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DOE/RL-2008-38

DRAFT A

SECTION

1 OF 3

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Remedial Investigation/Feasibility Study Report for the 200-MW-1 Miscellaneous Waste Sites Operable Unit

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

The overarching purpose of a 42 United States Code (USC) 9601, et seq., *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA),[1] remedial investigation and feasibility study (RI/FS) is to gather and evaluate information about a given waste site or group of waste sites, and identify, screen, and evaluate feasible alternatives for the waste site(s) remediation. In turn, these studies support informed risk management decisions regarding the preferred remedy alternative, which will be presented in a separate Proposed Plan at a future date.

Several contaminant impact assessments are typically included as part of the Remedial Investigation (RI) phase of the RI/FS. They include the baseline risk assessment, including the human health and ecological assessments, and the fate and transport evaluation for groundwater protection. These assessments were completed during the FS phase and are included as appendices to this report.

This RI/FS report focuses on the seven 200-MW-1 Operable Unit (OU) waste sites located in the eastern portion of the Hanford Site 200 Area.

- **Cribs 216-A-2, 216-A-4, 216-A-21, and 216-A-27**: These four cribs are located south of the Plutonium Uranium Extraction (PUREX) plant. The cribs received, and subsequently discharged to the soil column, low to moderate volumes of aqueous and organic process and laboratory wastes that contained varying amounts of radionuclide and non-radionuclide constituents generated at the PUREX plant from 1956 through approximately 1970.
- **Reverse Wells 216-B-4 and 216-C-2**: The two reverse wells are located north-northwest of the PUREX plant near the B Plant (216-B-4) and near Semi-Works (216-C-2). The reverse wells received, and discharged to the soil column, low volumes of stack condensate and floor drainage containing varying amounts of radionuclide and non-radionuclide constituents.
- **The 200-E-102 Trench**: This disposal trench, located south of PUREX, received soil that was contaminated by an overflow associated with the 216-A-4 Crib.

1 *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, 42 USC 9601, et seq. Available at: http://uscode.house.gov/download/pls/42C103.txt.

The scope of the RI included downhole geophysical logging and soil sampling at the 216-A-2, 216-A-4, and 216-A-21 Cribs, and the 200-E-102 Trench. Information drawn from the logging and sampling updated the base of knowledge regarding the nature and extent of contamination at these sites. The sampling of the 216-A-4 Crib confirmed that the potential contaminants of concern are radionuclides. Specifically americium-241, cesium-137, strontium-90 and plutonium-239/240 radionuclides, and potentially uranium and nitrate are COCs at the 216-A-4 Crib.

A baseline risk assessment was conducted to evaluate the potential risks associated with exposure to contaminants at the 200-MW-1 OU sites. Evaluation of an unrestricted land-use scenario was used as the basis for determining the need to take remedial action. The three contaminant impact assessments (the baseline risk assessment including the human health and ecological assessments, the ecological risk assessment, and the fate and transport evaluation for groundwater protection) concluded that EPA's threshold value of 1×10^{-4} is exceeded under the hypothetical rural residential exposure scenario, indicating that further evaluation in the FS is needed.

There are no contaminants of concern (COCs) identified in the shallow zone soil at the 216-A-2 Crib. In addition, there is no direct-contact risk associated with the 216-A-2, 216-A-21, and 216-A-27 Cribs or 216-B-4 and 216-C-2 Reverse Wells based on current data and site conditions. The depth of cover under the current waste site configuration prevents the exposure pathway associated with the restricted access scenario from being complete. However, there is some uncertainty in the data; therefore, controls may be needed to ensure that the cover thickness is maintained consistent with the current and potential future land use designations. Administrative measures are required for the two reverse wells because they have not been decommissioned per State of Washington decommissioning regulations.

Although the BRA did not identify ELCR risk at the 216-A-4 Crib, borehole geophysical methods detected elevated levels of cesium-137 in the near surface to a 4.6-m (15-ft) depth interval. Given this uncertainty, confirmatory sampling at the 216-A-4 Crib is deemed necessary. Similarly, confirmatory sampling at the 200 E-102 Trench is deemed necessary due to uncertainty between the RI findings and historical reports on the level of radionuclide contaminated soil placed in the trench.

The remedial action technologies screened in DOE/RL-98-28, *200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program*,[2] were re-evaluated using 200-MW-1 OU site specific information to develop a final list of retained technologies and process options. These technologies and process options were then assembled into remedial alternatives as follows:

- No Action Alternative
- Alternative 1 – Institutional Controls (ICs) and Monitored Natural Attenuation (MNA)
- Alternative 2 – Evapotranspiration (ET) Barrier
- Alternative 3 – Removal, Treatment, and Disposal (RTD)

Once the remedial alternatives were assembled, a detailed evaluation was performed in accordance with the threshold and balancing criteria specified in 40 CFR 300.430(e)(9)(iii), "National Oil and Hazardous Substances Pollution Contingency Plan," "Remedial Investigation/Feasibility Study and Selection of Remedy," "Feasibility Study," "Detailed Analysis of Alternatives," "Nine Criteria for Evaluation."[3] The findings of the detailed evaluation indicate that the No Action Alternative with unrestricted access does not meet the threshold criteria except for 216-A-2. Each of the remaining alternatives was found to meet the threshold criteria and perform well against the balancing criteria. The alternatives were then compared to assess relative trade-offs against one another and the alternatives ranked against the threshold and balancing criteria from least to most favorable. The results of this evaluation are summarized in Table ES-1. Table ES-2 lists the present net worth and non-discounted comparison costs of each alternative.

2 DOE/RL 98 28, 1999, *200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D199153696.

3 40 CFR 300.430(e)(9)(iii), "National Oil and Hazardous Substances Pollution Contingency Plan," "Remedial Investigation/Feasibility Study and Selection of Remedy," "Feasibility Study," "Detailed Analysis of Alternatives," "Nine Criteria for Evaluation," *Code of Federal Regulations*. Available at: http://edocket.access.gpo.gov/cfr_2009/julqtr/40cfr300.430.htm.

Table ES-1. Comparative Analysis Ranking Summary for the 200-MW-1 Operable Unit Waste Sites

	Overall Protectiveness of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction in Toxicity, Mobility and Volume Through Treatment	Short-Term Effectiveness	Implementability	Cost[a] (Net Present Worth)
For the 216-A-2 Crib							
No Action	Yes	Yes	Not Ranked[b]				$0
Alternative 1 – ICs and MNA	Yes	Yes	○	○	○	○	N/A
For the 216-A-4 Crib							
No Action	No	No	Not Ranked[b]				$0
Alternative 1 – ICs and MNA	Yes	Yes	○	○	○	○	$1,285,000
Alternative 2 – ET Barrier	Yes	Yes	◐	●	◐	◐	$1,860,000
Alternative 3 – RTD	Yes	Yes	○	○	◐	◐	$1,869,000
For the 216-A-21 Crib[a]							
No Action	No	No	Not Ranked[b]				$0
Alternative 1 – ICs and MNA	Yes	Yes	○	○	○	○	$1,285,000
Alternative 2 – ET Barrier	Yes	Yes	◐	●	◐	◐	$1,785,000
Alternative 3 – RTD	Yes	Yes	○	○	◐	◐	$1,286,000
For the 216-A-27 Crib[a]							
No Action	No	No	Not Ranked[b]				$0
Alternative 1 – ICs and MNA	Yes	Yes	○	○	○	○	$1,285,000
Alternative 2 – ET Barrier	Yes	Yes	◐	●	◐	◐	$1,857,000
Alternative 3 – RTD	Yes	Yes	○	○	◐	◐	$1,552,000
For the 200-E-102 Trench							
No Action	No	No	Not Ranked[b]				$0
Alternative 1 – ICs and MNA	Yes	Yes	○	○	○	○	$1,285,000
Alternative 3 – RTD	Yes	Yes	○	○	◐	◐	$663,000
For the 216-B-4 Reverse Well[a]							
No Action	No	No	Not Ranked[b]				$0
Alternative 1 – ICs and MNA	Yes	Yes	○	○	○	○	$1,535,000
Alternative 3 – RTD	Yes	Yes	○	○	●	●	$3,517,000

Table ES-1. Comparative Analysis Ranking Summary for the 200-MW-1 Operable Unit Waste Sites

	Overall Protectiveness of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction in Toxicity, Mobility and Volume Through Treatment	Short-Term Effectiveness	Implementability	Cost[a] (Net Present Worth)
For the 216-C-2 Reverse Well [a]							
No Action	No	No	Not Ranked [b]				$0
Alternative 1 – ICs and MNA	Yes	Yes	○	○	○	○	$1,509,000
Alternative 3 – RTD	Yes	Yes	○	○	●	●	$2,458,000

a. These cost estimates are based on the best available information for the site-specific anticipated remedial actions. The actual costs are expected to range from -30 percent to +50 percent of these estimated values. Major changes to assumed remedial action scope can result in remedial action costs outside of this range. Net present worth calculations are based on 1,000 years.

b. No Action Alternative not ranked because it does not meet the threshold criteria except for 216-A-2 Crib.

N/A = Not applicable

Explanation of Evaluation Metric

● = performs less well against the criterion relative to the other alternatives with significant disadvantages or uncertainty

◐ = performs moderately well against the criterion relative to the other alternatives with some disadvantages or uncertainty

○ = performs very well against the criterion relative to the other alternatives with minor disadvantages or uncertainty

Table ES-2. Cost Summary Comparison–Net Present Worth Cost Estimates (1,000 Years)

Cost	Alternative 1 Institutional Controls And MNA	Alternative 2 ET Barrier	Alternative 3 RTD to Meet Human and Ecological Use
216-A-2 Crib			
Capital Cost	N/A	N/A	N/A
Operations and Maintenance Cost	N/A	N/A	N/A
Non-discounted Cost	N/A	N/A	N/A
Present Worth Cost	N/A	N/A	N/A
216-A-4 Crib			
Capital Cost	$28,320	$603,454	$1,894,000

Table ES-2. Cost Summary Comparison–Net Present Worth Cost Estimates (1,000 Years)

Cost	Alternative 1 Institutional Controls And MNA	Alternative 2 ET Barrier	Alternative 3 RTD to Meet Human and Ecological Use
Operations and Maintenance Cost	$34,656,000	$34,656,000	$0
Non-discounted Cost	$34,684,000	$35,259,000	$1,894,000
Present Worth Cost	$1,285,000	$1,860,000	$1,869,000
216-A-21 Crib			
Capital Cost	$28,320	$528,577	$1,286,000
Operations and Maintenance Cost	$34,656,000	$34,656,000	$0
Non-discounted Cost	$34,684,000	$35,185,000	$1,286,000
Present Worth Cost	$1,285,000	$1,785,000	$1,286,000
216-A-27 Crib			
Capital Cost	$28,320	$600,644	$1,573,000
Operations and Maintenance Cost	$34,656,000	$34,656,000	$0
Non-discounted Cost	$34,684,000	$35,257,000	$1,573,000
Present Worth Cost	$1,285,000	$1,857,000	$1,552,000
200-E-102 Trench			
Capital Cost	$28,320	N/A	$663,000
Operations and Maintenance Cost	$34,656,000	N/A	$0
Non-discounted Cost	$34,684,000	N/A	$663,000
Present Worth Cost	$1,285,000	N/A	$663,000
216-B-4 Reverse Well			
Capital Cost	$278,320	N/A	$3,517,000
Operations and Maintenance Cost	$34,656,000	N/A	$0
Non-discounted Cost	$34,934,000	N/A	$3,517,000
Present Worth Cost	$1,535,000	N/A	$3,517,000
216-C-2 Reverse Well			
Capital Cost	$252,140	N/A	$2,458,000
Operations and Maintenance Cost	$34,656,000	N/A	$0
Non-discounted Cost	$34,908,000	N/A	$2,458,000

Table ES-2. Cost Summary Comparison–Net Present Worth Cost Estimates (1,000 Years)

Cost	Alternative 1 Institutional Controls And MNA	Alternative 2 ET Barrier	Alternative 3 RTD to Meet Human and Ecological Use
Present Worth Cost	$1,509,000	N/A	$2,458,000

Notes:

These cost estimates are based on the best available information for the site-specific anticipated remedial actions. The actual costs are expected to range from -30 percent to +50 percent of these estimated values. Major changes to assumed remedial action scope can result in remedial action costs outside of this range. Net present worth calculations are based on 1,000 years.

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Contents

Appendices

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Figures

Tables

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Terms

ACM	asbestos containing material
ALARA	as low as reasonably achievable
amsl	above mean sea level
ARAR	applicable or relevant and appropriate requirement
bgs	below ground surface
BRA	baseline risk assessment
CDM	conceptual design model
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	Code of Federal Regulations
COC	contaminant of concern
COPC	contaminant of potential concern
cps	counts per second
CSM	conceptual site model
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
DOE	U.S. Department of Energy
DQO	data quality objective
DQA	data quality assessment
DTW	depth to water
Ecology	Washington State Department of Ecology
ELCR	excess lifetime cancer risk
ESL	Environmental Sciences Laboratory
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ERDF	Environmental Restoration Disposal Facility
ESL	Environmental Sciences Laboratory
ET	evapotranspiration
FS	feasibility study
GPR	ground penetrating radar

GRA	general response action
GRR	ground penetrating radar
HAB	Hanford Advisory Board
HEAST	health effects assessment summary tables
HEIS	*Hanford Environmental Information System* (database)
HHE	human health and the environment
HI	hazard index
HMS	Hanford Meteorological Station
HQ	hazard quotient
HRLS	high rate logging system
HSP	health and safety plan
IC	institutional control
ID	inside diameter
IDW	investigation-derived waste
IRIS	Integrated Risk Information System
ISV	in situ vitrification
K_d	distribution coefficient
LLW	low-level waste
LTRR	long-term recharge rate
MCL	maximum contaminant level
MNA	monitored natural attenuation
MSSL	median specific screening level
NCEA	National Center for Environmental Assessment
NCLS	neutron captive logging system
NEPA	*National Environmental Policy Act of 1969*
NMLS	neutron moisture logging system
NPH	normal paraffin hydrocarbons
O&M	operations and maintenance
OSHA	Occupational Safety and Health Administration
OU	operable unit

PCB	polychlorinated biphenyl
PNLS	passive neutron logging system
PNNL	Pacific Northwest National Laboratory
PP	proposed plan
PPE	personal protective equipment
PRG	preliminary remediation goal
PUREX	Plutonium-Uranium Extraction (Plant)
QA	quality assurance
QC	quality control
RAO	remedial action objective
RCRA	*Resource Conservation and Recovery Act of 1976*
REDOX	reduction-oxidation
RESRAD	RESidual RADioactivity (computer code)
RI	remedial investigation
RL	U.S. Department of Energy, Richland Operations Office
RME	reasonable maximum exposure
ROD	record of decision
RTD	removal, treatment, and disposal
SAP	sampling analysis plan
SGLS	spectral gamma logging system
SIM	soil inventory model
SLERA	screening level ecological risk assessment
STOMP	Subsurface Transport Over Multiple Phases
SVOC	semi-volatile organic compound
TBC	to be considered
TBP	tri-butyl phosphate
TD	total depth
TRU	transuranic
TSCA	*Toxic Substances Control Act of 1976*
TSD	treatment, storage, and disposal

UCL	upper confidence limit
UPR	unplanned release
URM	underground radioactive material
USC	United States Code
VOC	volatile organic compound
WAC	*Washington Administrative Code*
WIDS	*Waste Information Data System*
WIPP	Waste Isolation Pilot Plant

1 Introduction

This remedial investigation and feasibility study (RI/FS) report is for the 200 Miscellaneous Waste Group Operable Unit (200-MW-1 OU) located within the 200 Area of the Hanford Site. The 200-MW-1 OU contains seven waste sites consisting of four cribs (216-A-2, 216-A-4, 216-A-21, and 216-A-27), one disposal trench (200-E-102), and two reverse wells (216-B-4 and 216-C-2). An eighth waste site, identified as the 299-E24-111 experimental test well, is still active and being retained for future use. The need for remedial action at the 299-E24-111 site will be assessed when a determination is made that the experimental test well will no longer be used. Submittal of this RI/FS report and the accompanying Proposed Plan (PP) meets Washington State Department of Ecology (Ecology), U.S. Environmental Protection Agency (EPA), and U.S. Department of Energy (DOE) (Tri-Parties), Ecology et al., 1989a, *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) Milestone M-015-044B.

1.1 Purpose and Scope of the Remedial Investigation/Feasibility Study Report

As shown in Figure 1-1, the RI/FS is Step 2 of 42 United States Code (USC) 9601, *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) process and represents the methodology that the Superfund program has established for characterizing the nature and extent of risks posed by uncontrolled hazardous waste sites and evaluating potential remedial options.

A significant challenge for the RI/FS process is managing the inherent uncertainties associated with the characterization and remediation of hazardous waste sites. These uncertainties can be numerous, ranging from unknowns regarding actual subsurface site characteristics and contaminant distribution to the performance of engineering controls and treatment technologies being considered as part of the overall remedial strategy. While these uncertainties foster a natural desire to want to know more, this desire competes with the Superfund mandate to perform cleanups within designated schedules. Therefore, the objective of the RI/FS process is not the unobtainable goal of removing all uncertainty, but to gather information sufficient to support an informed risk management decision regarding which remedy appears to be most appropriate for a given site.

