 (7.5/24.5)		7.5/24.5	U		0.18 (7.9/26)		7.9/26	U		0.12 (2.6/8.4)		2.6/8.4	U	
Aroclor1260	NA	2.5 (7.5/24.5)		7.5/24.5	U		U		NA	U		U		NA	U	
1,1,2-Trichloro-1,2,2-trifluoroethane	NA	ND		ND	ND		0.014 (0.9/3) [h]		3. 8/12.4	ND		ND		ND	ND	
4-Methyl-2-pentanone	NA	U		NA	U		0.088 (0.9/3) [i]		9.3/30.4	U		U		NA	U	
Carbon Disulfide	NA	0.006 (4.6/15.0)[e]		7.5/24.5	U		0.005 (3.8/12.4) [g]		9.3/30.4	U		U		NA	U	
Chloroform	NA	0.002 (6.9/22.5)[e]		6.9/22.5	U		0.0009 (9.3/30.4) [g]		9.3/30.4	U		U		NA	U	
Hexane	NA	0.0081 (7.5/24.5)[h]		7.5/24.5	ND		ND		ND	ND		ND		ND	ND	

Table 4-13. 316-3 Trench Summary of Contaminant Soil Data (399-3-15, 399-3-16, and 399-3-17)

Constituent	Background	Concentration and Distribution								
		LFI Borehole 399-3-15[a]			LFI Borehole 399-3-16[b]			LFI Borehole 399-3-17[c]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (20.7 m/68 ft bgs)	Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (18.3 m /60 ft bgs)	Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (19.8 m/65 ft bgs unless otherwise noted)
Tetrachloroethene	NA	0.006 (7.5/24.5)	7.5/24.5	U	0.028 (0.9/3)	0.9/3	U	U	NA	U
Trichloroethene	NA	0.005 (7.5/24.5)[e]	7.5/24.5	U	0.17 (0.9/3)	0.9/3 [g]	U	U	NA	U
Trichloromonofluoromethane	NA	0.017 (2.7/9)[h]	2.7/9.0	ND	ND	ND	ND	ND	ND	ND

a. Borehole data obtained from HEIS. The water table was encountered at 16.8 m (55 ft) bgs. Well was drilled to 20.7 m (68 ft) total depth.

b. Borehole data obtained from HEIS. The water table was encountered at 15.1 m (49.4 ft) bgs. Well was drilled to 18.3 m (60 ft) total depth.

c. Borehole data obtained from HEIS. The water table was encountered at 15.5 m (51 ft) bgs. Well was drilled to 19.8 m (65 ft) total depth.

d. Original radiological data presented in the left column with decay corrected value to year 2012 in right column.

e. All analytical results for carbon disulfide, chloroform, cadmium, fluoride, selenium, and trichloroethene in 399-3-15 are flagged with a U, UJ, or UR in *Summary of Remedial Investigations at the 307 Retention Basins and 307 Trenches (316-3), 300-FF-2 Operable Unit* (WHC-SD-EN-TI-279). The U and/or R qualifier was likely assigned during data validation but the validation package is not available. Data is not presented in profiles.

f. Maximum mercury concentration for Borehole 399-3-16 was detected in two consecutive sample intervals, at 3.1 and 3.8 m (10.3 and 12.4 ft) bgs. This table presents the deeper of the two intervals as the depth of maximum concentration.

g. All analytical results for selenium and trichloroethene in 399-3-16 deeper than 0.9 m (3 ft) bgs and silver deeper than 3.8 m (12.4 ft) bgs are flagged with a U, R, UR, or UJ in *Summary of Remedial Investigations at the 307 Retention Basins and 307 Trenches (316-3), 300-FF-2 Operable Unit* (WHC-SD-EN-TI-279). All analytical results for carbon disulfide and chloroform in 399-3-16 are flagged with a U or UJ in *Summary of Remedial Investigations at the 307 Retention Basins and 307 Trenches (316-3), 300-FF-2 Operable Unit* (WHC-SD-EN-TI-279). The U and/or R qualifier was likely assigned during data validation but the validation package is not available. Data is not presented in profiles.

h. Analytical results for hexane, trichlormonofluoromethane (Freon 11), and 1,1,2-trichloro-1,2,2-trifluoroethane (CFC-113) were TICs in the data packages. A TIC is a compound that can be detected by the analytical testing method, but the identity and concentration cannot be confirmed without further analytical investigation. While the subject TICs were previously loaded into the HEIS database, data from TICs were not included in *Summary of Remedial Investigations at the 307 Retention Basins and 307 Trenches (316-3), 300-FF-2 Operable Unit* (WHC-SD-EN-TI-279). Data is not presented in profiles.

i. All analytical results for 4-methyl-2-pentanone in 399-3-16 are flagged with a U, UJ, or UR in *Summary of Remedial Investigations at the 307 Retention Basins and 307 Trenches (316-3), 300-FF-2 Operable Unit* (WHC-SD-EN-TI-279). The U and/or R qualifier was likely assigned during data validation but the validation package is not available. Data is not presented in profiles.

HEIS = Hanford Environmental Information System
J = estimate
NA = not applicable
NR = not reported
R = rejected
TIC = tentatively identified compound
U = undetected

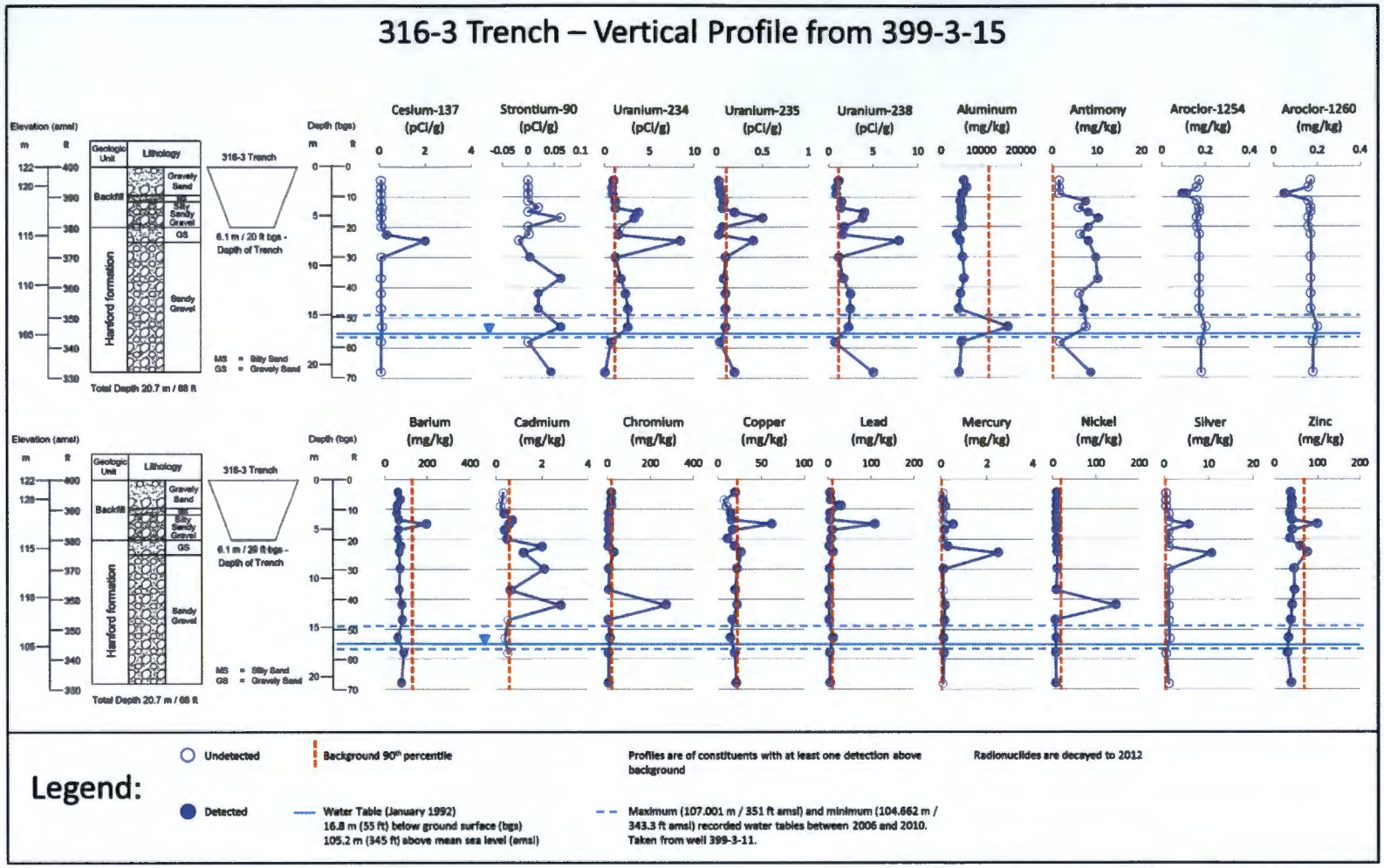


Figure 4-23. Vertical Profile from LFI Borehole A8080 (Well 399-3-15) at Waste Site 316-3