The overall approach for conducting the 200-MW-1 OU RI/FS was presented in DOE/RL-2001-65, *200-MW-1 Miscellaneous Waste Group Operable Unit RI/FS Work Plan*. The approach relied on the concept of using data from a supplemental site to augment the site characterization and evaluation required to support remedial action decision making. This approach relates waste sites with similar histories and contaminants, and field investigation data from the supplemental site are used for the following purposes:

- Supporting the development of contaminant distribution models for the subject waste site.
- Conducting a baseline risk assessment (BRA) to determine the need for remedial action at the subject waste site.
- Aiding in the development, evaluation, and selection of remedial alternatives for the subject waste site.
- Determining what post-decision verification sampling is required in the remedial design planning stages to ensure that the remedy is appropriate for the 200-MW-1 OU sites.

1.1.1 Remedial Investigation

The RI is the primary mechanism for developing the information needed to determine if remedial action at a waste site is required. The following specific objectives for the RI were established in the approved 200-MW-1 OU planning documents (DOE/RL-2001-65, DOE/RL-2005-47, *Sampling and Analysis Plan for Additional Remedial Investigation Activities at the 216-A-4 and 200-E-102 Trench*, DOE/RL-2006-77, *Sampling and Analysis Plan for Supplemental Remedial Investigation Activities at the 216-A-2 Crib and the 216-A-21 Crib*):

- Define the nature and distribution of contaminants in subsurface soil.
- Verify or refine preliminary contaminant distribution models and develop strategies to address data gaps.
- Perform a BRA to determine if vadose zone soil contamination occurs at levels that pose a threat to human health and the environment (HHE).

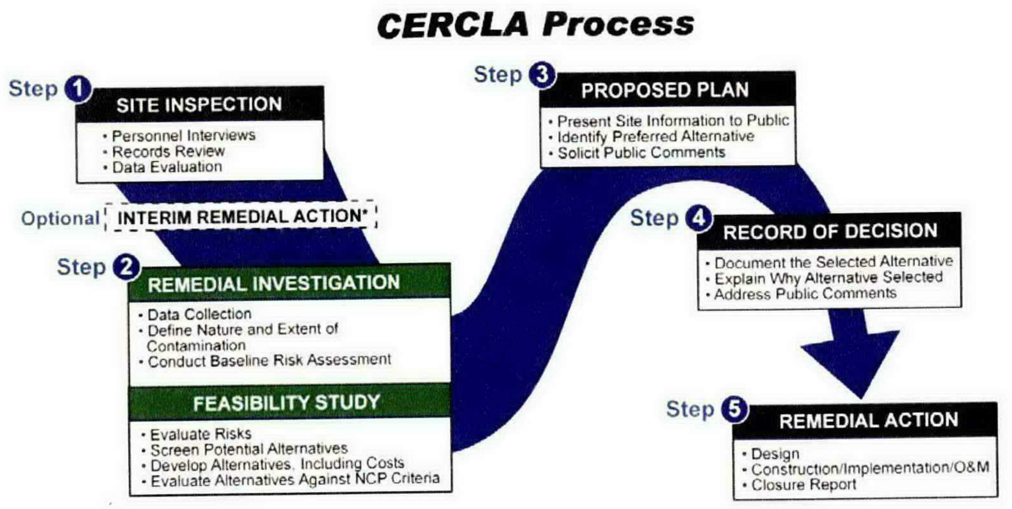
The 200-MW-1 OU RI initially focused on the 216-A-4 Crib, which was selected as the primary site to investigate. The investigation at the 216-A-4 Crib revealed field measured radionuclide activity at levels higher than expected. Consequently, the 216-A-2 Crib was selected to replace the 216-A-4 Crib as the primary site to investigate. Although field investigation and sampling at the remaining sites were less rigorous by design, the contaminant distribution models developed for these waste sites have been supplemented in this RI/FS report with information from a supplemental waste site (216-A-5). The 216-A-5 Crib has been well characterized and can be helpful in reducing uncertainty associated with the 200-MW-1 OU site relationships. The 200-MW-1 OU RI was conducted between July 2004 and January 2008. The RI results are presented in Chapters 2 through 6 of this document.

The field investigation work was performed concurrently with the approval of a new work plan (DOE/RL-2007-02,Vol. I, *Supplemental Remedial Investigation/Feasibility Study Work Plan for the 200 Areas Central Plateau Operable Units: Volume I: Work Plan and Appendices*, and Vol. II, *Supplemental Remedial Investigation/Feasibility Study Work Plan for the 200 Areas Central Plateau Operable Units: Volume II: Site-Specific Field-Sampling Plan Addenda* [Supplemental Work Plan]). The Tri-Parties agreed during the supplemental data quality objective (DQO) process that the characterization work completed for the 216-A-2 and 216-A-21 Cribs (DOE/RL-2006-77) is consistent with requirements defined under DOE/RL-2007-02.

1.1.2 Feasibility Study

The FS is the mechanism for the development, screening, and detailed evaluation of remedial action alternatives. If remedial action is necessary, based on the findings of the BRA, the RI data are used to support the development of remedial alternatives. The FS for the 200-MW-1 OU waste sites is presented in Chapters 7, 8, and 9 of this report.

To address the statutory requirements and the technical and policy considerations important for selecting remedial alternatives, the FS includes an evaluation of remedial action alternatives based on the two threshold and five balancing criteria defined under CERCLA. The two modifying criteria are evaluated through the public review process in the PP (EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, Interim Final, OSWER Directive 9355.3-01). These criteria serve as the basis for conducting a detailed and comparative analyses and, subsequently, for identifying a preferred alternative(s). A preferred alternative (or alternatives) will be presented to the public for review and comment in a PP. Following public review, the lead regulatory agency (the EPA) will prepare a CERCLA Record of Decision (ROD) that identifies the remedial alternative(s) to be implemented for the 200-MW-1 OU waste sites.



*Interim Remedial Action normally occurs after Site Inspection, but could occur at any point in the process when a concern has been identified

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

Step 2. The Remedial Investigation/Feasibility Study. The topic of the combined segments are:
Remedial Investigation. "Remedial Investigation" consists of conducting an environmental study to identify the nature and extent of contamination and performing a preliminary evaluation of the risk posed to human health and the environment.

Feasibility Study. The "Feasibility study" includes the details of a remedial alternatives evaluation, which includes a complete risk assessment of current conditions and an evaluation of the potential risk reduction presented for each of the remedial alternatives that are considered.

Step 3. Proposed Plan. The "Proposed Plan" (this document) is based on previous field investigations and reports that are completed in the first three steps of the CERCLA process described above. The Proposed Plan summarizes the remedial alternative evaluations and presents the preferred alternative recommended in the FS to the public for comments.

Step 4. Record of Decision. The "Record of Decision" (ROD) formally documents the cleanup alternative that was selected after the Tri-Parties reviewed and responded to public comments on the Proposed Plan.

Step 5. Remedial Action. "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.

CHPRC0902-16

Figure 1-1. The CERCLA Process

As stated in DOE Order 451.1B, *National Environmental Policy Act Compliance Program*, DOE will "...incorporate NEPA values, such as analysis of cumulative, off-site, ecological, and socioeconomic impacts, to the extent practicable, in DOE documents prepared under the Comprehensive Environmental Response, Compensation, and Liability Act." A discussion of NEPA values is provided in Section 9.4.

1.2 Site Background

This section presents background information for the 200-MW-1 OU waste sites and other general information for the 200 East Area of the Hanford Site where the 200-MW-1 OU waste sites are located.

1.2.1 Site Description

The 200-MW-1 OU contains seven waste sites that include four cribs (216-A-2, 216-A-4, 216-A-21, and 216-A-27), one trench (200-E-102), and two reverse wells (216-B-4 and 216-C-2). All seven waste sites are located in the 200 East Area of the Hanford Site in south-central Washington State (Figure 1-2). Five waste sites are located just south of the Plutonium-Uranium Extraction (PUREX) Plant (Figure 1-3). The other two waste sites are located to the south and east of the 221-B Building or B Plant (Figure 1-4). Waste disposed at the 200-MW-1 OU waste sites located south of the PUREX facility generally contained radionuclide and chemical constituents associated with PUREX operations.

The following subsections provide general information on the characteristics of each waste site and their operational history. Much of this information is also summarized in Table 1-1.

1.2.1.1 200-MW-1 Operable Unit Cribs

A crib is a buried waste site designed to distribute liquid effluent to the subsurface soil. The term "crib" arises from the initial use of wood timbers to construct the cribs, which resembled embankment or mining support type structures. As the designers gained more experience, crib design evolved into a perforated pipe and gravel filled structure. The four 200-MW-1 OU cribs (216-A-2, 216-A-4, 216-A-21, and 216-A-27) were constructed using the perforated pipe and gravel fill design at depths ranging between 4.9 and 8.5 m (13 and 28 ft).

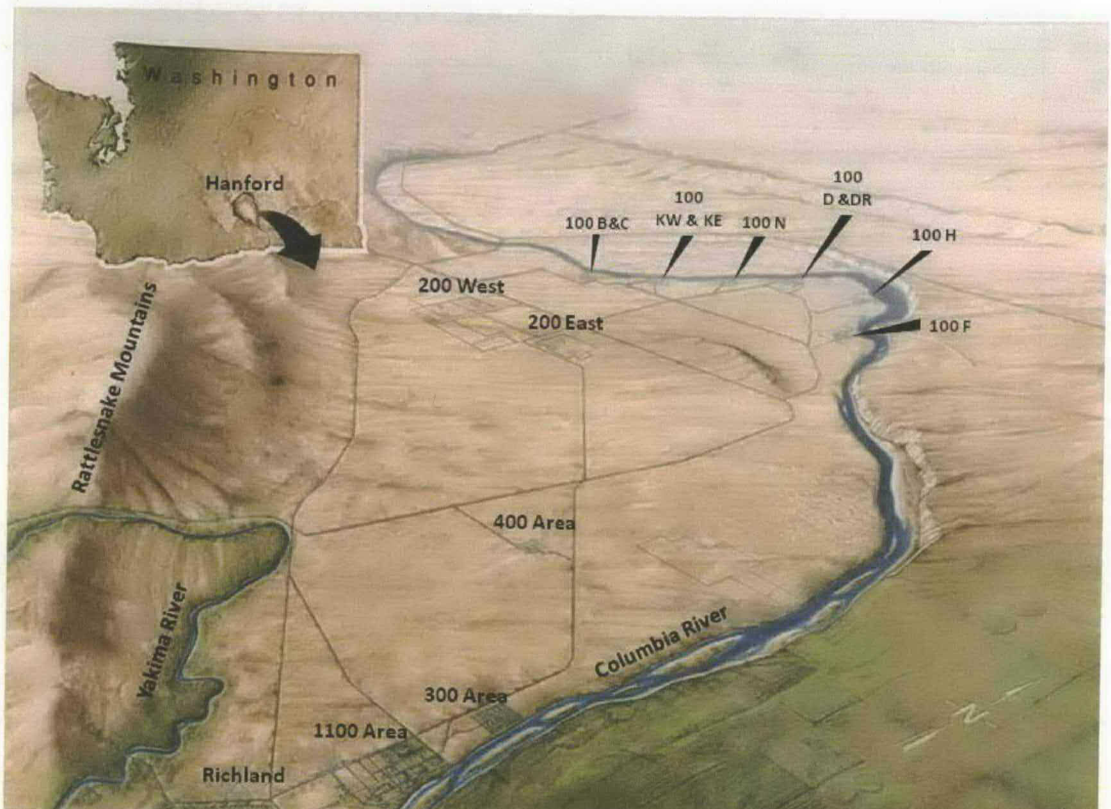
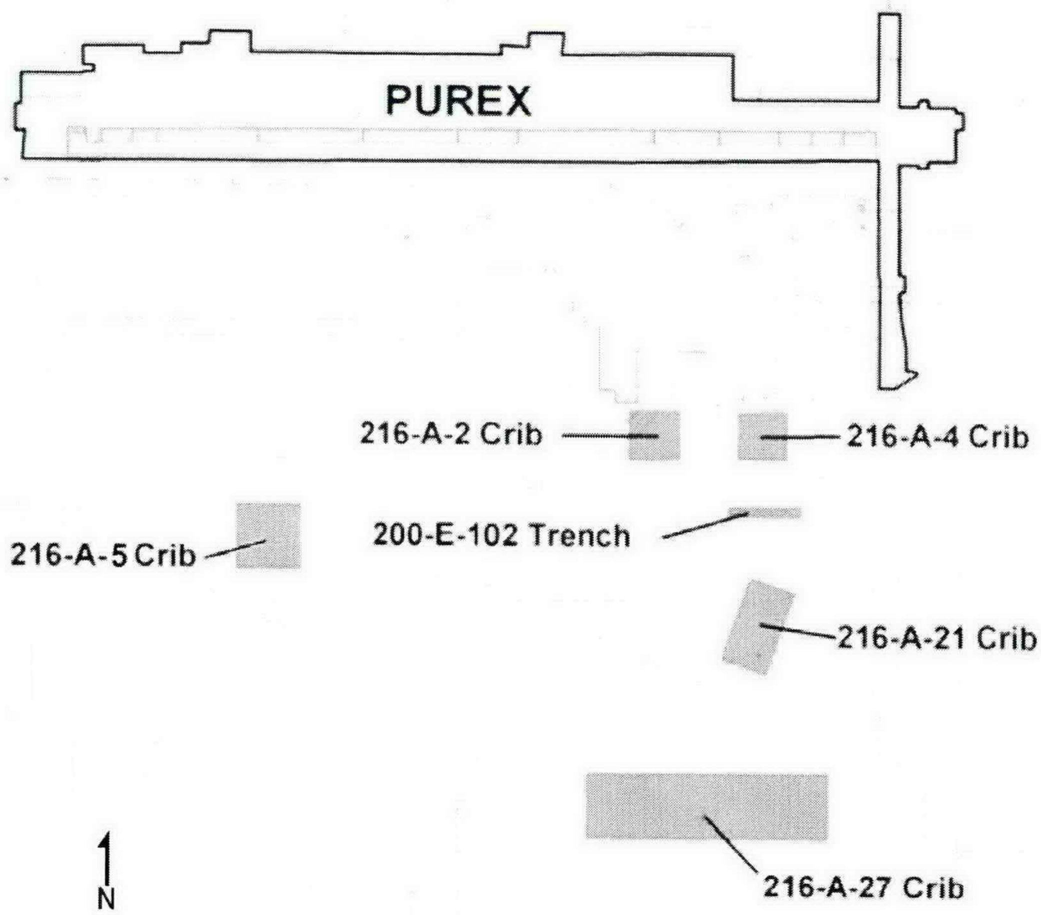


Figure 1-2. Location of the Hanford Site and the 200 East and West Areas



Notes: PUREX = Plutonium-Uranium Extraction Plant

Figure 1-3. Location of 200-MW-1 Operable Unit Cribs, 200-E102 Trench, and the 216-A-5 Supplemental Waste Site in the 200 East Area

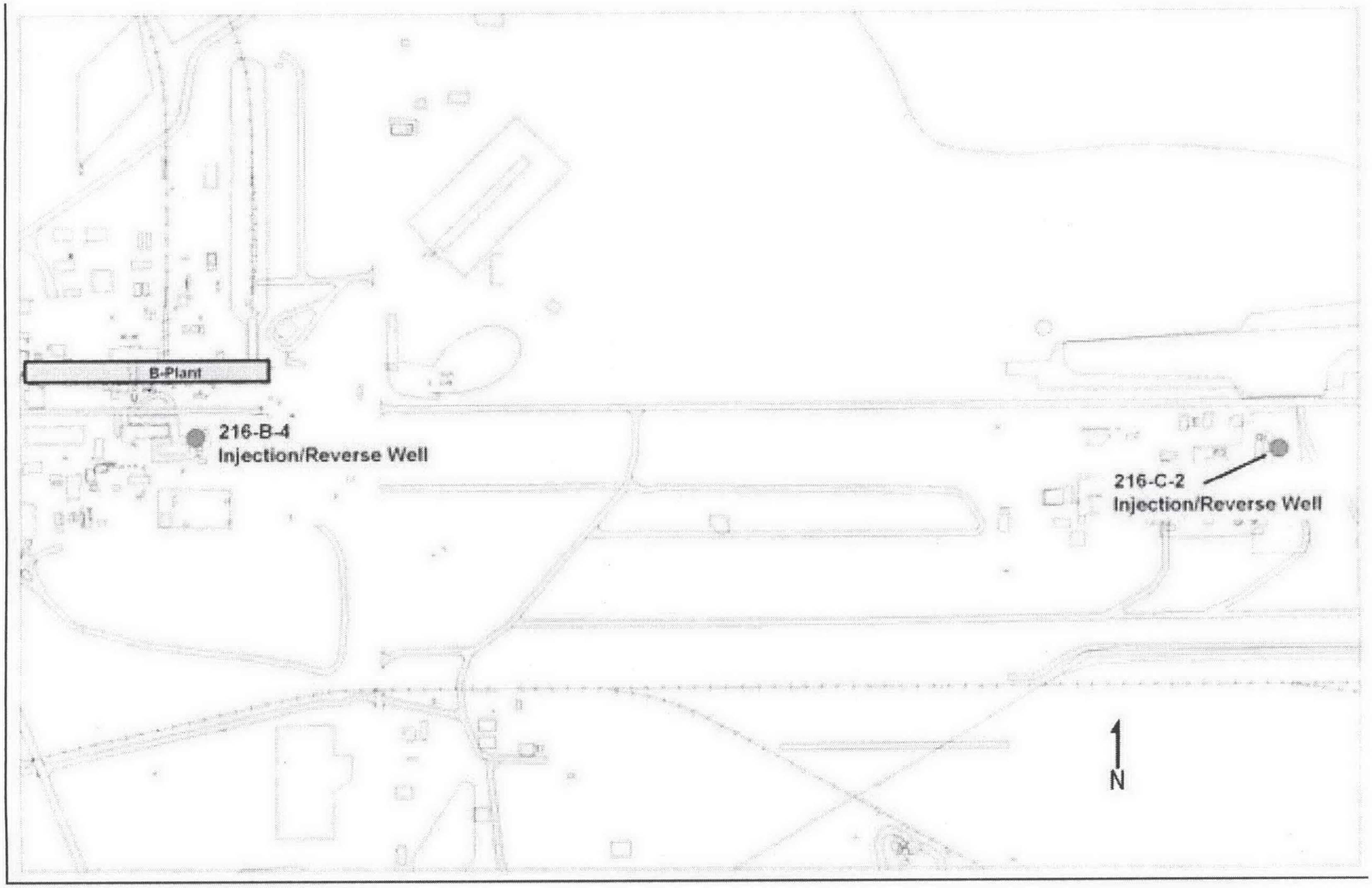


Figure 1-4. Location of 216-B-4 and 216-C-2 Reverse Well Waste Sites

Table 1-1. Comparison of Dimensions and Operating Parameters for the 200-MW-1 OU Sites

Waste Unit	Bottom Depth m (ft)	Bottom Dimensions	Thickness of Gravel Infiltration Gallery m (ft)	Footprint Shape and Dimensions[a] m^2 (ft^2)	Footprint Area m^2 (ft^2)	Dimensions at Ground Surface m^2 (ft^2)	Depth of Distribution System m (ft) bgs	Total Volume of Waste Received L (gal)	Operational Period	Lifetime Average Flow Rate to Site[b] L/min (gpm)	Estimated Pore Volumes Released to Waste Site[c]
216-A-2 Crib	8.2 (27)	6.1 m x 6.1 m (20 ft x 20 ft)	1.8 (6)	Square (top of infiltration gallery) 13.4 m x 13.4 m (44 ft x 44 ft)	180 (1,936)	32.6 m x 32.6 m (107 ft x 107 ft)	6.4 (21)	228,000 (61,000)	Jan 1956 to Jan 1963	0.06 (0.02)	0.05
216-A-4 Crib	7.9 (26)	6.1 m x 6.1 m (20 ft x 20 ft)	2.4 (8)	Square (top of infiltration gallery) 15.9 m x 15.9 m (52 ft x 52 ft)	251 (2,704)	32.3 m x 32.3 m (106 ft x 106 ft)	5.5 (18)	6,210,000 (1,640,000)	Dec 1955 to Dec 1958	3.9 (1.0)	0.9
216-A-21 Crib	5.9 (19.4)	15.2 m (50 ft length); width is V-shaped	1.8 (6)	Rectangular (top of infiltration gallery) 5.5 m x 18.3 m (18 ft x 78 ft)	130 (1,404)	18.9 m x 36.3 m (62 ft x 118 ft)	2.1 and 3-4.6 (7 and 10-15)	77,900,000 (20,500,000)	Oct 1957 to Jun 1965 (less 6 mos.)	21 (5.4)	22
216-A-27 Crib	4.6 (15)	3 m x 61 m (10 ft x 200 ft)	1 (5.3)	Rectangular (top of infiltration gallery) 8 m x 65.9 m (26 ft x 216 ft)	522 (5,616)	18.3 m x 76.2 m (60 ft x 250 ft)	3.1 (10.3)	23,100,000 (6,150,000)	1965 to Jun 1970	8.8 (2.3)	1.6
200-E-102 Trench	1.2 (4)	3 m x 18.3 m (10 ft x 60 ft)	NA	Rectangular (at ground surface) 3 m x 18.3 m (10 ft x 60 ft)	55 (600)	3 m x 18.3 m (10 ft x 60 ft)	NA	NA	1958	NA	NA
216-B-4 Reverse Well	33.5 (110)	0.20 m (0.67 ft) diameter casing	NA	Circular (assumed) Assumed 1 m (3.3 ft) radius saturation zone	3.14 (33.8)	0.20 m (0.67 ft) diameter casing	25.9–30.5 (85–100)	10,000 (2,600)	1945 to 1949	0.005 (0.001)	0.2
216-C-2 Reverse Well	12.2 (40)	0.30 m (1 ft) diameter casing	NA	Circular (assumed) Assumed 1 m (3.3 ft) radius saturation zone	3.14 (33.8)	0.30 m (1 ft) diameter casing	4.6–12.2 (15–40) (estimated)	3,150,000 (832,000)	1953 to 1988	0.2 (0.05)	40
216-A-5 Crib[d]	10.7 (35)	10.7 m x 10.7 m (35 ft x 35 ft)	2.4 (8)	Square (top of infiltration gallery) 20.4 m x 20.4 m (67 ft x 67 ft)	416 (4,489)	45.1 m x 45.1 m (148 ft x 148 ft)	8.2 (27)	1,630,000,000 (431,000,000)	Dec 1955 to Nov 1961	523 (138)	150

Notes:

a. Footprint Dimensions and Dimensions at Ground Surface were calculated using the bottom depths shown in this table and the side slopes shown on the design drawings for the cribs (Chapter 4). These dimensions may differ from those shown on the design drawings. The calculated footprint dimensions were used to calculate the pore volumes.

b. Flow to the cribs is believed to have varied greatly. Some cribs received periodic flows. Values given are lifetime total volume received divided by operational period of the crib.

c. Pore volume is calculated as Footprint Size, multiplied by the depth to groundwater from the bottom of the unit (Bottom Depth), multiplied by an assumed porosity (30%). For the 216-A-27 Crib, the actual loading rate is higher, because some of the crib footprint is interpreted as having received no liquid waste effluent.

d. The 216-A-5 waste site actually belongs to the 200-PW-2 waste sites group. Site information is for comparison purposes only.

NA = not applicable

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The 200-MW-1 OU cribs have unlined bottoms overlain with 1 to 2 m (3 to 7 ft) of coarse-grade gravel (the drainage rock). The perforated distribution pipe was placed on top or near the top of the gravel layer. The gravel and piping were covered by fine sand and sisalkraft (a coarse paper) to provide a vapor and root barrier. The fine sand and paper also prevented fine-grained material present in the overlying earth backfill from infiltrating into the gravel. Some cribs were also equipped with a vent riser that extended to the ground surface. The vent allowed the crib gravels to breathe while liquid effluent was being discharged and subsequently drained from the crib. The ground surface above the crib was covered with stabilization material usually composed of crushed gravel.

216-A-2 Crib

The 216-A-2 Crib is an inactive liquid waste disposal site located inside the PUREX facility exclusion fence approximately 94 m (308 ft) south of the 202-A Building. The crib is square-shaped with a trapezoidal cross-section. The crib is marked by a vent at the ground surface with concrete posts at the corners (Figure 1-3).

The 216-A-2 Crib was activated in January 1956 and deactivated in January 1963 when the specific retention capacity was reached (Waste Information Data System [WIDS], 2008; RHO-CD-673, *Handbook 200 Areas Waste Sites*). Deactivation consisted of removing a section of the effluent piping. RPP-26744, *Hanford Soil Inventory Model, Rev. 1* (SIM), reports that the crib was active from 1956 to 1960. WIDS, 2008; RHO-CD-673; and RPP-26744 report that the crib received 230,000 liters (L) (61,000 gallons [gal]) of an organic-rich waste. Based on this volume and a groundwater depth of 96 m (315 ft), an estimated 0.05 pore volumes[1] of liquid effluent was discharged to the crib. This was the smallest effluent volume discharged of the four 200-MW-1 OU crib sites.

216-A-4 Crib

The 216-A-4 Crib is an inactive liquid disposal site located just east of the 216-A-2 Crib, inside the PUREX facility exclusion fence, approximately 94 m (308 ft) south of the 202-A Building. The crib is square-shaped with a trapezoidal cross-section. The crib is marked with concrete posts at the corners (Figure 1-6).

The 216-A-4 Crib was active from December 1955 to December 1958 (RHO-CD-673). The crib piping plugged in December 1958, flooding an area between the crib and the 291-A-1 Stack (DOE/RL-2001-65). Contaminated soil and blacktop were reportedly removed and placed in the 200-E-102 Trench, which lies near the crib's south boundary. The crib was deactivated in 1958 after the flooding event by blanking off the effluent piping. The crib received 6,210,000 L (1,640,000 gal) of aqueous wastes from the 202-A Building (WIDS, 2008). Based on this waste volume and a groundwater depth of 96 m (315 ft), an estimated 0.94 pore volumes of liquid effluent was discharged to the crib.

216-A-21 Crib

The 216-A-21 Crib is an inactive liquid waste disposal site located inside the PUREX facility exclusion fence approximately 160 m (525 ft) south of the 202-A Building. The crib is rectangular in shape with a V-shaped cross-section. The crib corners are marked with concrete posts (Figure 1-7).

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[1] The number of pore volumes of waste discharged to a crib is defined as the volume of pore space in the vadose zone between the top of the crib gravel and groundwater. A porosity of 30 percent was assumed.

The 200-MW-1 OU cribs have unlined bottoms overlain with 1 to 2 m (3 to 7 ft) of coarse-grade gravel (the drainage rock). The perforated distribution pipe was placed on top or near the top of the gravel layer. The gravel and piping were covered by fine sand and sisalkraft (a coarse paper) to provide a vapor and root barrier. The fine sand and paper also prevented fine-grained material present in the overlying earth backfill from infiltrating into the gravel. Some cribs were also equipped with a vent riser that extended to the ground surface. The vent allowed the crib gravels to breathe while liquid effluent was being discharged and subsequently drained from the crib. The ground surface above the crib was covered with stabilization material usually composed of crushed gravel.

216-A-2 Crib

The 216-A-2 Crib is an inactive liquid waste disposal site located inside the PUREX facility exclusion fence approximately 94 m (308 ft) south of the 202-A Building. The crib is square-shaped with a trapezoidal cross-section. The crib is marked by a vent at the ground surface with concrete posts at the corners (Figure 1-3).

The 216-A-2 Crib was activated in January 1956 and deactivated in January 1963 when the specific retention capacity was reached (Waste Information Data System [WIDS], 2008; RHO-CD-673, *Handbook 200 Areas Waste Sites*). Deactivation consisted of removing a section of the effluent piping. RPP-26744, *Hanford Soil Inventory Model, Rev. 1* (SIM), reports that the crib was active from 1956 to 1960. WIDS, 2008; RHO-CD-673; and RPP-26744 report that the crib received 230,000 liters (L) (61,000 gallons [gal]) of an organic-rich waste. Based on this volume and a groundwater depth of 96 m (315 ft), an estimated 0.05 pore volumes[1] of liquid effluent was discharged to the crib. This was the smallest effluent volume discharged of the four 200-MW-1 OU crib sites.

216-A-4 Crib

The 216-A-4 Crib is an inactive liquid disposal site located just east of the 216-A-2 Crib, inside the PUREX facility exclusion fence, approximately 94 m (308 ft) south of the 202-A Building. The crib is square-shaped with a trapezoidal cross-section. The crib is marked with concrete posts at the corners (Figure 1-6).

The 216-A-4 Crib was active from December 1955 to December 1958 (RHO-CD-673). The crib piping plugged in December 1958, flooding an area between the crib and the 291-A-1 Stack (DOE/RL-2001-65). Contaminated soil and blacktop were reportedly removed and placed in the 200-E-102 Trench, which lies near the crib's south boundary. The crib was deactivated in 1958 after the flooding event by blanking off the effluent piping. The crib received 6,210,000 L (1,640,000 gal) of aqueous wastes from the 202-A Building (WIDS, 2008). Based on this waste volume and a groundwater depth of 96 m (315 ft), an estimated 0.94 pore volumes of liquid effluent was discharged to the crib.

216-A-21 Crib

The 216-A-21 Crib is an inactive liquid waste disposal site located inside the PUREX facility exclusion fence approximately 160 m (525 ft) south of the 202-A Building. The crib is rectangular in shape with a V-shaped cross-section. The crib corners are marked with concrete posts (Figure 1-7).

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[1] The number of pore volumes of waste discharged to a crib is defined as the volume of pore space in the vadose zone between the top of the crib gravel and groundwater. A porosity of 30 percent was assumed.

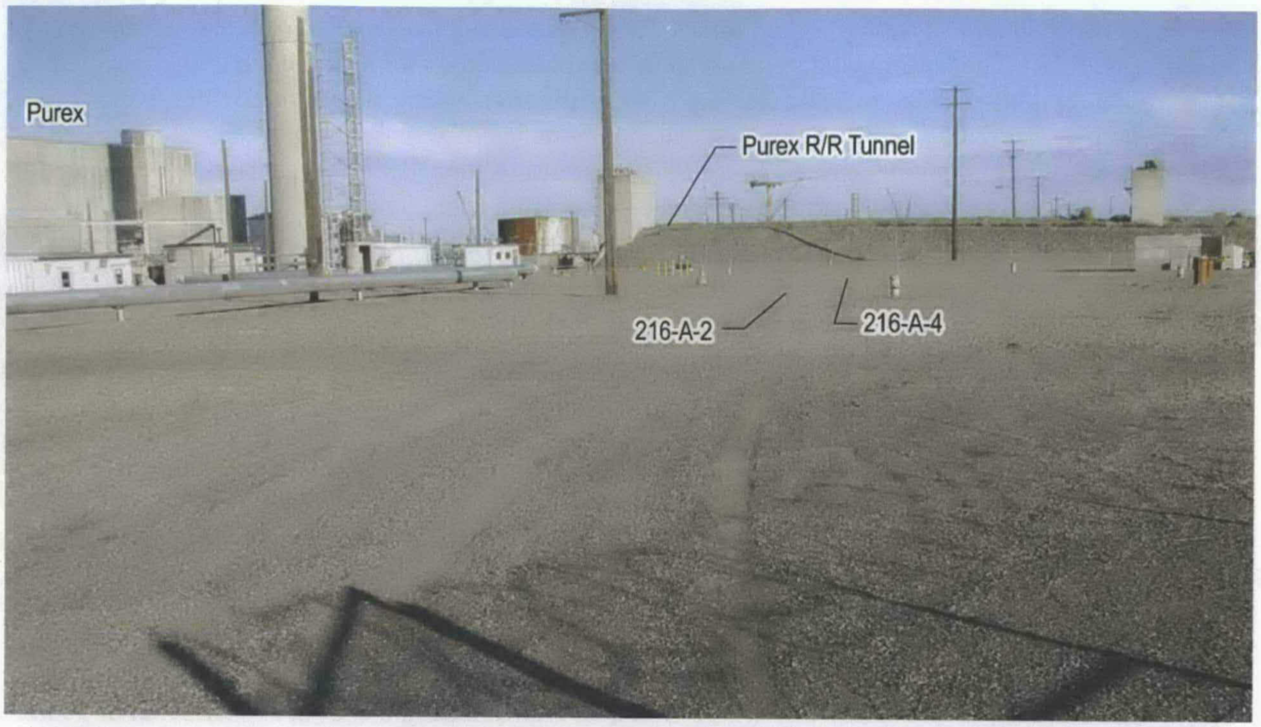


Figure 1-5. 216-A-2 Crib Site Photograph

Figure 1-6. 216-A-4 Crib Site Photograph (Looking East)

Figure 1-7. 216-A-21 Crib Site Photograph (Looking East)

The crib was active from October 1957 to June 1965, except for a period of about six months in 1958 when the crib was out of service to repair the original distribution piping (WIDS, 2008; RPP-26744). Before June 1958, waste was discharged through a 0.2 m (0.5 ft) diameter perforated clay distribution pipe located on top of the drain rock 4.2 m (13.9 ft) below ground surface (bgs). In June 1958, after eight to nine months of operation, this pipe failed, and the crib was temporarily taken out of service. A new distribution system (as described above) was installed, and the unit was brought back into service in December 1958 (WIDS, 2008) after the 216-A-4 Crib was deactivated. The crib received 77,900,000 L (20,500,000 gal) of liquid effluent (WIDS, 2008). Based on this volume and a groundwater depth of 96 m (315 ft), an estimated 22 pore volumes of liquid effluent were discharged to the crib. This is the largest effluent volume discharged of the four 200-MW-1 OU crib sites.