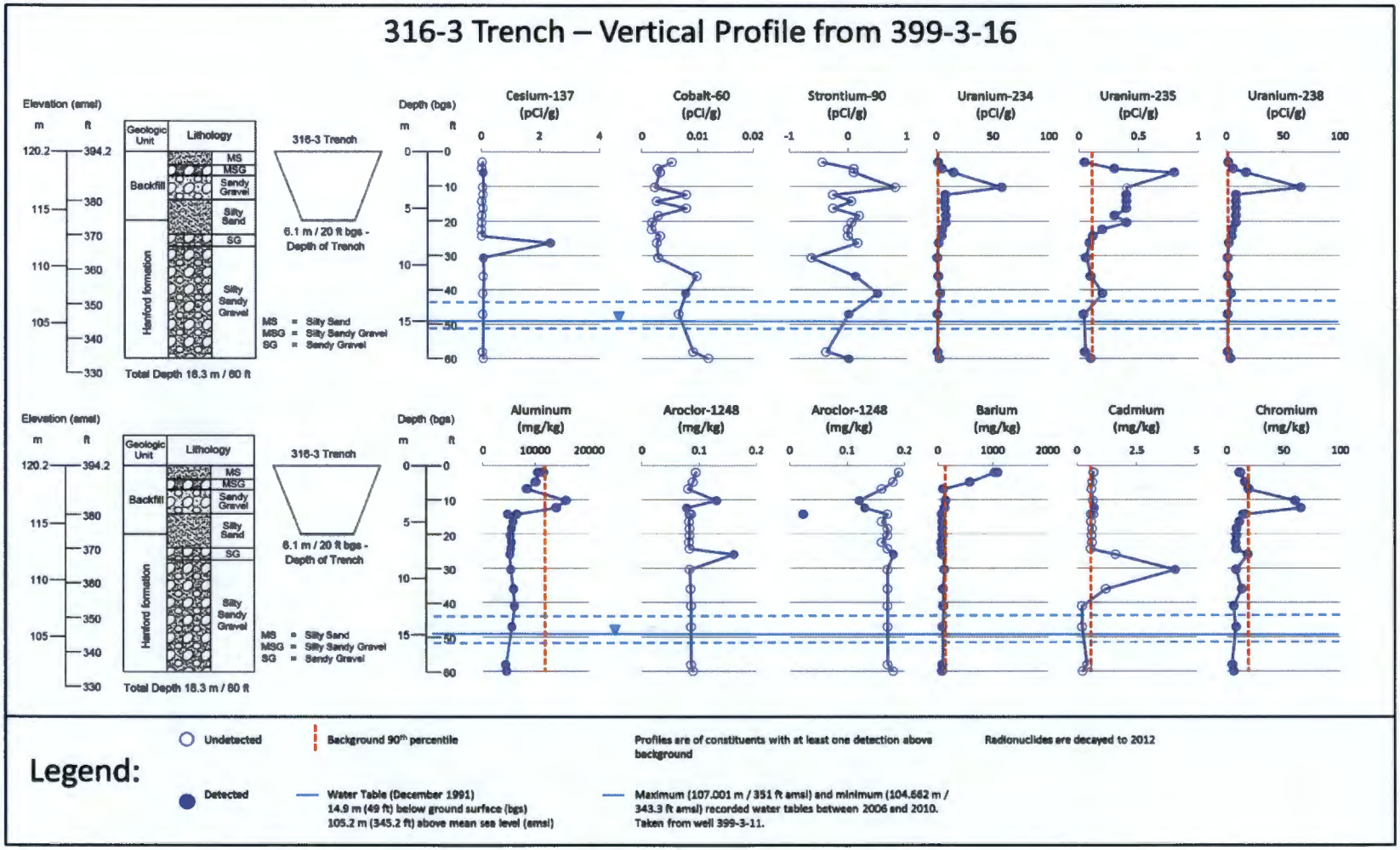


Figure 4-24. Vertical Profile from Borehole A8081 (Well 399-3-16) at Waste Site 316-3 (1 of 2)

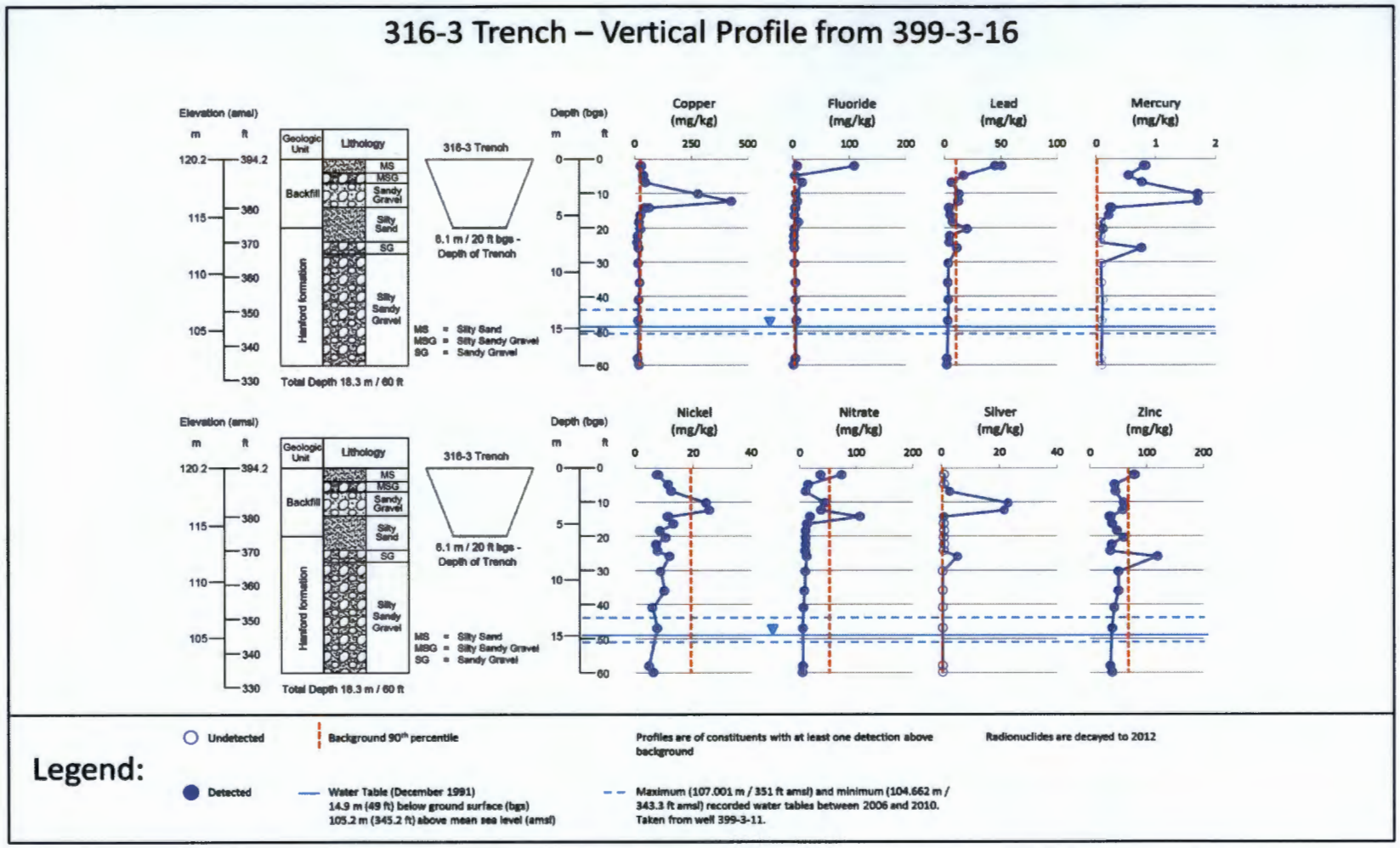


Figure 4-25. Vertical Profile from Borehole A8081 (Well 399-3-16) at Waste Site 316-3 (2 of 2)

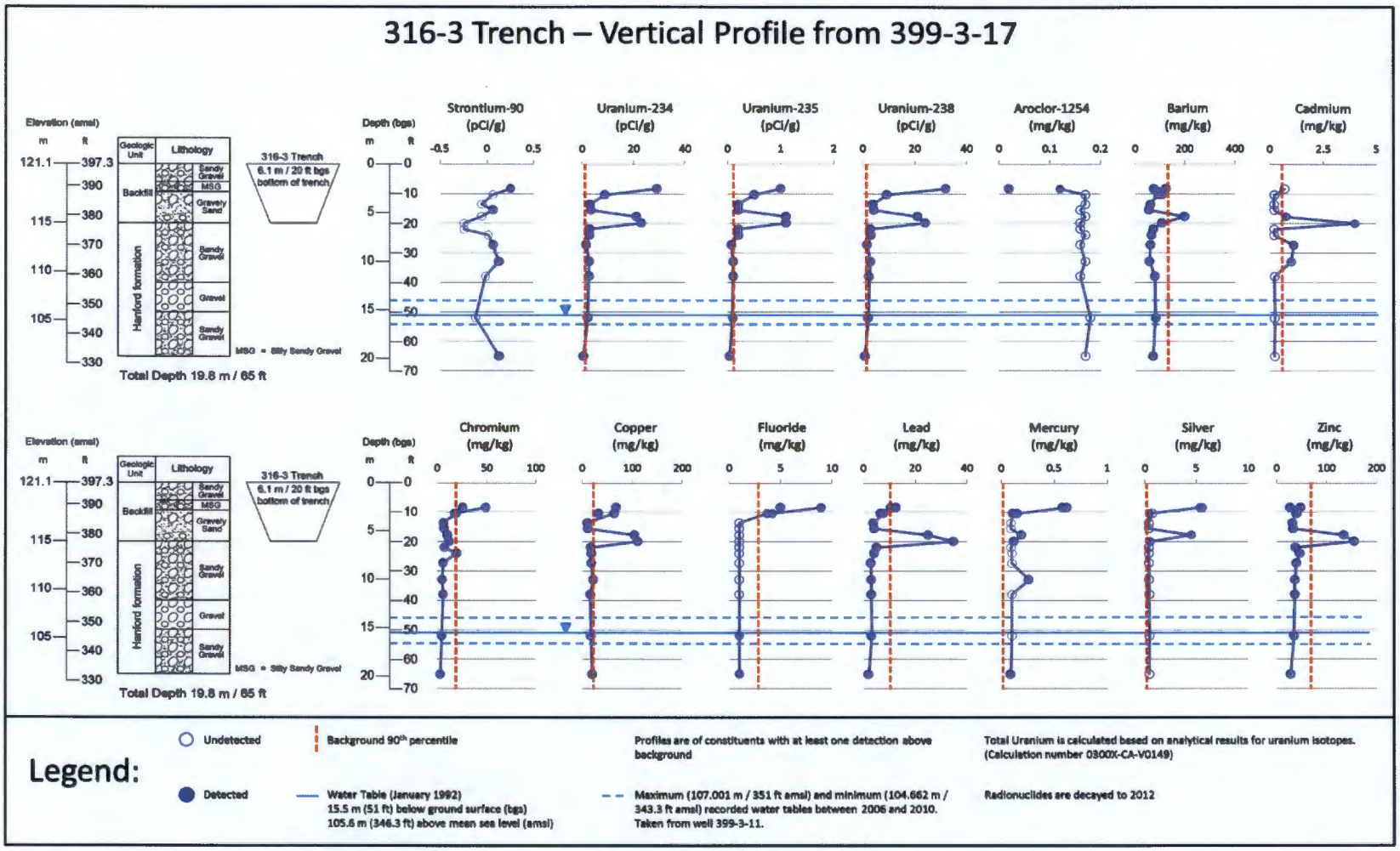


Figure 4-26. Vertical Profile from Borehole A8082 (Well 399-3-17) at Waste Site 316-3

Strontium-90 and the three uranium isotopes were detected above background levels. Strontium-90 had a maximum of 0.400 pCi/g at 2.6 m (8.4 ft) bgs. The uranium isotopes were detected above background in most samples. Their highest activity levels occurred at 2.6 m (8.4 ft) bgs, roughly mid-depth in the trench, and at 5.4 m (17.7 ft) bgs and 6.1 m (20 ft) bgs, near the bottom of the trench. The maximum activity for U-234 (29 pCi/g) occurred at 2.6 m (8.4 ft) bgs, with a similar value (23 pCi/g) occurring at 6.1 m (20 ft) bgs. The maximum activity levels for U-235 and U-238 (1.24 pCi/g and 44.4 pCi/g, respectively) both occurred at 6.1 m (20 ft) bgs. In the stratigraphic horizon approximately 4.6 m (15 ft) above the water table (sample collected at 11.6 m (38 ft) bgs), the activities for the three uranium isotopes were 2.6 pCi/g, 0.10 pCi/g, and 2.40 pCi/g, respectively. Based on these results, there appears to be minimal uranium contaminant mass at depth at this location.