216-A-27 Crib

The 216-A-27 Crib is an inactive liquid waste disposal site that straddles the PUREX facility exclusion fence approximately 206 m (675 ft) south of the 202-A Building. The crib is rectangular in shape with a trapezoidal cross-section. The crib is marked by a cable fence and concrete posts (Figure 1-8).

The 216-A-27 Crib was activated in 1965 and deactivated in June 1970. The waste stream that had been discharged to the 216-A-21 Crib (since at least 1958, and possibly 1957) was reportedly re-directed to 216-A-27 Crib when the specific retention capacity of the 216-A-21 Crib was reached (WIDS, 2008). The crib received 23,100,000 L (6,105,000 gal) of liquid effluent (WIDS, 2008). Based on this volume and a groundwater depth of 96 m (315 ft), an estimated 1.6 pore volumes of liquid effluent were discharged to the crib.

Figure 1-8. 216-A-27 Crib Site Photograph (Looking East)

216-A-5 Crib

The 216-A-5 Crib is an inactive liquid waste disposal site located inside the PUREX facility exclusion fence approximately 87 m (285 ft) south of the 202-A Building, and 170 m (570 ft) west of the 200-MW-1 OU crib sites. The 216-A-5 Crib, although being investigated under the 200-PW-2/4 OU-RI, is discussed in this document due to its proximity near the 216-A-21 and 216-A-27 Cribs. The 216-A-5 Crib has been extensively investigated, and its effluent volume and waste inventory are greater then the other cribs mentioned above. This makes the 216-A-5 investigation data very useful in providing supplemental secondary information on the vertical extent of contaminant migration under higher effluent discharge volumes.

1.2.1.2 200-E-102 Trench

The 200-E-102 Trench is a contaminated material disposal trench located inside the PUREX facility exclusion fence approximately 121 m (397 ft) south of the 202-A Building and 20.7 m (68 ft) south of the 216-A-4 Crib (Figure 1-9). The trench is not marked or posted. Based on the dimensions given in WIDS, 2008, the trench is 24.4 m (60 ft) long, 3.1 m (10 ft) wide, and 1.2 m (4 ft) deep. The contaminated material placed in the trench was covered with 0.3 m (1 ft) of soil. Approximately 0.2 m (0.5 ft) of surface stabilization material (crushed rock) was added to the surface in 1999 (BHI-01269, *Final Report for Interim Stabilization of PUREX Contamination Areas*).

The trench was used to bury contaminated soil and asphalt from an unplanned release (UPR), i.e., 200-E-15, at the 216-A-4 Crib. When the crib plugged in 1958, it caused the ground between the crib and the 291-A Turbine House to flood. The contaminated soil and asphalt were scraped up and placed into a slot trench near the south end of the crib. There is no inventory or characterization information for the material placed in the trench. Measurements performed at the time of the release reported eight rads per hour for the ground and asphalt surfaces outside the turbine house. The dimensions in WIDS, 2008 indicate that the trench could contain up to 24 m^3 (1,200 cubic ft^3) of contaminated material.

Figure 1-9. 200-E-102 Trench Site Photograph

1.2.1.3 200-MW-1 Operable Unit Reverse Wells

Reverse wells were drilled, vertically cased boreholes with perforations that were drilled or punched along the bottom of the steel casing. Liquid wastes were discharged to the wells directly from the generating facility or were accumulated first in settling tanks before batch discharge.

216-B-4 Reverse Well

The 216-B-4 Reverse Well is an inactive liquid waste disposal site located approximately 30.5 m (100 ft) south of the B Plant in the 200 East Area. The well is marked by a concrete post (Figure 1-10).

The well was placed in service in 1945 and deactivated in 1949. The well received 10,000 L (2,600 gal) of liquid effluent (WIDS, 2008). Based on this volume and a groundwater depth of 95 m (311 ft), an estimated 0.2 pore volumes of liquid effluent were discharged to the well.

216-C-2 Reverse Well

The 216-C-2 Reverse Well is an inactive liquid waste disposal site located approximately 600 m (2,000 ft) east of the B Plant in the 200 East Area. An earlier description (RHO-CD-673) describes its location as "100 ft southeast of the 291-C Stack." The well is marked by a concrete post (see Figure 1-10).

The 216-C-2 Reverse Well was placed in service in 1953 and deactivated in 1988 (RHO-CD-673 and DOE/RL-2001-65). The well received 3,150,000 L (832,000 gal) of liquid effluent (RPP-26744). Based on this volume and a groundwater depth of 95 m (311 ft), an estimated 40 pore volumes of liquid effluent were discharged to the well.

B-4 Reverse Well

C-2 Reverse Well

Figure 1-10. 216-B-4 and 216 C-2 Reverse Well Site Photographs

1.2.2 Site History

The history of each waste site was included in the site descriptions presented in Section 1.2.1. Additional historical information for selected 200-MW-1 OU waste sites is presented in SGW-44795, *Critical Review of Historical, Field Logging, and Analytical Data for PUREX A Cribs to Estimate Vertical Distribution and Horizontal Spreading of Risk Driving Contaminants*.

1.2.3 Previous Investigations and Remediation

Supporting documents that provided the basis for the RI report are listed in Table 1-2.

Table 1-2. Summary of Previous Investigations and Other Relevant Documents

Document Title	Document Number	Comments (relevance to current study,)
200 Areas Remedial Investigation/Feasibility Study Implementation Plan - Environmental Restoration Program	DOE/RL-98-28	This plan outlines a strategy to streamline the characterization and remediation of waste sites in the 200 Areas, including Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) past-practice sites, Resource Conservation and Recovery Act (RCRA) past-practice sites, and RCRA treatment, storage, and/or disposal (TSD) units. It outlines the framework for implementing assessment activities and evaluating remedial alternatives in the 200 Areas to ensure consistency in documentation, level of characterization, and decision making; lists potential applicable or relevant and appropriate requirements (ARARs); identifies preliminary remedial action objectives (RAOs); and discusses potentially feasible remedial technologies in the 200 Areas.
200-MW-1 Miscellaneous Waste Group Operable Unit RI/FS Work Plan	DOE/RL-2001-65	This work plan describes the path forward for the characterization of the 200-MW-1 OU. The 216-A-4 Crib, 216-B-4 Reverse Well, and the 216-C-2 Reverse Well are the only waste sites described in this work plan that are in 200-MW-1 OU as currently configured.
Remedial Investigation Data Quality Objectives Summary Report for the 200-MW-1 Operable Unit	BHI-01592	This report describes the data quality objective (DQO) process that was followed for the 216-A-4 site.
Remedial Investigation Report for the 200-MW-1 Miscellaneous Waste Group Operable Unit	DOE/RL-2005-62	This report describes characterization work carried out for waste sites formerly part of the 200-MW-1 OU under the Work Plan and does not include characterization results for any of the current 200-MW-1 OU waste sites.

Table 1-2. Summary of Previous Investigations and Other Relevant Documents

Document Title	Document Number	Comments (relevance to current study,)
Sampling and Analysis Plan for Additional Remedial Investigation Activities at the 216-A-4 Crib and the 200-E-102 Trench	DOE/RL-2006-47	This document describes planning sampling and analysis activities for a deep borehole (C5301 [299-E24-23]) drilled near the 216-A-4 Crib and a direct push borehole (C5302) drilled within the 200-E-102 Trench. This Sampling Analysis Plan (SAP) was completed in accordance with the Work Plan.
Sampling and Analysis Plan for Supplemental Remedial Investigation Activities at the 216-A-2 Crib and the 216-A-21 Crib	DOE/RL-2006-77	This document describes planned sampling and analysis activities for a direct push hole (C5570) and a deep borehole (C5515) at the 216-A-2 Crib, and a direct push hole (C5571) at the 216-A-21 Crib. This SAP was completed in accordance with the Work Plan.
Vol. 1, *Supplemental Remedial Investigation/Feasibility Study Work Plan for the 200 Areas Central Plateau Operable Units: Volume I: Work Plan and Appendices*, and Vol. II, *Supplemental Remedial Investigation/Feasibility Study Work Plan for the 200 Areas Central Plateau Operable Units: Volume II: Site-Specific Field-Sampling Plan Addenda*	DOE/RL-2007-02	This Work Plan describes supplemental characterization work that includes the 200-MW-1 OU waste sites. This Work Plan was not issued until all the field activities for the 200-MW-1 OU supplemental characterization effort had been completed in 2007. The field activities were consistent with this Work Plan, but they were initiated and completed under the original Work Plan. This Work Plan outlines the path forward for completing the remedial investigation/feasibility study (RI/FS) process. Addendum 5 presents a data summary and conceptual site model (CSM) for the 216-A-5 Crib.

1.2.4 Regulatory Basis and History

This section presents the regulatory history of the MW-200-1 OU sites and defines the current and future land uses and demographics of the 200 areas.

1.2.4.1 Regulatory Basis

The characterization and remediation of Hanford waste sites are addressed in the Tri-Party Agreement. This agreement provides a standard approach for cleanup programs under CERCLA and 42 USC 6901, *Resource Conservation and Recovery Act of 1976* (RCRA) and ensures that applicable regulatory requirements are met. Details of this approach for the 200 Areas are presented in DOE/RL-98-28, *200 Areas Remedial Investigation/Feasibility Study Implementation Plan–Environmental Restoration Program* (Implementation Plan); DOE/RL-2001-65; and DOE/RL-2007-02.

Remedial action under CERCLA [Section 104 (a) (1)] is warranted when:

- There is a release, or substantial threat of release, of hazardous substances into the environment. This determination is made based on the findings of the RI.
- The hazardous substance release poses an imminent and substantial danger to public health, welfare, or the environment. This determination is made based on the findings of the BRA conducted as part of the RI.

- Remedial action is necessary to protect public health, welfare, or the environment. This determination is made based on a detailed and comparative evaluation of remedial action alternatives against the nine evaluation criteria described in 40 CFR 300.430(e)(9)(iii), "National Oil and Hazardous Substances Pollution Contingency Plan," "Remedial Investigation/Feasibility Study and Selection of Remedy," "Feasibility Study," "Detailed Analysis of Alternatives," "Nine Criteria for Evaluation."

As described in Chapter 4 of this report, there is evidence of a hazardous substance[2] release at the 216-A-2, 216-A-4, and 216-A-21 Cribs. Based on the SIM (RPP-26744) and historical operating information, hazardous substances may have been released to the environment at the 216-A-27 Crib, the 200-E-102 Trench, and the 216-B-4 and 216-C-2 Reverse Wells.

In making a determination on whether a hazardous substance release poses a threat to HHE, decisions are generally based on the following risk management thresholds (EPA, 1991, *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions*, OSWER Directive 9355.0-30):

- Remedial action is generally warranted at sites when the human health BRA indicates that the cumulative excess lifetime cancer risk (ELCR) to an individual is greater than 1×10^{-4} and/or the non-carcinogenic hazard quotient (HQ) is greater than 1 (risk management thresholds) based on the reasonable maximum exposure (RME) scenario for the current and reasonably anticipated future land use. The 1×10^{-4} ELCR threshold is not a discrete line. An ELCR estimate around 1×10^{-4} may be acceptable if justified based on site-specific conditions.

- Remedial action is generally not warranted at sites when the ELCR is less than 1×10^{-4} and/or the non-carcinogenic HQ is less than 1 based on the RME for both the current and reasonably anticipated future land use unless there are adverse environmental impacts, or uncertainties in the risk assessment results. RODs for remedial actions taken at sites posing an ELCR less than 1×10^{-4} and/or non-carcinogenic HQ less than 1 must explain why remedial action is necessary.

Adverse environmental impacts often prompt remedial action decisions when there is no significant risk to human health. Contaminants present in groundwater, identified as a current or future source of drinking water, at concentrations greater than maximum contaminant levels (MCLs) or non-zero MCL goals constitute an adverse environmental impact that may trigger a remedial action decision. Sites that pose a threat, or potential threat, to critical habitats, endangered species, or sensitive environmental receptors (aquatic organisms) may also trigger a remedial action decision.

1.2.4.2 Regulatory History

As originally defined in DOE/RL-98-28, the 200-MW-1 OU consisted of 50 CERCLA waste sites. Waste sites assigned to this OU were subsequently updated by the addition and removal of waste sites in accordance with Tri-Party Agreement guidelines for waste site reclassification. The Work Plan included 43 waste sites in the 200-MW-1 OU. As of November 30, 2005, as identified in the WIDS database (WIDS, 2008), two additional waste sites (216-A-22 Crib and UPR-200-E-17) were added and one waste site (216-Z-21 Pond) was removed from the 200-MW-1 OU, bringing the total number of waste sites to 44. These 44 waste sites were considered in a subsequent RI (DOE/RL-2005-62, *Remedial Investigation Report for the 200-MW-1 Miscellaneous Waste Group Operable Unit*).

In 2007, two Tri-Party Agreement change requests (C-06-02 and C-07-01) were approved by the Tri-Parties. These change requests updated OU designations for Central Plateau waste sites, based on changes identified in Tri-Party Agreement Milestone M-15-06-02. As part of these change requests, all

[2] Radionuclides are identified as hazardous substances under 40 CFR 302.4, "Designation, Reportable Quantities, and Notification," "Designation of Hazardous Substances," Appendix B, "Radionuclides."

but 16 of the originally defined 200-MW-1 OU waste sites were transferred to the newly created 200-MG-1 or 200-MG-2 OUs (Change Request C-06-02), and one additional waste site (216-A-2 Crib), originally part of the 200-PW-3 OU, was assigned to the 200-MW-1 OU (Change Request C-07-01). After a recent review of the WIDS database (WIDS, 2008), ten other waste sites within the 200-MW-1 OU were identified as rejected, consolidated with other units, or closed out. Based on these milestone changes and the WIDS review, the 200-MW-1 OU was reduced to ten waste sites. The 299-E24-111 experimental test well is still active and being retained for future use. The need for remedial action at the 299-E24-111 site will be assessed when a determination is made that the experimental test well will no longer be used. Two sites (616-WS-1 and 216-Z-21) have been reclassified as "clean closed" and "no action", respectively, resulting in the final number of seven waste sites evaluated in this report (216-A-2 Crib, 216-A-4 Crib, 216-A-21Crib, 216-A27 Crib, 200-E-102 Trench, and the 216-B-4 and 216-C-2 Reverse Wells).

The Tri-Party Agreement Milestone M-15-06-02 change request states that existing RI reports will not be updated to incorporate new supplemental data or changes in waste site groupings. Thus, RI reports that contain information about waste sites that subsequently have been transferred to other OUs will remain unchanged (that is, any previous characterization of the transferred waste sites will be retained under the existing RI reports). Any new or additional supplemental data will be incorporated into newly submitted or updated FS reports.

The characterization completed as part of this investigation was performed concurrently with the approval of a new, supplemental work plan (DOE/RL-2007-02). The Tri-Parties agreed during the supplemental DQO process that the characterization work completed for the 216-A-2 and 216-A-21 Cribs (DOE/RL-2006-77) was consistent with requirements defined under the Supplemental Work Plan.

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

The following paragraphs present information on current land use and demography to characterize the human populations that could potentially be exposed to contaminants associated with the 200-MW-1 OU waste sites.

1.2.5.1 Land Use

The DOE, with support from cooperating agencies and stakeholders, has defined land use goals for the Hanford Site and developed future land-use plans (Drummond, 1992, *The Future for Hanford: Uses and Cleanup, The Final Report of the Hanford Future Site Uses Working Group*). Cooperating agencies and stakeholders that participated in future land use planning included the National Park Service, Tribal Nations, the states of Washington and Oregon, regional county and city governments, economic and business development interests, environmental groups, and agricultural interests. These activities initially were reported by Drummond (1992) and culminated in DOE/EIS-0222-F, *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*, and 64 FR 61615, "Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS)," issued in 1999.

The following subsections discuss current and reasonably anticipated future land uses for the 200 Areas. All seven of the 200-MW-1 OU waste sites are located within the 200 Areas industrial-exclusive land use area identified in DOE/EIS-0222-F.

Current Land Use

All current land use activities associated with the Central Plateau are industrial in nature. The facilities located in the 200 Areas were built to process irradiated fuel from the plutonium production reactors located in the 100 Areas. Most of the facilities directly associated with fuel reprocessing are now inactive and awaiting final disposition.

Several permitted waste management facilities are currently operating within the 200 Area. These facilities include permanent waste disposal facilities such as the Environmental Restoration Disposal Facility (ERDF), radioactive low-level waste (LLW) burial grounds, and a mixed-waste trench permitted under RCRA. The U.S. Department of the Navy also uses the 200 Area nuclear waste treatment, storage, and disposal (TSD) facilities. A commercial radioactive LLW disposal facility, operated by U.S. Ecology, Inc., is operating on a 200 Area tract that is leased to the State of Washington. Construction of a treatment facility to vitrify 200 Area tank farm wastes was initiated in 2000, and the 200 Area is the planned disposal location for the treated (vitrified) low-activity waste material.

To support current land use plans consistent with DOE/EIS-0222-F, DOE's 200 Area projects will maintain current facilities for continuing missions, remediate waste sites with soil and groundwater contamination as necessary to support future industrial land uses, lease facilities for waste disposal (i.e., U.S. Ecology, Inc.), and decommission existing facilities that have no further beneficial use.

Reasonably Anticipated Future Land Use

Per the land-use ROD (64 FR 61615), an industrial (exclusive) land use is expected to continue for the area. An industrial (exclusive) land use is defined as an area suitable and desirable for TSD of hazardous, dangerous, radioactive, and non-radioactive wastes. An industrial-exclusive land use will preserve DOE control of ongoing remediation activities and would use the existing compatible infrastructure required to support activities such as dangerous waste, radioactive waste, and mixed-waste TSD facilities. The DOE and its contractors, and the U.S. Department of Defense and its contractors, could continue their federal waste-disposal missions; and the Northwest Low-Level Radioactive Waste Compact could continue using the U.S. Ecology, Inc. site for commercial radioactive waste. Research supporting the dangerous waste, radioactive waste, and mixed-waste TSD facilities also would be encouraged within this land use designation. New uses of radioactive materials, such as food irradiation, could be developed, and the products could be packaged for commercial distribution under this land use designation.

Eventually, portions of the area may be used for non-DOE-related industrial uses. ICs will be maintained until existing contamination is no longer hazardous to HHE. DOE operations at the Hanford Site are expected to terminate in approximately the year 2050, and active ICs are assumed to remain in effect for approximately another 100 years (i.e., year 2150). Passive engineering controls are being designed and constructed to provide protection for at least 500 years, which is the time period stated for ERDF (EPA/ROD/R10-95/100, *Declaration of the Interim Record of Decision for the Environmental Restoration Disposal Facility*).

1.2.5.2 Water Use

Groundwater beneath the 200 Areas is not currently used, and the level of contaminants present in groundwater precludes its use as a drinking water source for the foreseeable future (DOE/EIS-0222-F). All drinking water for the 200 Areas is supplied by DOE from a treatment plant that draws water from the Columbia River.

Based on the risk framework workshops (Hanford Advisory Board [HAB], 2002, *Report of the Exposure Scenarios Task Force*), groundwater use inside and outside the industrial (exclusive) use area has been restricted until remediation efforts achieve groundwater cleanup standards. Once the restoration effort is complete (not expected before the year 2150), it is anticipated that unrestricted groundwater use outside the industrial use area could be allowed. However, long-term groundwater use restrictions inside the industrial use area will likely remain because portions of this area are expected to remain waste management areas for the foreseeable future. The PUREX facility and its immediate surrounding area, which includes many of the 200-MW-1 OU waste sites, will likely reside within a waste management area.

1.2.5.3 Demographic and Socioeconomic Summary

Based on the 2000 census, the 80-km (50-mi) radius area surrounding the Hanford Site had a total population of 482,300 and a minority population of 178,500. The ethnic composition of the minority population is primarily Hispanic (24 percent), self-designated "other and multiple races" (63 percent), and Native American (6 percent). Asians and Pacific Islanders (4 percent) and African Americans (3 percent) make up the remainder of the population in the area. The Hispanic population resides predominantly in Franklin, Yakima, Grant, and Adams Counties. Native Americans within the 80-km (50-mi) area reside primarily on the Yakama Reservation and upstream of the Hanford Site near the town of Beverly, Washington.

An estimated total of 155,100 people lived in Benton County, and 57,000 lived in Franklin County during 2004, totaling 212,100, which is an increase of almost 11 percent from the census count for the year 2000. According to the 2000 census, population totals for Benton and Franklin Counties were 142,475 and 49,347, respectively. Both Benton and Franklin Counties grew at a faster pace than Washington as a whole during the 1990s. The population of Benton County grew 26.6 percent, up from 112,560 during 1990. The population of Franklin County grew 31.7 percent, up from 37,473 during 1990.

As reported in PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization,* activity on the Hanford Site plays a dominant role in the socioeconomics of the Tri-Cities (i.e., the cities of Pasco, Richland, and Kennewick, Washington) and other parts of Benton and Franklin Counties. The agricultural community also has a significant effect on the local economy. Any major changes in Hanford Site activity would potentially affect the Tri-Cities and other areas of Benton and Franklin Counties.

The Hanford Site accounts for approximately 14 percent of the total jobs in the local economy. Total employment in the Tri-Cities metropolitan statistical area averaged 99,900 during 2004, up from 96,400 in 2003. Based on employee records as of February 2005, 91 percent of the direct employees of the Hanford Site live in Benton and Franklin Counties. Approximately 73 percent of Hanford Site employees reside in Richland, Pasco, or Kennewick. More than 36 percent are Richland residents, 10 percent are Pasco residents, and 26 percent live in Kennewick. Residents of other areas of Benton and Franklin Counties (including West Richland, Benton City, and Prosser) account for approximately 17 percent of the total Hanford Site employment. The remaining 10 percent reside in surrounding counties.

2 Study Area Investigation

This chapter summarizes RI field data collection activities for the 200-MW-1 OU. These activities are also described in SGW-33959, *Borehole Summary Report for Well 299-E24-23 (Borehole C5301) and Borehole C5302 Drilled in the Vicinity of the 216-A-4 Crib and the 216-E-102 Trench* (correct designation is 200-E-102 Trench), and SGW-35574, *Borehole Summary Report for 200-MW-1 Operable Unit Boreholes C5515, C5570, and C5571 Drilled in the 216-A-2 and 216-A-21 Cribs*. The RI field activities were performed in accordance with DOE/RL-2001-65; DOE/RL-2006-47, *Sampling and Analysis Plan for Additional Remedial Investigation Activities at the 216-A-4 Crib and the 200-E-102 Trench*; and DOE/RL-2006-77. The data needs for the 200-MW-1 OU were initially developed and presented in BHI-01592, *Remedial Investigation Data Quality Objectives Summary Report for the 200-MW-1 Operable Unit*, which summarizes the DQO process for this OU. Specific supplemental activities, including drilled boreholes and direct push boreholes for the waste sites in the 200-MW-1 OU, are identified in Table 1-2 of DOE/RL-2007-02.

2.1 Investigation Activities

Investigation activities completed for the supplemental RI are described in this section. Activities included reviewing historical information and historic and cultural resources. Field activities included surface geophysical and radiological surveys, air monitoring, borehole drilling, sampling, and borehole geophysical surveys.

2.1.1 Historical Information Review

This section describes historical information including cultural and historical resources.

2.1.1.1 Cultural and Historic Resources

In accordance with 36 CFR 800.3.1, "Protection of Historic Properties," "Initiation of the Section 106 Process," before the field activities were initiated, cultural and historic resource reviews were completed within the Work Plan timeline for all potentially affected areas. The DOE Richland Operations Office (RL) Hanford Cultural and Historic Resources Program determined that the proposed supplemental field investigations were not the type of undertaking with potential to cause effects to historic properties, and no further action was required. This determination was based on a review of aerial photographs that confirm disturbance at and around the waste sites.

Much of the 200 Area has been altered by Hanford Site operations. The Hanford Cultural Resources Laboratory conducted a comprehensive archaeological resources survey of the fenced portions of the 200 Area during 1987 and 1988 (PNNL-6415). The results do not indicate evidence of cultural resources associated with the Native American cultural landscape, early settlers/farming landscape, or archaeological discoveries associated with the 200-MW-1 OU.

In planning for a proposed undertaking such as remediation, renovation, or demolition, the *National Historic Preservation Act of 1966* requires agencies to consult with the State Historic Preservation Officer and the Advisory Council on Historic Preservation to ensure that all potentially significant cultural resources, including structures and associated sites, are adequately identified, evaluated, and considered. The 200-MW-1 OU waste sites do not contain any representative examples of buildings or structures associated with the Manhattan Project and Cold War landscape that are eligible for the National Register as contributing properties within the Historic District requiring individual documentation (PNNL-6415).

2.1.1.2 Historical Information

Historical information for each of the waste sites investigated during the RI is included in SGW-44795. The report summarizes information pertaining to facility usage, waste inventories, and waste site construction.

2.1.2 Surface Features

Surface geophysical surveys (ground penetrating radar [GPR]) were conducted at the borehole locations (shown in Figure 2-1) before drilling to screen for subsurface hazards and obstacles. The surveys were performed to verify the location of underground waste sites and to identify potential underground hazards.

Survey data for the new boreholes are presented in Table 2-1. The borehole locations and elevations were surveyed in accordance with internal procedures for geodetic surveys. Vertical coordinates were recorded using NAVD88, *North American Vertical Datum of 1988*, and the horizontal coordinates were recorded using NAD83, *North American Datum of 1983*, as revised, for the Washington State Plane (South Zone) with the 1991 adjustment for horizontal coordinates.

2.1.3 Contaminant Source Investigations

Six boreholes were installed to investigate contamination within the footprints of the waste sites. As shown in Table 2-1, these boreholes include C5515 and C5570 at the 216-A-2 Crib; C4560 and C4671 at the 216-A-4 Crib; C5571 at the 216-A-21 Crib; and C5302 at the 200-E-102 Trench. One borehole, C5301, was installed outside the footprint of the 216-A-4 Crib and then converted into Monitoring Well 299-E24-23. Borehole geophysical surveys were also performed at two existing monitoring wells: 299-E-24-53 at the 216-A-2 Crib and 299-E-24-54 at the 216-A-4 Crib. Historical borehole geophysical survey information from existing Monitoring Wells 299-E17-2 and 299-E17-3 was used to assess conditions at the 216-A-27 Crib. The samples collected and analyses performed at these locations are discussed in Section 2.1.8 and Section 2.1.9.

2.1.4 Land and Water Use Surveys

Land and water uses for the Central Plateau, and 200 East Area, were previously defined under DOE/RL-2001-65; therefore, these surveys were not required for the 200-MW-1 OU RI.

2.1.5 Meteorological Investigations

Meteorological investigations were not performed under the 200-MW-1 OU RI because airborne transport is not expected to be a significant contaminant transport pathway for the 200-MW-1 OU waste sites.

2.1.6 Air Investigations

Because airborne transport is not expected to be significant, contaminant transport pathway air sampling was not performed. Air monitoring was conducted during field investigation activities in accordance with WDOH, 2001, *Environmental Program ALARACT Demonstration for Drilling*, to verify that contamination did not migrate from the waste site.

2.1.7 Surface Water and Sediment Investigation

Surface water and sediment sampling was not performed under the 200-MW-1 OU RI. These media are not present within the OU boundaries, nor are these media expected to be affected by contaminant migration from the 200-MW-1 OU waste sites.

Table 2-1. Borehole Location and Geophysical Survey Information

Borehole Number	Approximate Location	Coordinates (Wash. State Plane, NAD83[91]) Northing (m)	Easting (m)	Total Depth m bgs (ft bgs)	Borehole Use	Geophysical Survey Type	Geophysical Survey Depth m bgs (ft bgs)
C4560	216-A-4 Crib (Inside Crib)	135530.72	575216.75	7.62 (25)	Soil Characterization Borehole	Not Surveyed	Not Surveyed
C4671	216-A-4 Crib (Inside Crib) (~ 2 m NW of C4560)	135531.50	575215.18	18.3 (60)	Geophysical Logging Push Hole	SGLS, HRLS, PNLS	18.3 (60)
C5301	216-A-4 Crib (~ 17 m SW of C4560)	135517.81	575205.25	109.7 (360)	Soil Characterization Borehole	SGLS, NMLS	108.2 (355)
C5302	200-E-102 Trench (Inside Trench)	135501.34	575207.69	17.2 (56.4)	Soil Characterization & Geophysical Logging Push Hole	SGLS, NMLS, PNLS, NCLS	16.8 (55)
C5515	216-A-2 Crib (Inside Crib)	135530.89	575180.05	99.1 (325)	Soil Characterization Borehole	SGLS, HRLS, NMLS, PNLS	98.1 (322)
C5570	216-A-2 Crib (Inside Crib) (Adjacent to C5515)	135530.51	575180.02	10.9 (35.8)	Geophysical Logging Push Hole	SGLS, HRLS	10.7 (35)
C5571	216-A-21 Crib (Inside Crib)	135465.01	575216.27	18.3 (60)	Soil Characterization & Geophysical Logging Push Hole	SGLS, HRLS, NMLS, PNLS	18.3 (60)
299-E24-54	216-A-4 Crib (~ 10 m NE of C4560)	135536.19	575224.41	30.5 (100)	Existing Monitoring Well	SGLS	31.1 (102)
299-E24-53	216-A-2 Crib (~19 m NW of C5301)	135527.69	575189.28	18.3 (60)	Existing Monitoring Well	SGLS, HRLS, NMLS	18.3 (60)
299-E17-2	216-A-27 Crib (outside crib)	135389.809	575221.115	121.9 (400)	Existing Monitoring Well	SGLS, HRLS	33.5 (110)
299-E17-3	216-A-27 Crib (outside crib)	135390.5	575,160.63	121.3 (398)	Existing Monitoring Well	SGLS, Scintillation Probe	92.7 (304)

Table 2-1. Borehole Location and Geophysical Survey Information

Borehole Number	Approximate Location	Coordinates (Wash. State Plane, NAD83[91])		Total Depth m bgs (ft bgs)	Borehole Use	Geophysical Survey Type	Geophysical Survey Depth m bgs (ft bgs)
		Northing (m)	Easting (m)				

Notes:
All soil characterization boreholes were drilled using cable tool drilling technology.

All push-holes were driven using diesel percussion casing hammer technology.

NAD83, *North American Datum of 1983*

bgs = below ground surface

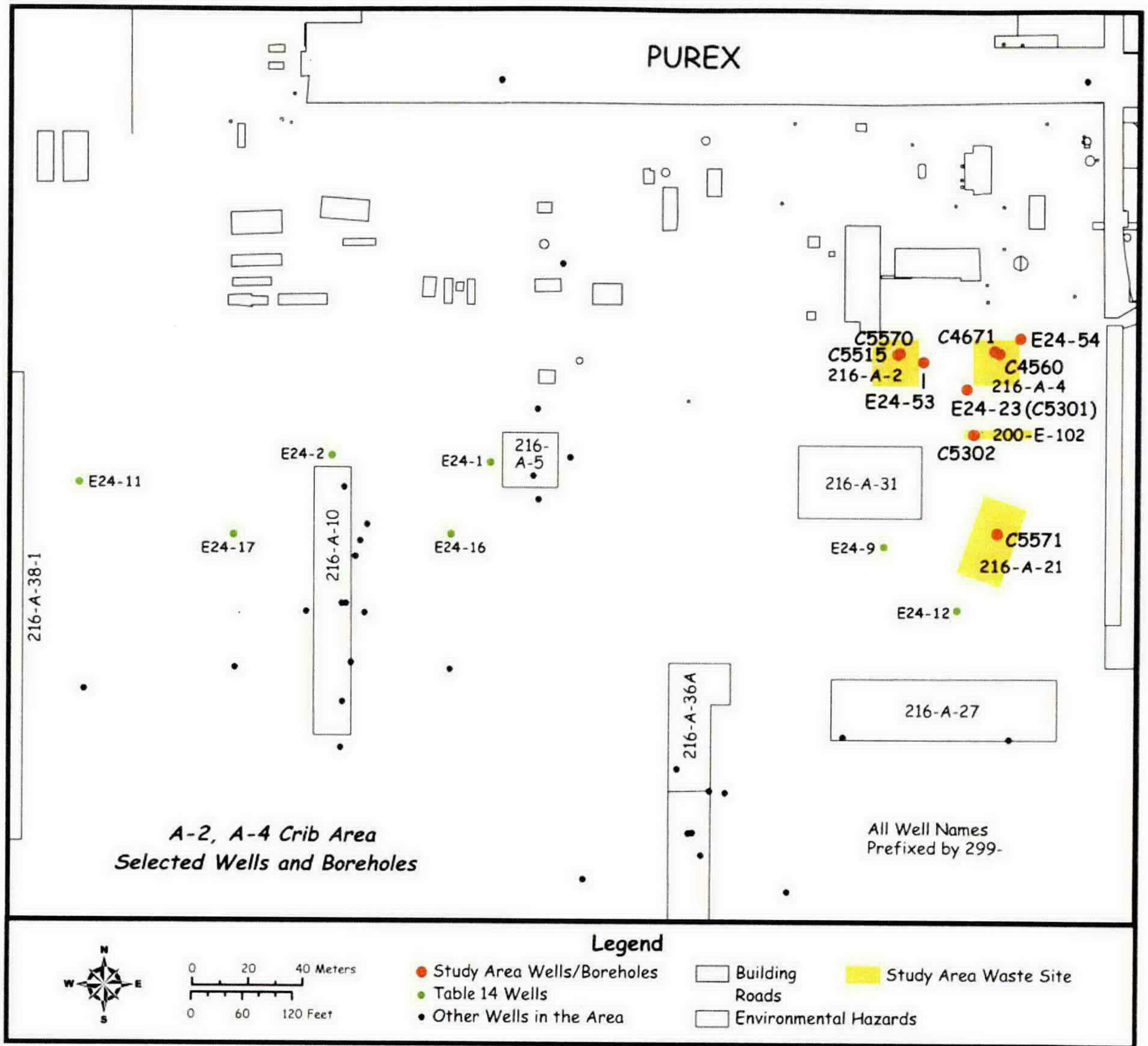
HRLS = High Rate Logging System

NCLS = Neutron Capture Logging System

NMLS = Neutron Moisture Logging System

PNLS = Passive Neutron Logging System

SGLS = Spectral Gamma Logging System



2008/DCL/A2A4/003 (05/02)

Figure 2-1. 216-A-2 Crib, 216-A-4 Crib, 216-A-21 Crib, 216-A-27 Crib, and 200-E-102 Trench Borehole Location Map

2.1.8 Geological Investigations

Geological investigations included recording field visual observations of lithologic properties, conducting geophysical surveys, and collecting and analyzing samples for physical properties.