The maximum total uranium concentration calculated from the isotopic values was 133 mg/kg at 6.1 m (20 ft) bgs. In the stratigraphic horizon approximately 4.6 m (15 ft) above the water table (sample collected at 11.6 m (38 ft) bgs), the total uranium concentration was 7.2 mg/kg. Other metals detected above background levels included barium, cadmium, chromium, copper, lead, mercury, silver, and zinc. The sample collected at 2.6 m (8.4 ft) bgs contained maximum concentrations for chromium (49.2 mg/kg), copper (181 mg/kg), mercury (0.580 mg/kg) and silver (5.60 mg/kg). The sample collected at 5.4 m (17.7 ft) bgs contained the maximum barium concentration (199 mg/kg). The sample collected at 6.1 m (20 ft) contained the highest concentrations of cadmium (4.00 mg/kg), lead (34.9 mg/kg), and zinc (155 mg/kg).

Fluoride was found at a maximum concentration of 4.90 mg/kg at 2.6 m (8.4 ft) bgs. It was the only anion detected.

Aroclor 1254 was the only organic compound detected. It was identified in the sample collected at 2.6 m (8.4 ft) bgs at a concentration of 0.120 mg/kg (below the PQL).

4.3.5 Residual Contamination beneath the 300 Area 307 Retention Basins (WIDS Site 307 RB)

The 307 RB (WIDS Site 307 RB) is an FF-2 waste site and currently classified as "Accepted." The RI did not include new characterization activities at this site.

The 307 RB were constructed in 1953, along with the 340 Complex, the 307 Process Trenches, the 300 RPS and the 300 RLWS, to support the large defense production expansion and construction of the 325, 326, 327, and 329 Buildings. The facility consists of four 95,000 L (25,000 gal) open, epoxy coated concrete receiving basins, used in pairs as short-term holding facilities for process effluents, to facilitate diversion of higher activity process effluents to the 200 Area tank farms. Wastes below established radiological thresholds were discharged to the 307 Disposal Trenches. Waste that exceeded the thresholds was redirected to the two 57,000 L (15,000 gal) collection tanks housed in a below-grade containment vault in the 340 Building.

In 1969, a long-duration leak was discovered in the cast iron transfer line between the 307 RB and the 340 Vault. The corroded section of pipe released roughly 900 Ci of short-lived radionuclides (including 10 Ci each of Sr-90 and Cs-137) to the soil column, over a period as long as a year. Contaminated soil was removed and disposed and the pipe was repaired and put back into service.

Available characterization data are limited to results from LFI Borehole A8078 (Well 399-3-13) and LFI Borehole A8079 (Well 399-3-14), drilled in 1991 (Figure 4-27). Data for these boreholes were obtained from two sources. Nonradionuclide data was obtained from HEIS. However, radionuclide data was not available in HEIS, and therefore was obtained from the associated investigation summary report, *Summary of Remedial Investigations at the 307 Retention Basins and 307 Trenches (316-3), 300-FF-2 Operable Unit* (WCH-SD-EN-TI-279). A cursory comparison of the HEIS data for nonradionuclides with

the same data in *Summary of Remedial Investigations at the 307 Retention Basins and 307 Trenches (316-3), 300-FF-2 Operable Unit* (WCH-SD-EN-TI-279) identified several discrepancies related to laboratory qualifiers for certain analyses. The discrepancies were not resolved, but for the purposes of this document, the following analytical results are presented in the associated tables, but are excluded from analyte profiles and contaminant discussion because of the following uncertainties associated with the data:

- Analytical results for benzene, carbon disulfide, chloroform and TCE in Borehole A8078 (399-3-13)
- Analytical results for cadmium and carbon disulfide in Borehole A8079 (399-3-14)

LFI Borehole A8078 (Well 399-3-13). Borehole A8078 (399-3-13) was drilled immediately west of the 307 RB, roughly 127 m (420 ft) southwest of the South Process Pond. It was advanced to a total depth of 20.4 m (67 ft) bgs, encountering the water table at about 13.4 m (44 ft) bgs. Soil samples were collected at 13 discrete intervals between ground surface and the shallow portion of the unconfined aquifer. Analytical results for these samples are summarized in Table 4-14 and shown on Figure 4-28.

Radionuclides detected in Borehole A8078 included Sr-90 and the three uranium isotopes. Strontium-90 activities were extremely low, the maximum activity of 0.680 pCi/g occurring at 3.2 m (10.5 ft) bgs. Each of the three uranium isotopes had activities lower than their background levels in all samples except those collected at 2.3 m (7.5 ft) bgs. The activities at that depth were analysis 6.1 pCi/g for U-234, 0.500 pCi/g for U-235, and 5.4 pCi/g for U-238.

The only metals detected above background concentrations were copper and selenium. Copper exceeded background in one sample that was collected at 0.6 m (2 ft) bgs (29.1 mg/kg). Selenium exceeded background in samples collected at 3.2 m (10.5 ft), 4 m (13 ft), and 7 m (23 ft) bgs.

Fluoride exceeded its background level in all samples collected at 3.2 m (10.5 ft) bgs and deeper. The maximum concentration was detected in the 7 m (23 ft) bgs sample.

Aroclor 1254 was detected in one sample collected at 0.6 m (2 ft) bgs. The estimated concentration was 53 mg/kg, which was below the PQL. Benzene, carbon disulfide, chloroform, and TCE were included in the data summary table; however, due to the discrepancies, they are omitted from the discussion and the data profiles.

LFI Borehole A8079 (Well 399-3-14). Borehole A8079 (399-3-14) was drilled immediately east of the 307 RB, roughly 108 m (354 ft) south-southwest of the South Process Pond. It was advanced to a total depth of 17 m (56 ft) bgs, encountering the water table at about 14.3 m (47 ft) bgs. Soil samples were collected at 16 discrete intervals between ground surface and the shallow portion of the unconfined aquifer. Analytical results for these samples are summarized in Table 4-14 and shown in Figure 4-29.

Radionuclides detected in Borehole A8079 included Co-60, Sr-90, and the three uranium isotopes. Cobalt-60 was detected in a single sample in the deep vadose zone (1.26 pCi/g at 12.8 m [42 ft] bgs). Strontium was detected in several samples between 4 m (13 ft) and 17.1 m (56 ft) bgs, with a maximum of 9.1 pCi/g at 14.3 m (47 ft) bgs. The uranium isotopes were not detected above background levels in any of the shallow samples. Each had maximum activities in the deep vadose zone at 12.8 m (42 ft) bgs. Maximum activities at that depth were U-234 at 47 pCi/g, U-235 at 2.7 pCi/g, and U-238 at 38 pCi/g. Only U-238 was detected above its background level in deeper sample intervals (3.05 pCi/g at 14.3 m [47 ft] bgs). These data suggest the presence of a moderate uranium contaminant mass within the stratigraphic horizon of the PRZ. Potential sources of the mass are the 307 RB or the historical water table, possibly associated with groundwater mounding from the South Process Pond (316-1) located about 106 m (348 ft) to the northeast.