Borehole geologic observations and geophysical log interpretations for the two deep boreholes (C5515 and C5301) were used to infer the lithology beneath the 216-A-2 and 216-A-4 Cribs. Detailed borehole geologic logs, describing the lithology encountered during drilling, were prepared for deep borehole C5301, located adjacent to the 216-A-4 Crib, and deep borehole C5515, located within the 216-A-2 Crib. Copies of the detailed geologic logs are presented in SGW-33959 and SGW-35574. Geophysical logging for moisture content was performed at these two boreholes and at Monitoring Well 299-E24-53 located northwest of the 216-A-2 Crib, borehole C5302 within the 200-E-102 Trench, and borehole C5571 located in the 216-A-21 Crib (see Table 2-1). A Neutron Moisture Logging System

(NMLS), which qualitatively detects changes in moisture content, was used. Results are provided in Appendix B.

A number of subsurface soil samples were collected from boreholes at the 216-A-2, 216-A-4, and 216-A-21 Cribs and the 200-E-102 Trench to determine moisture content and bulk density. At the 216-A-2 Crib, moisture content (by weight) was determined for 128 samples (spaced approximately every 0.8 m [2.5 ft] of vertical depth) in the vadose zone. Bulk densities were not calculated for soil at the 216-A-2 Crib. At the 216-A-4 Crib, moisture content was determined for 110 samples (spaced approximately every 0.8 m [2.5 ft] of vertical depth) in the vadose zone. Dry bulk densities were measured at the following four intervals in the vadose zone at the 216-A-4 Crib: 13.1 to 13.9 m (43 to 45.5 ft) bgs, 37.2 to 37.8 m (22 to 24 ft) bgs, 79.2 to 79.9 m (260 to 262 ft) bgs, and 86.3 to 86.9 m (283 to 285 ft) bgs. At the 216-A-21 Crib, moisture content was determined for four samples in the vadose zone, as follows: 6.4 to 6.9 m (21 to 22.5 ft) bgs, 7.7 to 8.1 m (25.1 to 26.6 ft) bgs, 11.9 to 12.3 m (39 to 40.5 ft) bgs, and 17.7 to 18.3 m (58.2 to 59.9 ft) bgs. Bulk densities were not determined for these samples. At the 200-E-102 Trench, moisture content was determined for one sample in the vadose zone, collected at a depth of 16.7 m (55 ft) bgs. Bulk density was not determined for this sample.

2.1.9 Soil and Vadose Zone Investigations

Boreholes were installed during the RI by cable tool and direct push methods, as indicated in Table 2-1 and shown in Figure 2-2, in order to investigate the vadose zone. Boreholes used for soil characterization, including C5515 at the 216-A-2 Crib and C4560 and C5301 (same borehole as 299-E24-23) at the 216-A-4 Crib, were drilled using cable tool methods. Cable tool drilling with drive-barrel technology was used to construct these boreholes. No water was added to aid the drilling process in any of the boreholes. Split-spoon sampling and grab sampling were the primary methods used for soil acquisition.

Soil samples were collected for chemical and radionuclide analyses. After the total depth was reached, borehole C4560 was decommissioned by removing the temporary casing, backfilling the borehole with granular bentonite, and placing a concrete surface seal, in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells." The 216-A-4 Crib borehole (C5301) was completed as a shallow groundwater monitoring well (299-E24-23) to support the underlying CERCLA 200-PO-1 Groundwater Operable Unit monitoring network. The 216-A-2 Crib borehole (C5515) was completed with a dedicated geophysical electrode probe located within the vadose zone.

Boreholes C5570 at the 216-A-2 Crib, C4671 at the 216-A-4 Crib, C5571 at the 216-A-21 Crib, and C5302 at the 200-E-102 Trench were installed using direct push technology. The direct push boreholes driven through the 200-E-102 Trench (C5302) and 216-A-21 Crib (C5571) were constructed using a diesel percussion drilling method (also known as a Becker hammer) with carbon steel casing and a removable tip. No water was added to the hole to aid the drilling process. Samples were obtained with a 0.76-m (2.5-ft) long split-spoon sampler. After total depth was reached, the boreholes were decommissioned by removing the temporary casings and backfilling the borehole with granular bentonite, and placing a concrete surface seal embedded with a brass borehole identifier at the surface in accordance with WAC 173-160.

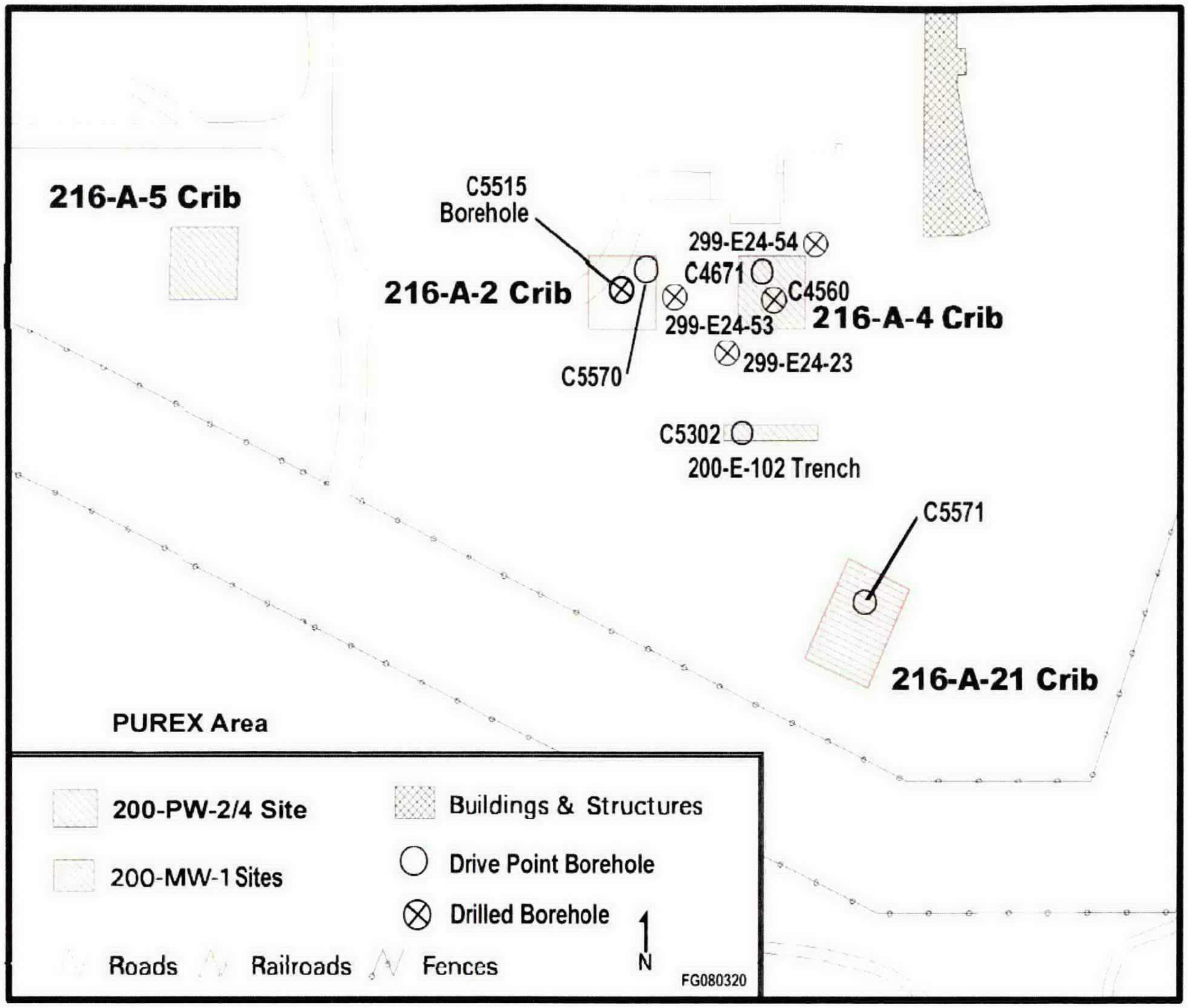


Figure 2-2. Drive Point and Drilled Borehole Locations

Surface radiological surveys were conducted at the borehole locations to screen for surface radiological contamination. Activity readings greater than two times background were the action levels used as an indicator of high contamination. Background was established by measuring activity at ground surface in a clean area away from the borehole locations. No surface contamination zones were identified by radiological surface screening during the surveys.

Soil samples were collected for chemical and radionuclide analysis and determination of physical properties. Sample collection was guided by the sample schedule in Appendix A of the Work Plan (DOE/RL-2001-65) and the Sampling and Analysis Plans (DOE/RL-2006-47 and DOE/RL-2006-77). The sampling approach generally required a greater sample frequency near the bottom of each waste site structure (i.e. crib bottom), which was the area of highest suspected contamination. Analyses performed from split-spoon and grab samples collected at the 216-A-2 and 216-A-4 Cribs are provided in Appendix A. The distance between the sample intervals generally increased below depths of approximately 9.14 to 13.7 m (30 to 45 ft) because these depths were below the zone of highest contamination.

A total of 67 split-spoon samples were collected from boreholes C5515, C4560, C5301, and C5571, including 37 primary samples, seven duplicate/split samples, and 23 quality control (QC) samples. This sample data set was used for risk assessment evaluation. A total of 327 grab samples were collected from boreholes C5515, C5301, and C5302. A subset of these samples was analyzed, and the results were used to provide additional information on the vertical distribution of chemical and radionuclides in the subsurface.

As required by the sampling and analysis plans (SAPs), the soil samples were analyzed for various radionuclides, anions, cations, hexavalent chromium, hydrocarbons, metals, physical properties, polychlorinated biphenyls (PCBs), semi-volatile organic compounds (SVOCs), and volatile organic compounds (VOCs).

Selected grab samples collected at 0.8 m (2.5 ft) intervals were analyzed by the PNNL Environmental Sciences Laboratory (ESL). Analyses included metals, selected radionuclides, selected anions, and physical properties.

Geophysical logging was completed at all of the new boreholes (except for C4560) and at existing Monitoring Wells 299-E24-53 and 299-E24-54. Existing geophysical logging associated with the 216-A-27 Crib was performed in 2005, 1970, 1968, and 1963. As shown in Table 2-1, not every tool was used in every borehole. These logging systems provided a continuous radiological signature of the soils through the casing to the total drilled depth. The borehole geophysical logging, data collection, and reduction were performed by S. M. Stoller Corporation Geophysical Services, Hanford Office in Richland, Washington.

Several different downhole geophysical survey methods (Spectral Gamma Ray Logging System [SGLS], High Rate Logging System [HRLS], NMLS, Passive-Neutron [PNLS], and Neutron Capture Logging System [NCLS]) were used to measure the radiological signature at selected boreholes. SGLS detects the presence of process uranium, Cs-137, americium, cobalt, europium, and several other radionuclides. HRLS is used to log zones of extremely high radioactivity. NMLS qualitatively detects changes in moisture content. PNLS is a qualitative screening tool for locating plutonium. NCLS potentially detects and quantifies various elements. Appendix B presents the geophysical logs and detailed reports for the 216-A-4 Crib (boreholes C4560, C4671, and C5301), the 200-E-102 Trench (borehole C5302), the 216-A-2 Crib (boreholes C5515 and C5570), the 216-A-21 Crib (borehole C5571), and the 216-A-27 Crib (Monitoring Wells 299-E17-2 and 299-E17-3).

2.1.9.1 216-A-4 Crib and 216-A-2 Crib

216-A-4 Crib. The Work Plan used for the original 200-MW-1 OU characterization directed sampling from borehole C4560 at the 216-A-4 Crib using a non-statistical sampling design (that is, professional judgment) to select sample locations (DOE/RL-2006-77 and DOE/RL-2006-47). Following the focused sampling approach, the first sampling was to begin above the crib bottom and continue at specified depth intervals (based on the site conceptual contaminant distribution model, results of nearby borehole logging events, and professional judgment of the field geologist) until a significant decrease in contamination was noted. This focused sampling approach was selected based on process knowledge, the expected distribution of target contaminants, observed distribution of contamination in the field, waste site configuration, and the preliminary conceptual contaminant distribution model developed for the waste site. Sample locations were selected that would increase the likelihood of encountering the worst-case conditions or maximum concentrations of contaminants. Borehole C4560 was planned to be drilled through the entire vadose zone and stopped when the water table was encountered.

In July 2004, during drilling of the first investigation borehole within the 216-A-4 Crib (C4560), the borehole was terminated at 7 m (23 ft) bgs before reaching the planned depth when unexpectedly high field contamination levels were encountered. Because of the unexpected contamination, this borehole was used only to obtain a few shallow soil samples for laboratory analysis. Most of the temporary casing and some drilling tools were left in the borehole. No geophysical survey was completed. Table 2-2 shows planned versus actual split-spoon soil sampling depths at C4560. A revised, supplemental SAP (DOE/RL-2006-47) was prepared to allow RI activities to continue at the 216-A-4 Crib.

Table 2-2. Planned Versus Actual Vadose Zone Split-Spoon Sediment Sampling Depths for the 216-A-4 and 216-A-2 Cribs

216-A-4 Crib				216-A-2 Crib	
C4560		C5301		C5515	
Planned m bgs (ft bgs)	Actual m bgs (ft bgs)	Planned m bgs (ft bgs)	Actual m bgs (ft bgs)	Planned m bgs (ft bgs)	Actual m bgs (ft bgs)
0.15–0.91 (0.5–3)	0.15–0.91 (0.5–3)	--	--	--	--
3.8–4.6 (12.5–15)	3.7–4.4 (12–14.5)	--	--	3.8–4.6 (12.5–15)	3.96–4.72 (13–15.5)
5.6–6.4 (18.5–21)	5.5–6.3 (18–20.5)	--	--	7.2–7.9 (23.5–26)	8.23–8.38 (27–27.5)
8.1–8.8 (26.5–29)	Not Collected*	--	--	8.4–9.1 (27.5–30)	8.84–9.60 (29–31.5)
8.8–9.6 (29–31.5)	Not Collected*	8.8–9.6 (29–31.5)	8.8–9.6 (29–31.5)	9.1–10 (30–32.5)	9.75–10.5 (32–34.5)
10.4–11.1 (34–36.5)	Not Collected*	13–3.7 (42.5–45)	13.1–13.9 (43–45.5)	14.5–15.2 (47.5–50)	14.5–15.1 (47.5–49.5)
19.1–19.8 (62.5–65)	Not Collected*	--	--	15.2–16 (50–52.5)	15.2–16 (50–52.5)
29.7–30.5 (97.5–100)	Not Collected*	37.3–38.1 (122.5–125)	37.2–37.8 (122–124)	16–16.8 (52.5–55)	15.9–16.6 (52–54.5)
45–45.7 (147.5–150)	Not Collected*	48.8–49.5 (160–162.5)	48.9–49.7 (160.5–163)	16.8–17.5 (55–57.5)	16.6–17.4 (54.5–57)
60.2–61 (197.5–200)	Not Collected*	--	--	40.2–41.3 (132–135.5)	40.4–41.2 (132.5–135)
87.6–88.4 (287.5–290)	Not Collected*	79.3–80 260–262.5	79.3–79.9 (260–262)	76.2–77 (250–252.5)	76.4–77.1 (250.5–253)
94.2–95 (309–311.5)	Not Collected*	86.1–86.9 (282.5–285)	86.3–86.9 (283–285)	86.9–87.6 (285–287.5)	86.9–87.5 (285–287)
--	--	--	--	96–96.8 (315–317.5)	96.6–97.4 (317–319.5)

* Sample was not collected because the well was terminated.

-- = not required

bgs = below ground surface

Shallow drive point C4671 was installed inside the 216-A-4 Crib next to the terminated borehole C4560 and geophysically logged to determine the depth distribution and magnitude of the high-activity zone (geophysical results are provided in Appendix B). The borehole was installed to a total depth of 18.3 m (60 ft) bgs and was used for geophysical logging within the casing using SGLS, HRLS, and PNLS. Based on these new data, a revised sampling strategy was developed to evaluate the vadose zone at both the 216-A-2 and 216-A-4 Cribs. Installation activities began on January 4, 2006, and decommissioning activities took place on November 7, 2006.

Two SAPs (DOE/RL-2006-47 and DOE/RL-2006-77) were subsequently developed for supplemental 200-MW-1 OU RI characterization. These SAPs directed sampling in two new boreholes: borehole C5301 located adjacent to the 216-A-4 Crib and borehole C5515 located within the 216-A-2 Crib. The same focused sampling approach initiated by the Work Plan was implemented at both the 216-A-4 and 216-A-2 Cribs. Detailed borehole geologic logs describing the lithology encountered during drilling were prepared for each of these deep boreholes.

However, because the conceptual model for the 216-A-4 Crib had changed since the Work Plan was prepared (based on data from C4560 and C4671), a revised sampling strategy was developed to evaluate contaminant distribution in the vadose zone at both cribs (DOE/RL-2006-47). To gain a better understanding of the distribution of mobile contaminants, grab samples were collected every 0.8 m (2.5 ft), starting at 6.1 m (20 ft) bgs. The sampling design objective at replacement borehole C5301 (see Table 2-2) was to begin sampling at the depth corresponding to the crib bottom and continue sampling intermittently (based on the site's revised conceptual contaminant distribution model, results of nearby borehole logging events, and the professional judgment of the field geologist) to the water table, which was estimated at 96 m (315 ft). The zone near the bottom of the crib was expected to have the highest potential for contamination associated with low-mobility contaminants, and replacement borehole C5301 would not include samples at intervals analyzed from borehole C4560 (intervals 0.2 to 0.9 m [0.5 to 3 ft], 3.8 to 4.6 m [12.5 to 15 ft], and 5.5 to 6.6 m [18 to 21.5 ft]).

Borehole C5301 was drilled at a distance of 2.5 m (8.2 ft) outside the 216-A-4 Crib boundary to the southwest. Drilling activities at borehole C5301 began on November 27, 2006 and were completed on March 8, 2007 (SGW-33959). The borehole reached a total depth of 109.7 m (360 ft) bgs. Groundwater was encountered at 95.7 m (314.1 ft) bgs on January 4, 2007. One groundwater sample was collected from the uppermost aquifer. Soil sampling included a combination of grab samples (collected at nominal 0.8 m [2.5 ft] intervals) and split-spoon samples. Soil samples were collected for chemical and radionuclide analyses (see Appendix A). The borehole was used for geophysical logging using SGLS and NMLS (see Appendix B). Borehole C5301 was completed as a groundwater monitoring well (299-E24-23) to support the underlying CERCLA 200-PO-1 Groundwater OU monitoring network.

Well 299-E24-54 (A5911), which is located 0.5 m (1.5 ft) outside the crib boundary to the northeast, was logged on April 7 and 11, 2005.

216-A-2 Crib. A direct push borehole (C5570) was installed within the footprint of the 216-A-2 Crib, with activities initiated on May 1, 2007 and completed on April 1, 2008. This borehole was installed to a depth of 10.9 m (35.8 ft) bgs and was used for geophysical logging using SGLS and HRLS within the casing. The geophysical logging results (see Appendix B) were used to screen for radionuclide contaminants (quantity and vertical extent) within and directly below the crib, to obtain field screening data for health and safety purposes, and to improve the sampling design for the proximal deep borehole (C5515). No soil samples were collected.

Subsequently, borehole C5515 was drilled adjacent to borehole C5570 through the crib, with drilling activities initiated on June 4, 2007 and completed on April 1, 2008. This borehole was used for geophysical logging (SGLS, HRLS, NMLS, and PNLS) and to provide a means for collection of soil samples for laboratory analysis. Appendix B presents the geophysical logs for the borehole. Table 2-2 shows planned versus actual soil sampling depths.

Also shown in Table 2-2, the sampling design for borehole C5515 (developed from the 216-A-4 Crib boreholes characterization results) was to begin sample collection at 3.8 to 4.6 m (12.5 to 15 ft) bgs within the crib, sample the crib bottom at 8.2 to 9 m (27 to 29.5 ft) bgs, and continue sampling. Sampling would include a combination of grab samples (collected at nominal 0.8 m [2.5 ft] intervals) and split-spoon samples (collected intermittently and at specific geologic interfaces) (DOE/RL-2006-77). Drilling and sampling was to stop when the water table was encountered. However, based on observational criteria, sampling data, and field screening results, drilling and sampling at the C5515 borehole was not stopped until 99.1 m (325 ft). Groundwater was encountered at a depth of 95.9 m (314.7 ft) bgs. One groundwater sample was collected from the uppermost aquifer. Soil samples were collected for chemical and radionuclide analyses (see Appendix A). The 216-A-2 Crib borehole (C5515) was completed with a dedicated geophysical electrode probe located within the vadose zone.

Borehole geophysical logging was also carried out at the existing Well 299-E24-53, located 15 m (49 ft) east of the 216-A-2 Crib, in 1999 and most recently between October 20-27, 2005. This work is described in the geophysical log data reports provided in Appendix B. Logging systems used by the geophysical contractor (Stoller) include SGLS, HRLS, and NMLS.

2.1.9.2 216-A-21 Crib and 200-E-102 Trench

216-A-21 Crib. Direct push borehole C5571 was installed through the 216-A-21 Crib between July 12, 2007 and September 4, 2007. The borehole was advanced to a total depth of 18.3 m (60 ft) bgs. The borehole was geophysically logged and sampled at four discrete depth intervals prior to decommissioning. The objective of the sampling design was to screen for gamma-emitting radionuclides and provide qualitative evaluation of moisture content beneath the crib. Logging systems employed by the geophysical contractor (Stoller) included SGLS, HRLS, NMLS, and PNLS (see Appendix B). Table 2-3 shows planned versus actual soil sampling depths.

Table 2-3. Planned Versus Actual Vadose Zone Split-Spoon Sediment Sampling Depths for the 216-A-21 Crib and 200-E-102 Trench

216-A-21 Crib		200-E-102 Trench	
C5571		C5302	
Planned m bgs (ft bgs)	Actual m bgs (ft bgs)	Planned m bgs (ft bgs)	Actual m bgs (ft bgs)
5.79–6.55 (19–21.5)	6.4–6.9 (21–22.5)	--	--
7.62–8.38 (25–27.5)	7.7–8.1 (25.1–26.6)	--	--
11.7–12.5 (38.5–41)	11.9–12.3 (39–40.5)	--	--
17.5–18.3 (57.5–60)	17.7–18.3 (58.2–59.9)	18.1–18.3 (59.5–60)	16.6–16. (54.4–54.9)

-- = not applicable

bgs = below ground surface

Soil sampling began at the approximate bottom of the crib, 5.79 m (19 ft) bgs, and continued at intermittent intervals until a total depth of 18.3 m (60 ft) was reached. Limited sample recovery volumes required the analyses to be prioritized. The analyses focused on key contaminants to ensure that the analytes of the highest need were analyzed to fill data gaps. Sampling was conducted first for VOCs; the remaining sample volume was homogenized and analyzed for the remainder of the target analytes (Appendix A).

200-E-102 Trench. One direct push borehole (C5302) was installed at the 200-E-102 Trench, with the field work initiated on October 25, 2006 and decommissioning completed on November 7, 2006. The total depth of the borehole was 17.2 m (56.4 ft) bgs. The main purpose for this borehole was to obtain geophysical logs to identify gamma-emitting radionuclides and percent moisture content and to test the depth capability of the diesel percussion hammer used to drive the casing. One grab sample was collected from the bottom of the borehole prior to decommissioning. The direct push sampling method typically provides only a limited soil volume; only water and acid extract analyses and physical property analyses were performed on the sample recovered.

2.1.9.3 216-A-27 Crib

In accordance with the approved SAPs, no field investigations were conducted for the 216-A-27 Crib as part of this RI. Existing information associated with the waste site's construction, radionuclide and non-radionuclide disposal inventory, and borehole geophysical logging events performed between 1963 and 2005 at two existing monitoring wells located along the crib's southern boundary provides the basis for the nature and extent evaluation and contaminant distribution model presented in Section 4.4.

2.1.9.4 216-B-4 and 216-C-2 Reverse Wells

In accordance with the approved SAPs, no field investigations were conducted for the 216-B-4 and 216-C-2 Reverse Wells as part of this RI. Existing information associated with the well's construction, radionuclide and non-radionuclide disposal inventory, and knowledge regarding how reverse well sites operate provides the basis for the nature and extent evaluation and contaminant distribution model presented in Section 4.4.

2.1.10 Groundwater Investigations

A groundwater sample was collected from the uppermost aquifer at borehole C5515 (located within the 216-A-2 Crib) and borehole C5301 (located adjacent to the 216-A-4 Crib). The approximate depth to groundwater at these waste site areas is 96 m (315 ft). A limited discussion of the analysis results is provided in SGW-44795.

The 216-A-4 Crib borehole (C5301) was completed as a shallow groundwater monitoring well (299-E24-23) to support the underlying CERCLA 200-PO-1 Groundwater OU monitoring network. The 216-A-2 Crib borehole (C5515) was completed with a dedicated geophysical electrode probe located within the vadose zone.

2.1.11 Ecological Investigations

Other than a visual survey of the 216-A-2 and 216-A-4 Crib sites, no other ecological investigations were performed for this RI. Ecological information for the 200 Area is summarized in Section 3.8.

2.2 Field Activity Documentation

Geophysical logs and technical memoranda documenting field activities are provided in Appendix B.

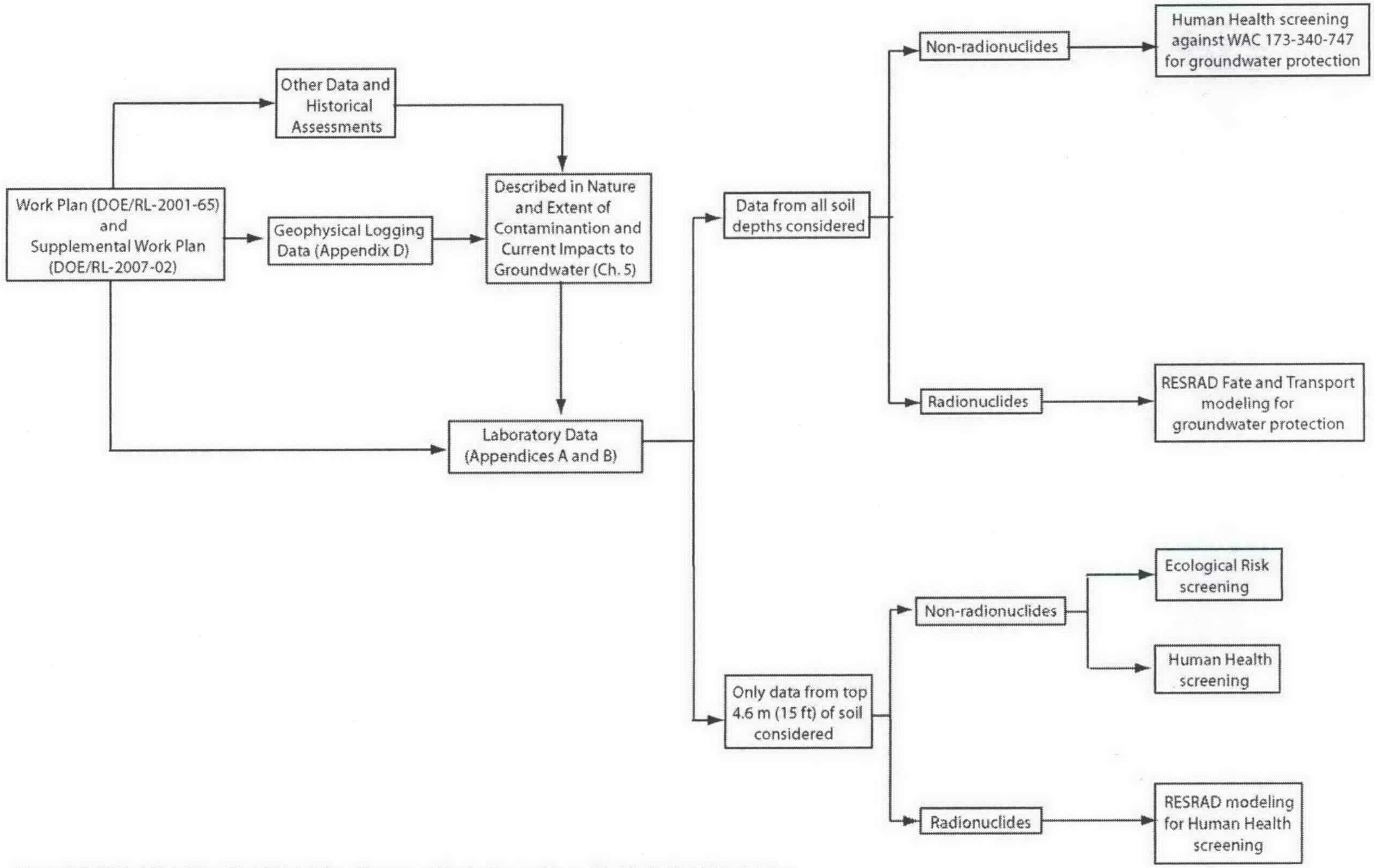
2.2.1 Data Quality

This evaluation process ultimately supports use of the data in the FS. The purpose of this RI report is to provide sufficient evaluation of different aspects of the data to support the FS development and evaluation of remedial alternatives and selection of a preferred remedy or remedies.

The data evaluation process was preceded by collection and validation of the data, and a data quality assessment (DQA) of the RI data was performed. These data were collected under the Work Plan, are consistent with the Supplemental Work Plan, and are based on DQOs established for this OU (BHI-01592). In accordance with the quality assurance (QA)/QC procedures specified in the SAP (Work Plan, Appendix A), at least five percent of all data were validated. A summary of the data validation results is presented in Appendix B of the DQA reports and in Appendix A of this document. Summary tables providing information such as frequency of detection and minimum and maximum detected values are also provided in Appendix A. A flowchart of the data evaluation process is provided as Figure 2-3.

The data evaluation process consists of the following:

- Data screening of contaminants reported as nondetects
- Data screening against background contaminants
- Human health risk assessment determinations for non-radionuclide contaminants
- Evaluation of ecological risk
- Human health dose and risk evaluation for radiological contaminants
- Comparison to WAC 173-340-745, "Model Toxics Control Act—Cleanup," "Soil Cleanup Standards for Industrial Properties"
- Evaluation of potential impacts to groundwater



Note: DOE/RL-2001-65, *200-MW-1, Miscellaneous Waste Group Operable Unit RI/FS Work Plan*

DOE/RL-2007-02, Vol. I, *Supplemental Remedial Investigation/Feasibility Study Work Plan for the 200 Areas Central Plateau Operable Units: Volume I: Work Plans and Appendices*, and Vol. II, *Supplemental Remedial Investigation/Feasibility Study Work Plan for the 200 Areas Central Plateau Operable Units: Volume II: Site-Specific Field-Sampling Plan Addenda*

WAC 173-340-747, "Model Toxics Control Act—Cleanup," "Deriving Soil Concentrations for Ground Water Protection"

RESRAD = RESidual RADioactivity (dose model) (ANL, 2007, *RESRAD*)

Figure 2-3. Data Evaluation Process

3 Physical Characteristics of the Study Area

This chapter describes the physical characteristics and environmental setting at the 200-MW-1 OU, including surface features, soils, geology, hydrology, meteorology, and ecology.

3.1 Surface Features

The 200-MW-1 OU waste sites are located in the 200 East Area of the Hanford Site. The 200 Area (East and West) is located on a broad, relatively flat plain that constitutes a local topographic high, commonly referred to as the Central Plateau (Figure 3-1). The plateau is a remnant paleo-flood bar (Cold Creek Bar) that trends generally east-west, with elevations varying between 197 and 225 m (647 to 740 ft) above mean sea level (amsl). The southern half of the 200 East Area is situated on the Cold Creek Bar, while the northern half of the 200 East Area lies off of the bar on the edge of a prominent former erosional flood channel. Additional information on the Central Plateau's physical setting is provided in Appendix F of DOE/RL-98-28.

Ground surface elevations in the 200-MW-1 OU are approximately 220 m (720 ft) in the area south of the PUREX building, and approximately 213 m (701 ft) at the 216-B-4 and 216-C-2 Reverse Wells. Waste site surface elevations in and around the 200 East Area range from approximately 220 m (720 ft) in the southwestern portion of the 200 East Area to 180 m (590 ft) near the northeast corner of the 200 East Area. The ground surface in this area generally slopes gently toward the northeast. The vadose zone beneath the 200 MW-1 OU is up to 96 m (315 ft) thick because of the OU's location atop the Cold Creek Bar (Central Plateau).

3.2 Meteorology

The Hanford Site lies within the semiarid shrub-steppe Pasco Basin of the Columbia Plateau in south-central Washington State. Climatological data for the Hanford Site are compiled at the Hanford Meteorological Station (HMS), which is located on the Hanford Site's Central Plateau, just outside the northeast corner of the 200 West Area and about 4 km (2.5 mi) west of the 200 East Area.

The prevailing surface winds on Hanford's Central Plateau are from the northwest and average from 2.7 m/s (6 mi/hr) to 4.0 m/s (9 mi/h).

Based on data collected from 1946 through 2004, the average monthly temperatures at the HMS range from a low of-0.7 C (31°F) in January to a high of 24.7°C (76°F) in July. The annual average relative humidity at the HMS is 55 percent. Average annual precipitation at the HMS is 17 cm (6.7 in.). Most precipitation occurs during the late autumn and winter months, with more than half of the annual amount falling between November and February. Average monthly snowfall amounts typically increase from 0.25 cm (0.1 in.) in October to a maximum of 13.2 cm (5.2 in.) in December and decrease to 1.3 cm (0.5 in.) in March. Snowfall accounts for about 38 percent of all precipitation for the December through February period.