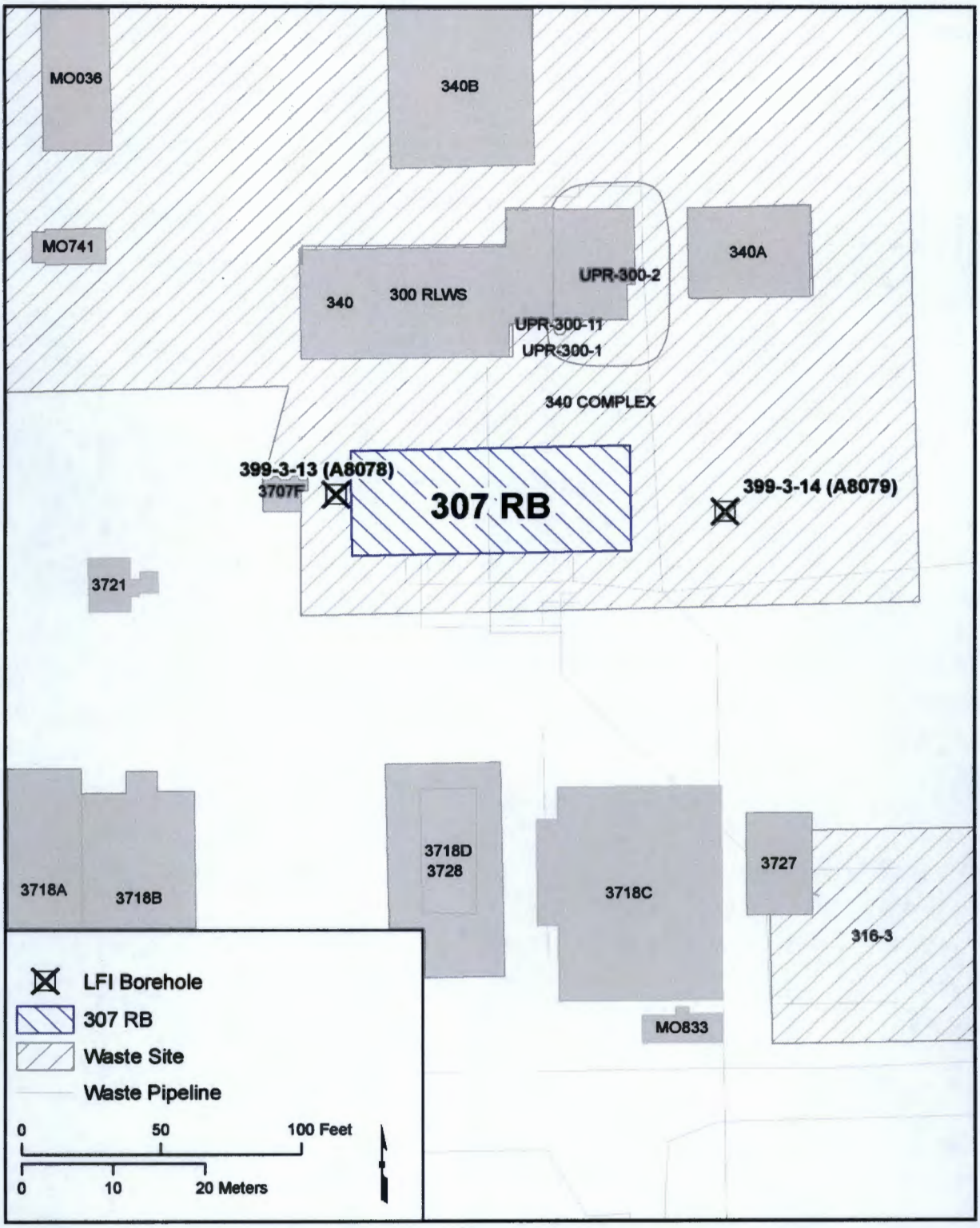


Figure 4-27. Sampling Location Map for the 307 RB

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Table 4-14. 307 RB Summary of Contaminant Soil Data (399-3-13 and 399-3-14)

Constituent	Background	Concentration and Distribution									
		Remedial Investigation Borehole 399-3-13[a]					Remedial Investigation Borehole 399-3-14[b]				
		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection above Background (m/ft bgs)	Result at Maximum Sample Depth (20.42 m/67 ft bgs Unless Otherwise Noted)		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (14.94 m/49 ft bgs Unless Otherwise Noted)	
Radionuclides (Original and Decayed Concentrations) (pCi/g)[c]											
		Original	Decayed		Original	Decayed	Original	Decayed		Original	Decayed
Cobalt-60	0.008	ND		ND	ND		1.26 (12.8/42)	0.0907	12.8/42	U[d]	
Strontium-90	0.18	0.680 (3.2/10.5)	0.422	9.8/32.0	U[e]		9.10 (14.3/47)	5.65	14.3/47	9.1e	5.65
Thorium-228	0	0.917 (7.0/23)	0.000653	13.4/44.0	0.444d	0.000316	0.867 (12.8/42)	0.000618	14.3/47	0.548e	0.000390
Uranium-234	1.1	6.10 (2.3/7.5)	6.10	2.3/7.5	0.600d	0.600	47.0 (12.8/42)	47.0	14.3/47	0.600e	0.600
Uranium-235	0.109	0.500 (2.3/7.5)	0.500	2.3/7.5	0.0800d	0.080	2.70 (12.8/42)	2.70	14.3/47	0.030e	0.030
Uranium-238	1.06	5.40 (2.3/7.5)	5.40	2.3/7.5	0.500d	0.500	38.0 (12.8/42)	38.0	14.3/47	0.500e	0.500
Nonradionuclides (mg/kg)											
Aroclor 1254	NA	0.0530 (0.6/2)		0.6/2	U		U		NA	U	
Benzene[f]	NA	0.003 (7.0/23)		7.0/23	U		U		NA	U	
Cadmium[f]	0.81	U		NA	U		2.00 (3.4/11)		8.2/27	U	
Carbon disulfide[f]	NA	0.0130 (0.6/2)		20.4/67	0.005		0.0650 (0.6/2)		8.2/27	U	
Chloroform[f]	NA	0.003 (13.4/44)		20.4/67	0.002		U		NA	U	
Copper	22	29.1 (0.6/2)		0.6/2	13.7		19.1 (14.3/47) (<BG)		NA	16.5 (<BG)	
Fluoride	2.81	15.6 (7.0/23)		13.4/44	1.94		10.3 (9.8/32)		14.9/49	8.9	
Trichloroethene[f]	NA	0.005 (7.0/23)		7.0/23	U		U		NA	U	

a. Borehole data obtained from HEIS. The water table was encountered at roughly 14.3 m (44 ft) bgs. Well was drilled to 20.4 m (67 ft) total depth.

b. Borehole data obtained from HEIS. The water table was encountered at 14.3 m (47 ft) bgs. Well was drilled to 17.1 m (56 ft) total depth.

c. Original radiological data presented in the left column with decay corrected value to year 2012 in right column.

d. Data from 13.41 m (44 ft).

e. Data from 14.32 m (47 ft).

f. Though listed as detected in HEIS, these values are shown as not detected data (U flagged) in *Summary of Remedial Investigations at the 307 Retention Basins and 307 Trenches (316-3), 300-FF-2 Operable Unit* (WCH-SD-EN-TI-279).

U = undetected

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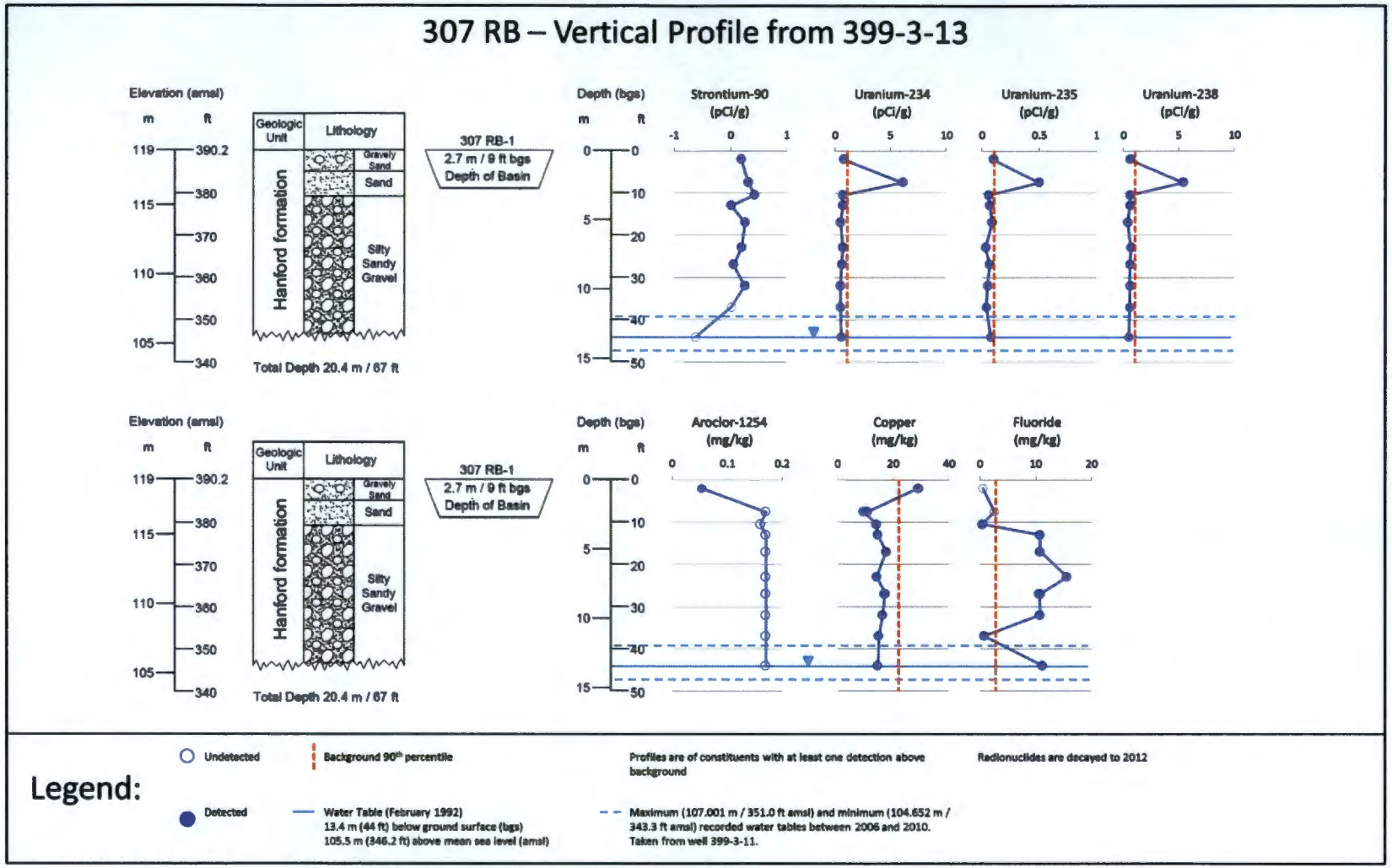

Figure 4-28. Vertical Profile from Borehole A8078 (Well 399-3-13) at Waste Site 307 RB

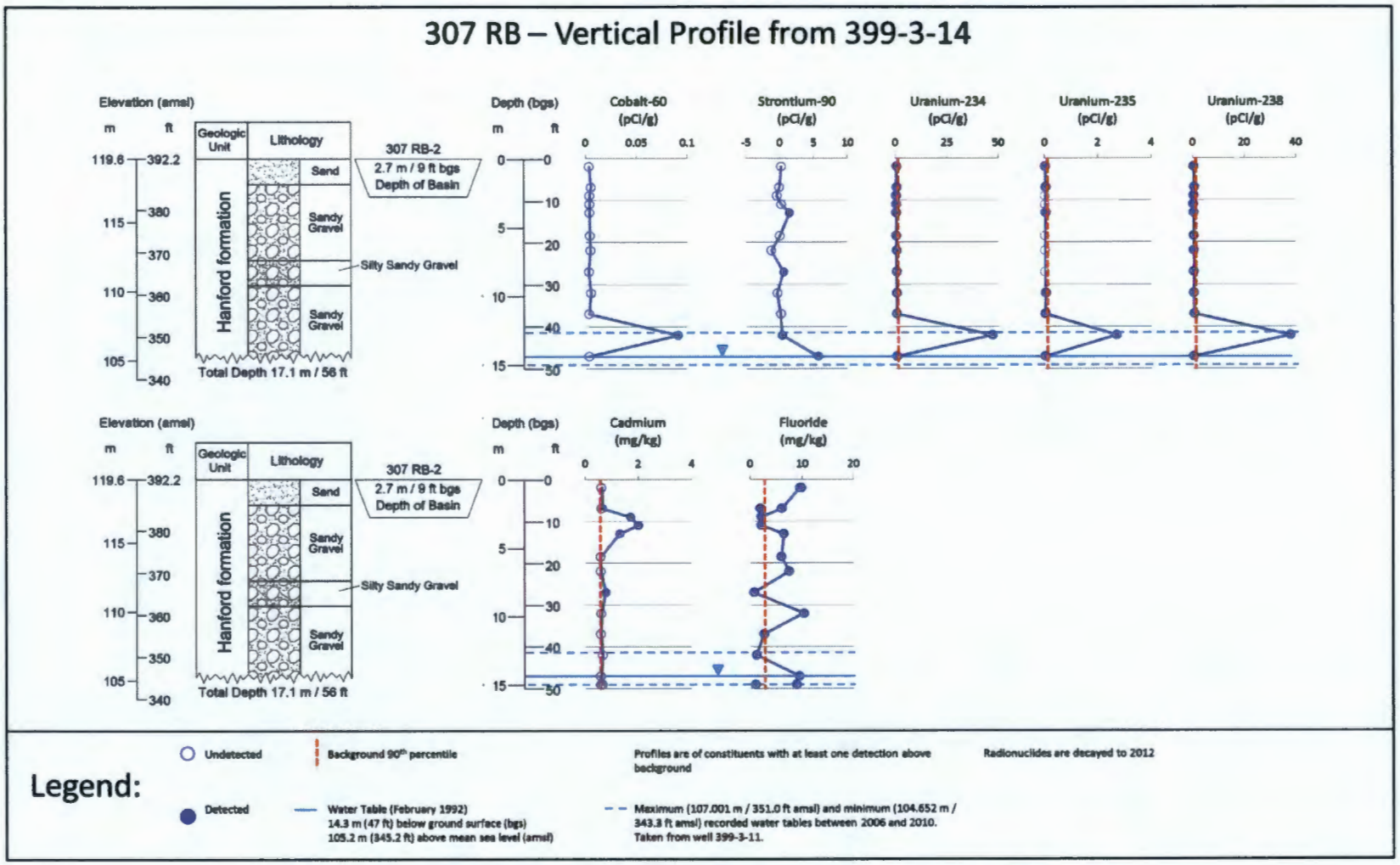

Figure 4-29. Vertical Profile from Borehole A8079 (Well 399-3-14) at Waste Site 307 RB

Cadmium was detected above background at 2.7, 3.4, 4.0, and 8.2 m (9, 11, 13, and 27 ft) bgs, with a maximum concentration of 1.7 mg/kg at 9 ft bgs. No other metals were identified at concentrations above background levels in this borehole.

Fluoride exceeded its background level in several samples between 0.6 m (2 ft) and 17.1 m (56 ft) bgs, with a maximum of 10.3 mg/kg at 9.8 m (32.0) ft bgs. No other anions were detected above background levels.

4.3.5.1 Characterization Results in remaining Seven RI Borings

In addition to the boreholes associated with the specific waste sites described above, an additional seven boreholes were drilled (and monitoring wells installed) with the purpose of collecting data to satisfy specific vadose zone and groundwater data needs described in the 300 Area RI/FS Work Plan (DOE/RL-2009-30). These wells were installed primarily to: (1) refine the understanding of uranium's distribution and mobility characteristics in the subsurface media, and (2) answer specific questions related to the presence and mobility of VOCs in groundwater. The following sections describe the results of the laboratory analysis of the soil samples collected from the vadose zone (including the PRZ) during the drilling of these seven wells. The wells are presented in order, based on the designations assigned in the work plan (i.e., 300-DU-1, 300-DU-2, etc.).

Borehole C7657 (RI Well 300-DU-1 / HEIS Well 399-1-58). Borehole C7657 was drilled about 150 m (500 ft) southwest of the 300 Area Process Trenches (316-5) and approximately 30 m (100 ft) west of the 618-3 Burial Ground. It was drilled to a total depth of 38.4 m (126 ft) bgs, with groundwater being encountered at 14.8 m (48.7 ft) bgs. Soil samples were collected at 11 depth intervals between 6.6 m (21.5 ft) and 14.8 m (48.5 ft) bgs within the vadose zone, including the PRZ and the water table. Figure 4-30 shows vertical profiles for analytes detected at concentrations above background levels. Table 4-15 summarizes analytical results.

The location was selected for characterization under the RI to provide additional information on the lateral distribution of uranium in the deeper portion of the vadose zone, away from the remediated principal liquid waste disposal sites (RI data need 8).

Tritium, the only radionuclide detected above its background level, was found only in the sample collected at 10.4 m (34 ft) bgs, with an activity of 4.27 pCi/g. The data suggest that there is no substantive radionuclide mass in the deep vadose zone at this location.

Chromium was detected above its background level in three samples, with a maximum concentration of 86.2 mg/kg in the sample collected at 11.0 m (36.3 ft) bgs. The only concentration of nickel detected above its background level was observed in this same sample interval at a concentration of 49.9 mg/kg. These sample results indicate potential stainless steel contamination from sampling equipment that increased the respective concentrations (see Section 4.3.2 for discussion). Chromium and nickel concentrations from intervals both above and below the 11.1 m (36.3 ft) sample are less than background.

The only other metals detected above background levels were antimony and molybdenum. Antimony only exceeded background in the shallowest sample, collected at 6.6 m (21.5 ft) bgs, where its concentration was 0.240 mg/kg. Molybdenum exceeded background in all samples, with a maximum concentration of 4.06 mg/kg at 8.3 m (27.2 ft) bgs. Concentrations of metals for which a background value is not available (strontium and tin) are consistent with concentrations measured in other 300 Area RI samples.

The only anion detected at concentrations above its background level was nitrate, which exceeded the background level in two samples. Its maximum concentration of 69 mg/kg was detected in the 11.1 m (36.3 ft) bgs sample.

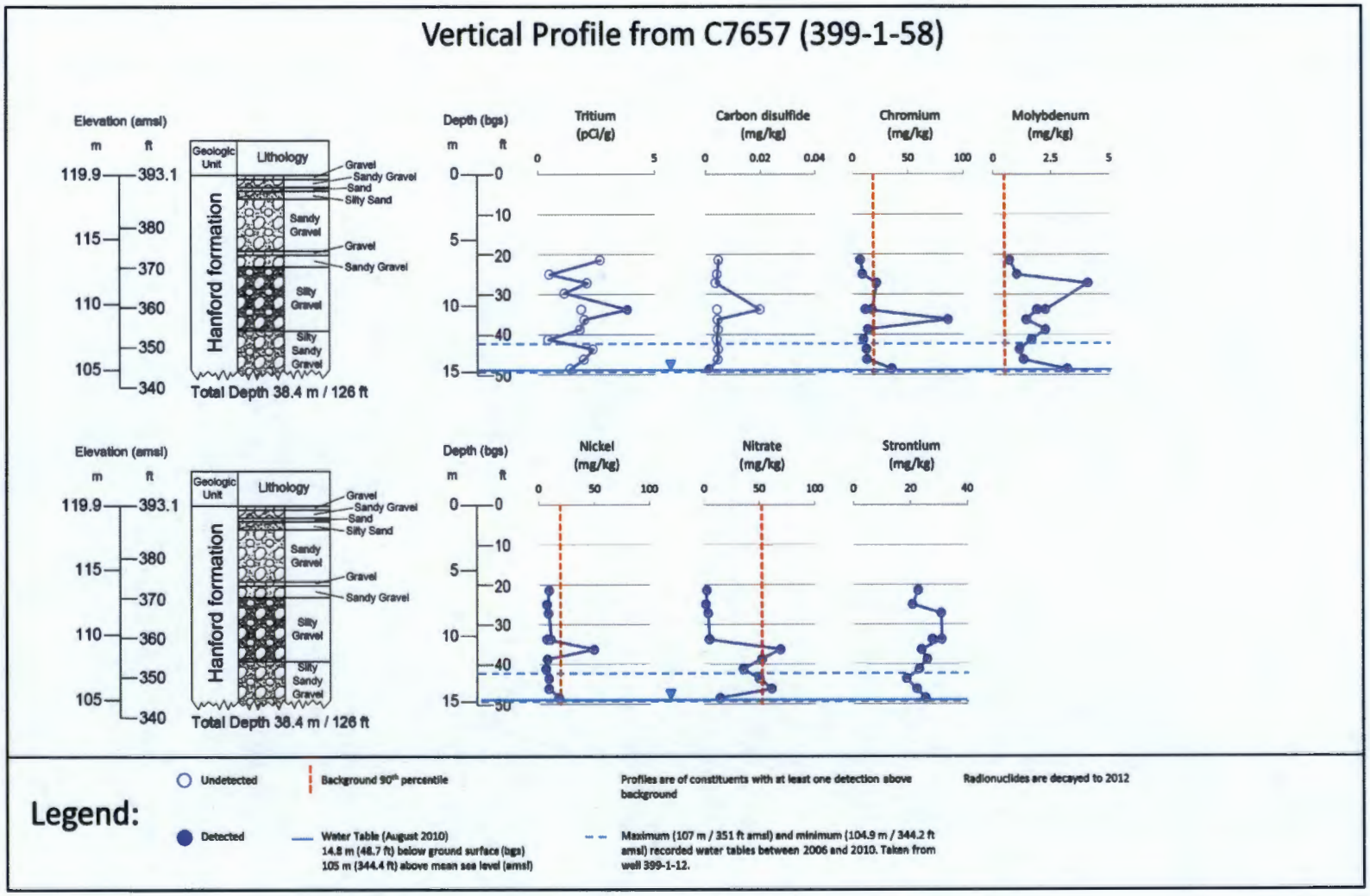

Figure 4-30. Vertical Profile from RI Borehole C7657 (Well 399-1-58)

The only organic compound detected was carbon disulfide, which was found only in the sample collected at 14.8 m (48.5 ft) bgs, at a concentration of 0.0011 mg/kg. This result is flagged as an estimate because it is below carbon disulfide's PQL of 0.00496 mg/kg.

No substantive contaminant mass was identified at this location.

Table 4-15. Borehole C7657 (RI Well 300-DU-1/HEIS Well 399-1-58) Summary of Contaminant Soil Data

Constituent	Concentration and Distribution					
	Background	Remedial Investigation Borehole C7657 (RI Well 300-DU-1)[a]				
		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection above Background (m/ft bgs)	Result at Maximum Sample Depth (14.8 m/48.5 ft bgs unless otherwise noted)	
Radionuclides (Original and Decayed Concentrations) (pCi/g)[b]						
		Original	Decayed		Original	Decayed
Tritium	NA	4.27 (10.4/33.8)	3.81	10.4/33.8	U	
Nonradionuclides (mg/kg)						
Antimony	0.13	0.24 (6.6/21.5)		6.6/21.5	U	
Chromium	18.5	86.2 (11.0/36.3)[c]		14.9/48.5	35.4	
Molybdenum	0.47	4.06 (8.3/27.2)		14.8/48.5	3.16	
Nickel	19.1	49.9 (11.0/36.3)[c]		11.0/36.3	18.0 (<BG)	
Strontium	NA	30.8 (10.4/33.8)		14.9/48.5	25	
Tin	NA	3.70 (8.3/27.2)		7.6/25	1.74	
Nitrate	52	69.0 (11.0/36.3)		14.1/46.2	14.2 (<BG)	
Carbon disulfide	NA	0.00110 (14.9/48.5)		14.9/48.5	0.0011	

a. Borehole data obtained from HEIS. The water table was encountered at 14.8 m (48.7 ft) bgs. Borehole was drilled to 38.4 m (126.0 ft) bgs total depth.

b. Original radiological data presented in the left column with decay corrected value to year 2012 in right column.

c. Results of chromium and nickel in B27JP2 collected at 11.1 m (36.3 ft) bgs indicate potential stainless steel contamination in the sample. Nickel concentrations are less than background in all other borehole samples. Concentrations of chromium and nickel are less than background in the sample intervals above and below B27JP2 collected at 10.3 m (33.8 ft) and 11.8 m (38.7 ft) bgs, respectively. See stainless steel contamination discussion in Section 4.3.2.

HEIS = Hanford Environmental Information System

NA = not applicable

U = undetected

Borehole C7658 (RI Well 300-DU-2/HEIS Well 399-6-3). Borehole C7658 was drilled about 488 m (1,600 ft) west of the South Process Pond (316-1) and approximately 30 m (100 ft) south-southwest of the former 314 Building (fuel fabrication and R&D). It was drilled to a total depth of 39.3 m (129 ft) bgs, with groundwater being encountered at 13.7 m (45 ft) bgs. Soil samples were collected at 12 depth intervals between 5.2 m (17 ft) and 14.6 m (48 ft) bgs within the vadose zone (including the PRZ) and the upper portion of the unconfined aquifer. Figure 4-31 shows vertical profiles for analytes detected at concentrations above background. Table 4-16 summarizes analytical results.

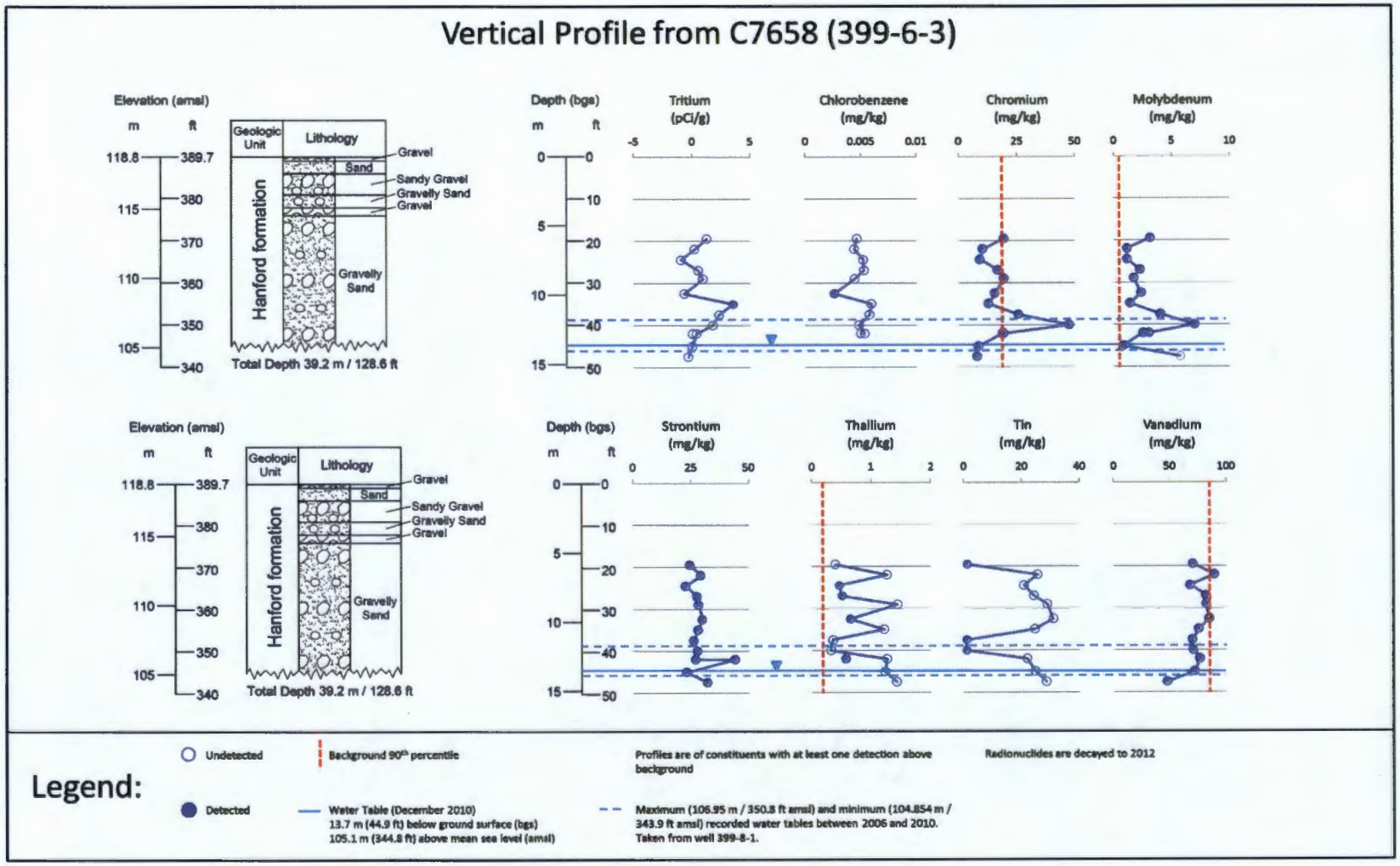

Figure 4-31. Vertical Profile from RI Borehole C7658 (Well 399-6-3)

Table 4-16. Borehole C7658 (RI Well 300-DU-2/HEIS Well 399-6-3) Summary of Contaminant Soil Data

Constituent	Concentration and Distribution					
	Background	Remedial Investigation Borehole C7658 (RI Well 300-DU-2) [a]				
		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (14.5 m/47.5 ft bgs unless otherwise noted)	
Radionuclides (Original and Decayed Concentrations) (pCi/g)[b]						
		Original	Decayed		Original	Decayed
Tritium	NA	3.96 (10.7/35)	3.54	10.7/35	U	
Nonradionuclides (mg/kg)						
Chromium	18.5	47.6 (12.2/40)		12.8/42	7.98 (<BG)	
Molybdenum	0.47	6.97 (12.2/40)		13.7/45	U	
Strontium	NA	44.3 (12.8/42)		14.6/47.5	32.2	
Thallium	0.185	0.650 (9.9/32.5)		12.8/42	U	
Tin	NA	1.30 (5.9/19.5)		12.2/40	U	
Vanadium	85.1	89.8 (6.7/22)		6.7/22	47.8 (<BG)	
Chlorobenzene	NA	0.00260 (10.1/32.5)		10.1/32.5	U (12.8/42)	

a. Borehole data obtained from HEIS. The water table was encountered at 14.9 m (49 ft) bgs. Borehole was drilled to 13.7 m (45 ft) bgs total depth.

b. Original radiological data presented in the left column with decay corrected value to year 2012 in right column.

BG = background
HEIS = Hanford Environmental Information System
NA = not applicable
U = undetected

The location was selected for characterization under the RI to provide additional information on the lateral distribution of uranium in the deeper portion of the vadose zone, away from the remediated principal liquid waste disposal sites (RI data need 8). The borehole was located at the western perimeter of the uranium plume.

Tritium was the only radionuclide detected above its background level. It was found in only in the sample collected at 10.7 m (35 ft) bgs, with an activity of 3.96 pCi/g.

Chromium exceeded background in 6 of the 12 sampled intervals, with a maximum concentration of 47.6 mg/kg detected at 12.2 m (40 ft) bgs. Vanadium exceeded its background level in only one sample, with a concentration of 89.8 mg/kg at 6.7 m (22 ft) bgs. Molybdenum levels exceeded background in all but the deepest sample, with a maximum concentration of 6.97 mg/kg at 12.2 m (40 ft) bgs. Thallium levels exceeded background in four samples, with a maximum concentration of 0.650 mg/kg at 9.9 m (32.5 ft) bgs. Concentrations of metals for which a background value is not available (strontium and tin) are consistent with concentrations measured in other 300 Area RI samples.

Chlorobenzene was the only organic compound detected. It was found in only one sample and at a very low concentration of 0.0026 mg/kg (below the PQL of 0.00387 mg/kg) at 10.1 m (36 ft) bgs.

The data suggest that no substantive contaminant mass exists in the deep vadose zone at this location.

Borehole C7659 (RI Well 300-DU-3/HEIS Well 399-1-59). Borehole C7659 was drilled approximately 107 m (350 ft) west of the South Process Pond (316-1). It was drilled to a total depth of 45.3 m (148.7 ft) bgs, intersecting the water table at 15.9 m (52.1 ft) bgs. Soil samples were collected at 13 depth intervals between 6.9 and 16.8 m (22.5 and 55.2 ft) bgs within the vadose zone (including the PRZ) and the upper portion of the unconfined aquifer. Figure 4-32 shows vertical profiles for analytes detected at concentrations above background. Table 4-17 summarizes analytical results.

This RI well location was chosen to evaluate the west end of the uranium plume and conditions downgradient from the 618-1 and 618-2 burial grounds. Vadose zone sampling was conducted to provide additional information on the lateral distribution of uranium in the deeper portion of the vadose zone, away from the remediated principal liquid waste disposal sites (RI data need 8).

The three targeted uranium isotopes were the only radionuclides identified. Uranium-233/234, U-235, and U-238 exceeded background in only one sample, collected at 13.7 m (45.2 ft) bgs, with maximum activities of 4.80, 0.497 and 5.47 pCi/g, respectively. Although this sample was collected approximately 2.1 m (7 ft) above the water table, the borehole log states that drilling returns became "muddy and moist" at this depth. Uranium-233/234 and U-238 activities were substantially lower both above and below this interval. Uranium-235 was not detected in any other depth interval. Residual uranium contamination, at very low concentrations, remains in the deep vadose zone at this location, potentially above the recent vertical extent of the PRZ. The data appear to support the CSM, suggesting that groundwater mounding associated with the principal liquid waste disposal sites (likely the South Process Pond in this instance) has stranded low levels of uranium in the deep vadose zone at locations some distance away from the point of discharge, where it may be accessible to a fluctuating water table. Alternatively, the contamination may be the result of UPRs from 300 Area industrial complex process sewer lines, located as near as 10.7 m (35 ft) from this borehole location.

Total uranium concentration in that same sample interval, 13.7 m (45.2 ft) bgs, was calculated to be 16.5 mg/kg, based on the isotopic values. Barium exceeded its background level in a single sample, collected at 15.2 m (49.8 ft) bgs, with a concentration of 170 mg/kg. Chromium was detected above its background level in four sample intervals, with a maximum concentration of 53.2 mg/kg at 11.5 m (37.6 ft) bgs. Nickel was detected above its background level in two samples, with a maximum concentration of 28.5 mg/kg, also at 11.5 m (37.6 ft) bgs. Elevated total chromium and nickel concentrations (53.2 and 28.5 mg/kg, respectively) observed in the sample collected at about 11.5 m (37.6 ft) bgs show evidence of potential stainless steel contamination from sampling equipment, which increased the respective concentrations (see Section 4.3.2 for discussion). In samples collected both above and below that sample, concentrations of chromium and nickel are less than background levels. While total chromium was detected above its background level in other samples, the elevated results appear to correlate with relatively elevated nickel results through the borehole (Figure 4-32).

Molybdenum levels exceeded background in all but one sample, manifesting a maximum concentration of 1.42 mg/kg at 14.5 m (47.7 ft) bgs. Thallium levels exceeded background in two samples, collected at 7.7 and 15.2 m (25.3 and 49.8 ft) bgs, with a maximum concentration of 0.228 mg/kg at 15.2 m (49.8 ft) bgs. Concentrations of metals for which a background value is not available (strontium and tin) are consistent with concentrations measured in other 300 Area RI samples.

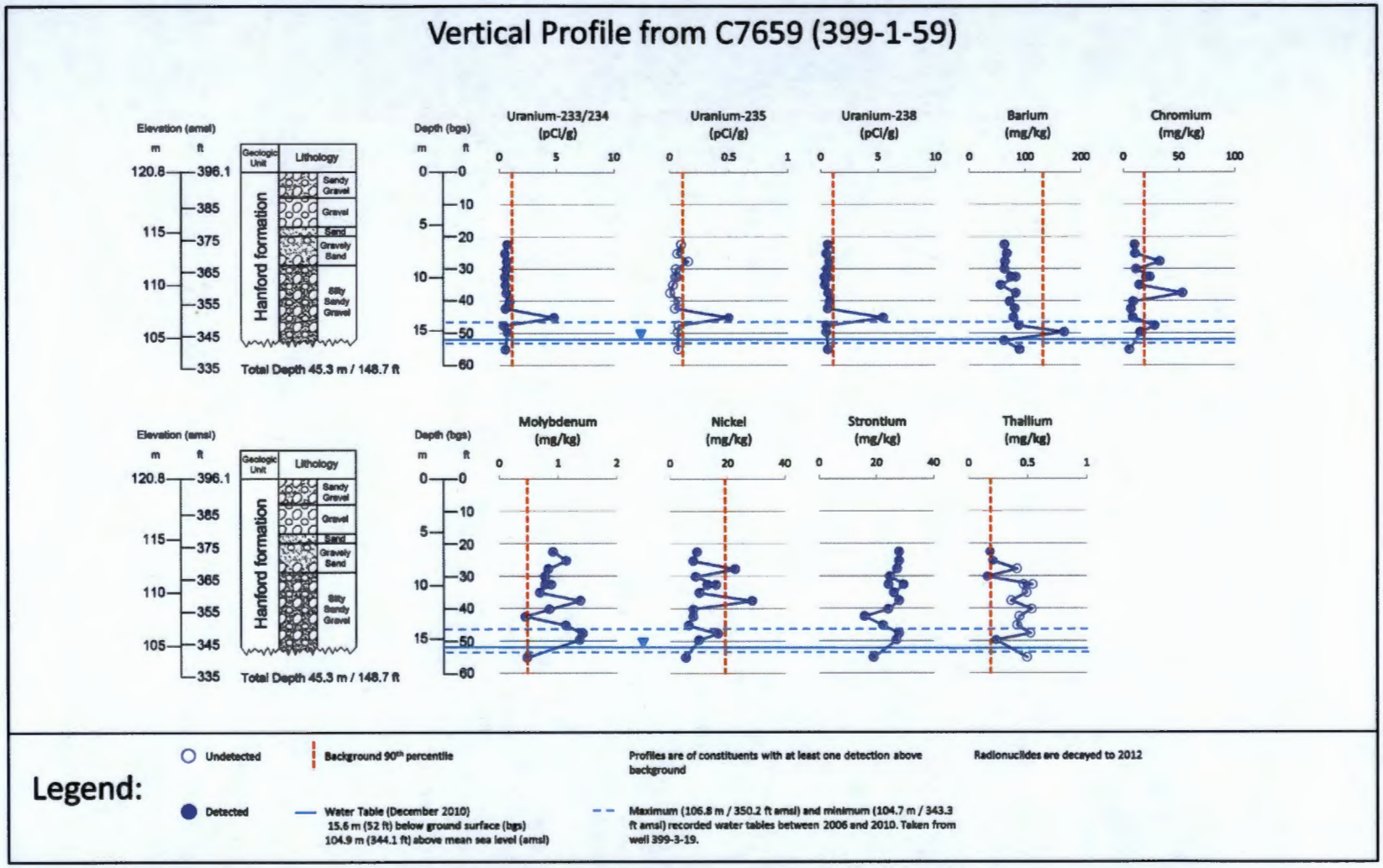

Figure 4-32. Vertical Profile from RI Borehole C7659 (Well 399-1-59)

Table 4-17. Borehole C7659 (RI Well 300-DU-3/HEIS Well 399-1-59) Summary of Contaminant Soil Data

Constituent	Concentration and Distribution					
	Background	Remedial Investigation Borehole C7659 (RI Well 300-DU-3) [a]				
		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection above Background (m/ft bgs)	Result at Maximum Sample Depth (16.8 m/55.2 ft bgs unless otherwise noted)	
Radionuclides (Original and Decayed Concentrations) (pCi/g)[b]						
		Original	Decayed		Original	Decayed
Uranium-233/234	1.1	4.80 (13.8/45.2)	4.80	13.8/45.2	0.540 (<BG)	0.540
Uranium-235	0.109	0.497 (13.8/45.2)	0.497	13.8/45.2	U	
Uranium-238	1.06	5.47 (13.8/45.2)	5.47	13.8/45.2	0.625 (<BG)	0.625
Nonradionuclides (mg/kg)						
Barium	132	170 (15.2/49.8)		15.2/49.8	90.4 (<BG)	
Chromium	18.5	53.2 (12.3/40.2) [c]		15.2/49.8	5.65 (<BG)	
Molybdenum	0.47	1.42 (14.5/47.7)		16.8/55.2	0.470	
Nickel	19.1	28.5 (11.5/37.6) [c]		11.5/37.6	5.31 (<BG)	
Strontium	NA	29.6 (10.0/32.7)		16.8/55.2	19.0	
Thallium	0.185	0.228 (15.2/49.8)		15.2/49.8	U	
Tin	NA	3.35 (15.2/49.8)		16.8/55.2	2.94	
Total Uranium (Calculated)	3.21	16.5 (13.8/45.2)		13.8/45.2	1.89 (<BG)	

a. Borehole data obtained from HEIS. The water table was encountered at 15.9 m (52.1 ft) bgs. Well was drilled to 45.3 m (148.7 ft) total depth

b. Original radiological data presented in the left column with decay corrected value to year 2012 in right column.

c. Results of chromium and nickel in B27R46 collected at 11.6 m (38.0 ft) bgs indicate potential stainless steel contamination in the sample. Concentrations of chromium and nickel are less than background in the sample intervals above and below B27R46 collected at 10.7 m (35.1 ft) and 12.3 m (40.2 ft) bgs, respectively. See stainless steel contamination discussion in Section 4.3.2.

HEIS = Hanford Environmental Information System

NA = not applicable

U = undetected

No anions or organic compounds were detected in samples collected from this borehole.

No substantive metal, anion, or organic compound contaminant mass was noted.

Boreholes C7661 and C8245 (RI Well 300-DU-4). The location was selected to provide additional information on the lateral distribution of uranium in the deeper portion of the vadose zone, away from the remediated principal liquid waste disposal sites (RI data need 8). The borehole was located near the southwest perimeter of the uranium plume. The initial borehole (C7661) was not advanced beyond 13 m (43 ft) bgs because of drilling difficulties; a second borehole (C8245) was drilled at new location and RI Well 300-DU-4 was installed.

Borehole C7661 (HEIS Well 399-6-4) was drilled about 396 m (1,300 ft) west-southwest of the South Process Pond (316-1), near the southeast corner of the former 3706 Building (original radiochemistry and radiometallurgy laboratory). It was drilled to a total depth of 13.1 m (43 ft) bgs, where the split spoon sampler broke and attempts to recover it were unsuccessful. The water table was not encountered. Samples were collected at eight depth intervals between 6.1 and 12.2 m (20 and 40 ft) bgs.

Replacement borehole C8245 (RI Well 300-DU-4/HEIS Well 399-6-5) was drilled a few feet north of borehole C7661. It was drilled to a total depth of 47.5 m (156 ft) bgs, encountering the water table at about 13.7 m (45 ft) bgs. Sample collection at C8245 was initiated at a depth just below the deepest sample attained at C7661. Samples for vadose zone characterization were collected at five depth intervals between 12.2 and 15.2 m (40 and 50 ft) bgs.

Both boreholes provided vadose zone samples and, because of their proximity, analytical results from both are considered representative of the site. Table 4-18 summarizes the combined analytical results from boreholes C7661 and C8245. Figure 4-33 and Figure 4-34 show vertical profiles for analytes detected at concentrations above their background levels in the two separate boreholes.

Table 4-18. Boreholes C7661 and C8245 (RI Well 300-DU-4) Summary of Contaminant Soil Data

Constituent	Concentration and Distribution					
	Background	Remedial Investigation Boreholes C7661[a] and C8245[b] (RI Well 300-DU-4/Wells 399-6-4 and 399-6-5)				
		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (15.3. m/50.3 ft)	
Radionuclides (Original and Decayed Concentrations) (pCi/g)[c]						
		Original	Decayed		Original	Decayed
Tritium	NA	3.83 (11/36.4)	3.62	11/36.4	U	
Nonradionuclides (mg/kg)						
Chromium	18.5	19.5 (8.9/29.2)		13.1/42.8	7.57	
Molybdenum	0.47	2.98 (8.9/29.2)		15.3/50.3	0.673	
Strontium	NA	35.7 (6.7/22.3)		15.3/50.3	13.5	
Thallium	0.185	0.491 (12.3/40.3)		12.3/40.3	U	
Vanadium	85.1	96.1 (6.7/22.3)		6.7/22.3	U	
Chlorobenzene	NA	0.00114 (7.6/24.9)		7.6/24.9	U	

a. Borehole data obtained from HEIS. Borehole was drilled to 13.1 m (43 ft) bgs total depth, where drilling difficulties resulted in relocation. The boring did not reach the water table. No well was installed.

b. Borehole data obtained from HEIS. The water table was encountered at 13.7 m (45 ft) bgs. Borehole was drilled to 47.5 m (156 ft) bgs total depth.

c. Original radiological data presented in the left column with decay corrected value to year 2012 in right column

BG = background

HEIS = Hanford Environmental Information System

NA = not applicable

U = undetected

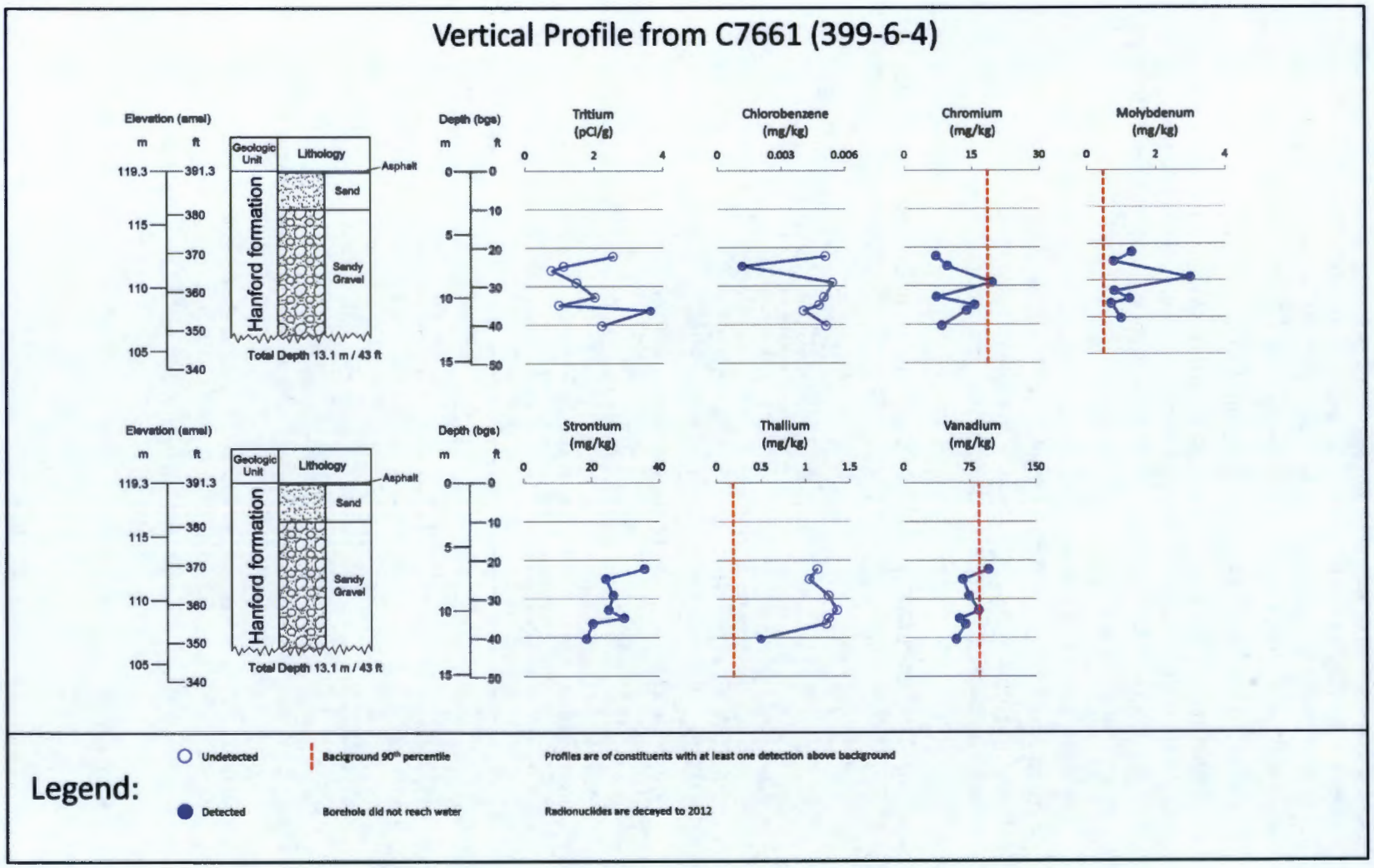

Figure 4-33. Vertical Profile from RI Borehole C7661 (Well 399-6-4)

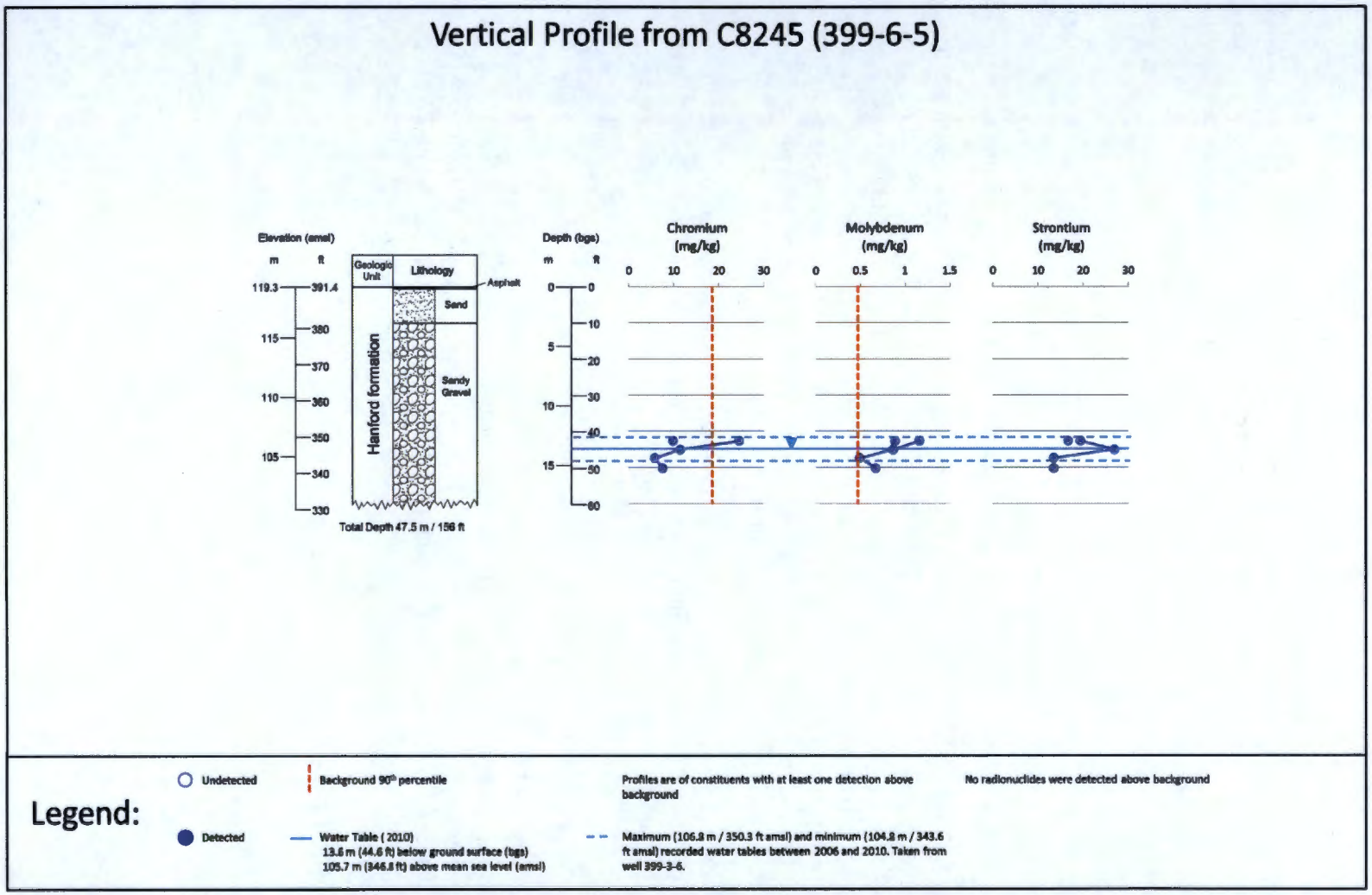

Figure 4-34. Vertical Profile from RI Borehole C8245 (Well 399-6-5)