3.3 Surface Water Hydrology

The primary surface water feature associated with the Hanford Site is the Columbia River, which flows through the northern and eastern boundaries of the Hanford Site (Figure 3-1). The 200 Area is not on a designated flood plain of the Columbia River.

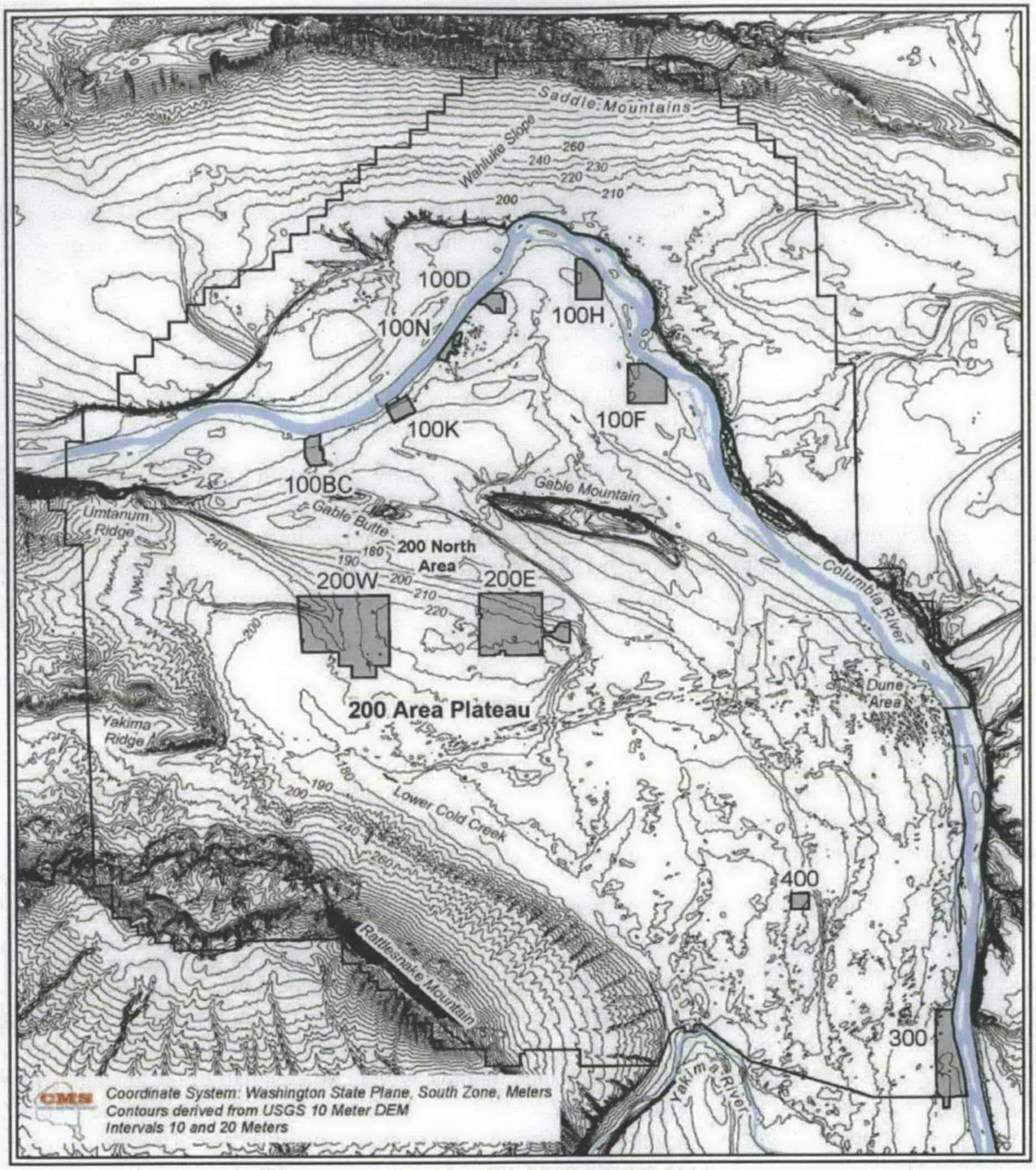
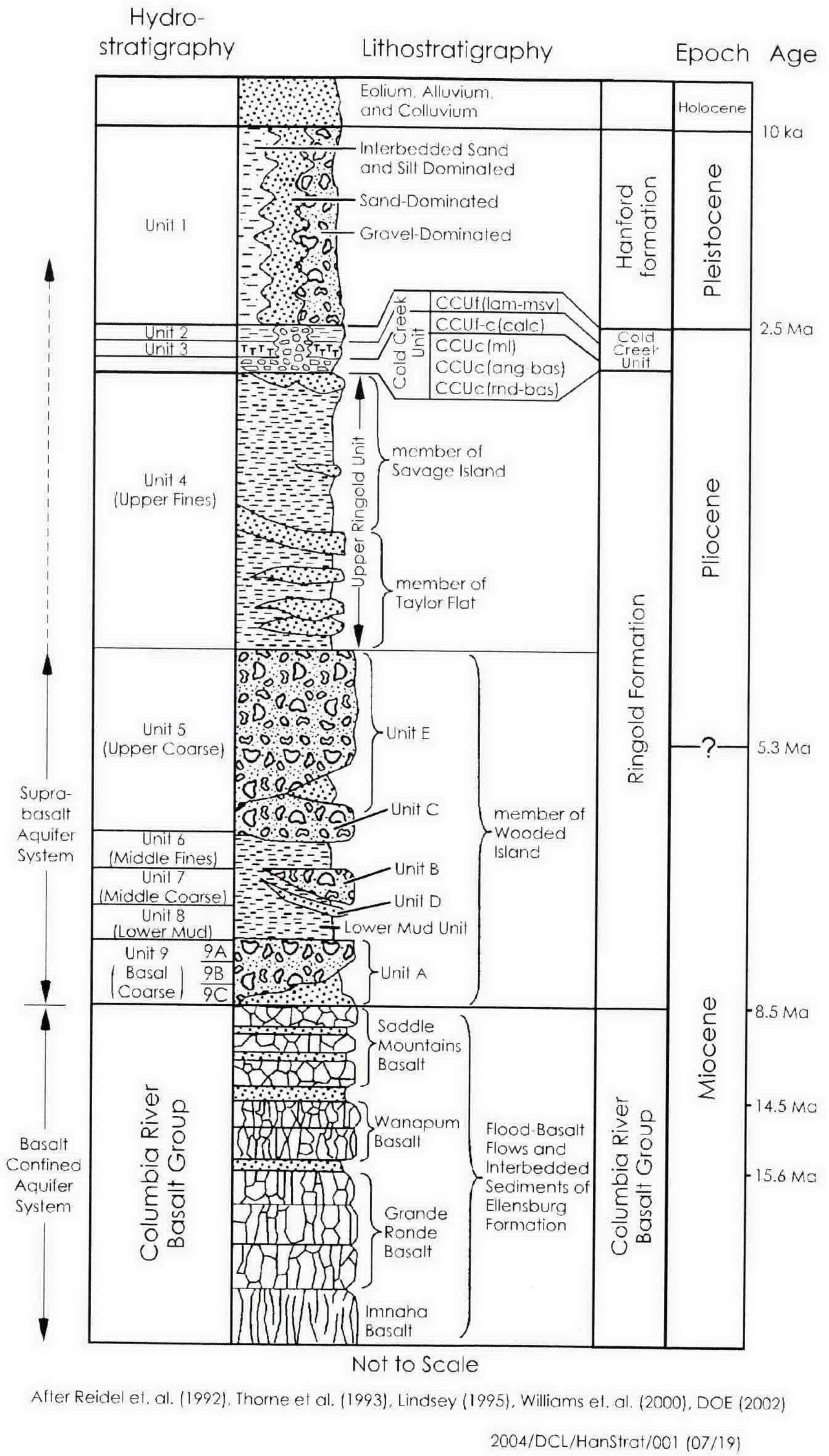


Figure 3-1. Topographic Map of the Hanford Site

3.4 Geology

The Hanford Site is located in the Pasco Basin, a major structural and topographic basin within the Columbia Plateau. Basalts of the Miocene Columbia River Basalt Group and a relatively thick sequence of unconsolidated suprabasalt sediments underlie the 200-MW-1 OU waste sites. From oldest to youngest, the major stratigraphic units underlying the 200 East Area include the Elephant Mountain Member of the Columbia River Basalt Group, the Ringold Formation, the Cold Creek unit, the Hanford formation, and surficial deposits. Figure 3-2 shows a generalized stratigraphic column for the 200 Areas.



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

Figure 3-2. Generalized Stratigraphic Column for the 200 Areas

3.4.1 Elephant Mountain Member

The Elephant Mountain Member of the Saddle Mountains Basalt Formation is the uppermost basalt unit (that is, bedrock) in the 200 Areas (DOE/RL-98-28, Appendix F). Except for a small area north of the 200 East Area boundary, where it has been uplifted and subsequently eroded away, the Elephant Mountain Member is laterally continuous throughout the 200 Areas. The RI field investigations in this study did not penetrate to the basalt because it is located many meters below the water table and forms the base of the suprabasalt aquifer system.

3.4.2 Ringold Formation

The Ringold Formation consists of an interstratified fluvial-lacustrine sequence of unconsolidated to semi-consolidated clay, silt, sand, and granule-sized gravel to cobble gravel deposited by the ancestral Columbia River (PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*; PNNL-13858, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington*; and PNNL-15955, *Geology Data Package for the Single-Shell Tank Waste Management Areas at the Hanford Site*). These sediments (see Figure 3-2) consist of three major units, including (from oldest to youngest) the member of Wooded Island, the member of Taylor Flat, and the member of Savage Island.

The member of Wooded Island consists of extensive fluvial gravel and interbedded sand formed in a gravelly braided plain with widespread paleosols. These sediments are divided into a series of units, ranging from Unit A at the bottom of the member to Unit E at the top. A widespread lacustrine-overbank deposit known as the Ringold Lower Mud overlies Unit A and is nearly continuous under the 200 West Area and most of the southern half of the 200 East Area. The fluvial gravels and sand of the member of Wooded Island are overlain by the sand-dominated member of Taylor Flat, and in turn by principally lacustrine sediments of the member of Savage Island. Data from nearby deeper drilled boreholes (and PNNL-12261) suggest that the Ringold Formation sediment does occur deeper within the uppermost unconfined aquifer. The RI field investigations in this study did not penetrate to the Ringold Formation because these units are located deeper beneath the water table within the suprabasalt aquifer system.

3.4.3 Cold Creek Unit

The Cold Creek unit includes several post-Ringold Formation and pre-Hanford formation units present beneath a portion of the 200 East and West Areas (DOE/RL-2002-39, *Standardized Stratigraphic Nomenclature for Post-Ringold Formation Sediments Within the Central Pasco Basin*). The Cold Creek unit includes the formations formerly described as the "Plio-Pleistocene unit," "caliche layer," "early Palouse soil," and "Pre-Missoula gravels." Sediments of the Cold Creek unit were deposited in the central part of the Pasco Basin approximately 2 to 3 million years ago. Deposition was bracketed by two significant geologic events (PNNL-15955). The older bounding event was a drop in the base-level caused by regional uplift, followed by incision of the Ringold Formation (Fecht et al., 1987, "Paleodrainage of the Columbia River System on the Columbia Plateau of Washington State–A Summary"). The younger bounding event is the initiation of Ice Age cataclysmic flooding, at the beginning of the Pleistocene, about 1.5 to 2.5 million years ago (Bjornstad et al., 2001, "Long History of Pre-Wisconsin, Ice-Age, Cataclysmic Floods: Evidence from Southeastern Washington State").

The Cold Creek unit has been divided into five lithofacies: fine-grained, laminated to massive (fluvial-overbank and/or aeolian deposits, formerly known as the early Palouse soil); fine-to coarse-grained, calcium-carbonate cemented (calcic paleosol, formerly known as caliche); coarse-grained, multilithic (mainstream alluvium, formerly known as the Pre-Missoula gravels); coarse-grained, angular, basaltic (colluvium); and coarse-grained, rounded, basaltic (sidestream alluvium, formerly known as sidestream alluvial facies). At the Hanford Site, the Cold Creek unit is more extensive and easily differentiated in the 200 West Area than it is in the 200 East Area where it has been partially removed by erosion. This unit was not encountered or identified during characterization activities related to the 200-MW-1 OU waste sites.

3.4.4 Hanford Formation

The Hanford formation is an informal stratigraphic name used to describe Pleistocene cataclysmic flood deposits in the Pasco Basin (PNNL-15955, DOE/RL-2002-39). These deposits were the result of the glacial outburst flood waters that flowed during the last Ice Age (18,000 to 12,000 years ago), and in multiple previous Ice Ages, from Glacial Lake Missoula, pluvial Lake Bonneville, and perhaps from subglacial outbursts across the channeled scablands. Net erosion by these floods was minimal and probably associated with only the earliest floods; later floods only partially incised into older flood deposits before backfilling (i.e., Cold Creek Bar and areas near Gable Gap).

The Hanford formation consists predominantly of unconsolidated sediments that range from boulder-size gravel to sand, silty sand, and silt. The sorting ranges from poorly sorted (for gravel facies) to well-sorted (for fine sand and silt facies). The Hanford formation is divided into three main lithofacies: interbedded sand-to silt-dominated (formerly called the Touchet beds or slackwater facies); sand-dominated (formerly called the sand-dominated flood facies); and gravel-dominated (formerly called the Pasco gravels) that have been further subdivided into 11 textural-structural lithofacies (DOE/RL-2002-39). Clastic dikes are common in the Hanford formation (DOE/RL-2002-39). They appear as vertical to subvertical sediment-filled structures, especially within sand- and silt-dominated units. The cataclysmic floodwaters that deposited sediments of the Hanford formation also locally reshaped the topography of the Pasco Basin. The floodwaters deposited a thick sand and gravel bar (Cold Creek Bar). In the waning stages of the Ice Age, approximately 11,000 years ago, these floodwaters also eroded a channel north of the 200 Areas in the area currently occupied by Gable Mountain Pond and the West Lake ephemeral pond. These floodwaters removed all of the Ringold Formation from this area and deposited Hanford formation sediments directly over the basalt.

The Hanford formation is the primary geologic zone of interest, comprising the entire vadose zone interval underlying the 200-MW-1 OU waste sites, and was the focus of the RI. Beneath the 200-MW-1 OU waste sites, the Hanford formation includes all three facies associations. The gravel-dominated facies are generally found at depths greater than approximately 91.5 m (300 ft) and consist of cross-stratified, coarse-grained sands and granule-size gravel to boulders that are uncemented and matrix-poor. Where the sand and silt content is low in the gravel-dominated facies, an open-framework texture is common. The sand-dominated facies are generally found at depths between 9 m (30 ft) and approximately 91.5 m (300 ft) and consist of well-stratified fine- to coarse-grained sand and granule-sized gravel. The silt-dominated facies is variable in its occurrence and primarily found at the base of, or interbedded within, the sand-dominated facies. During the RI, a significant silt bed was identified at depths between 86.7 m (284.5 ft) and 92 m (302.5 ft) at boring C5515 (216-A-2 Crib) and between 86 m (282.5 ft) and 90.7 m (297.5 ft) at boring C5301 (216-A-4 Crib). Less significant and laterally less continuous silt and silty sand interbeds were also encountered at these borings at depths between 9 m (30 ft) and 82 m (270 ft). These silt beds are geologically important in that they can form localized infiltration and contaminant transport barriers. All of the subsurface material (beneath the waste sites) affected by liquid waste discharges to the 200-MW-1 OU waste sites lies within the Hanford formation.

3.4.5 Surficial Deposits

Surficial deposits include Holocene aeolian sheets of sand that form a thin veneer over the Hanford formation across the 200 Area, except in localized areas where these deposits are absent. Surficial deposits consist of very fine to medium-grained sand to occasionally silty sand. Silty deposits less than 1 m (3 ft) thick also have been documented at waste sites where fine-grained, wind-blown material has settled out through standing water over many years (DOE/RL-98-28, Appendix F).

3.4.6 Summary of Stratigraphy at the 216-A-2 Crib, 216-A-4 Crib, 216-A-21 Crib, and 200-E-102 Trench

Stratigraphic units beneath the 216-A-2 Crib and the 216-A-4 Crib (in ascending order) consist of the Elephant Mountain Member basalt, Ringold Formation and Hanford formation sedimentary units, and aeolian surficial veneer. Although not fully confirmed, available data indicate that the Ringold Lower Mud and portions of the Ringold Formation Unit A sediments have likely been removed by erosion beneath these waste sites. The stratigraphy at the 216-A-2 Crib (Figure 3-3) is based on geologic descriptions from borehole C5515, from proximal borehole C5301 (drilled near the 216-A-4 Crib), and the stratigraphy as described in PNNL-12261. Borehole C5515 was drilled to approximately 3 m (10 ft) below the water table in sediments of the Hanford formation. The water table was encountered at a depth of 96.3 m (315.8 ft) bgs.

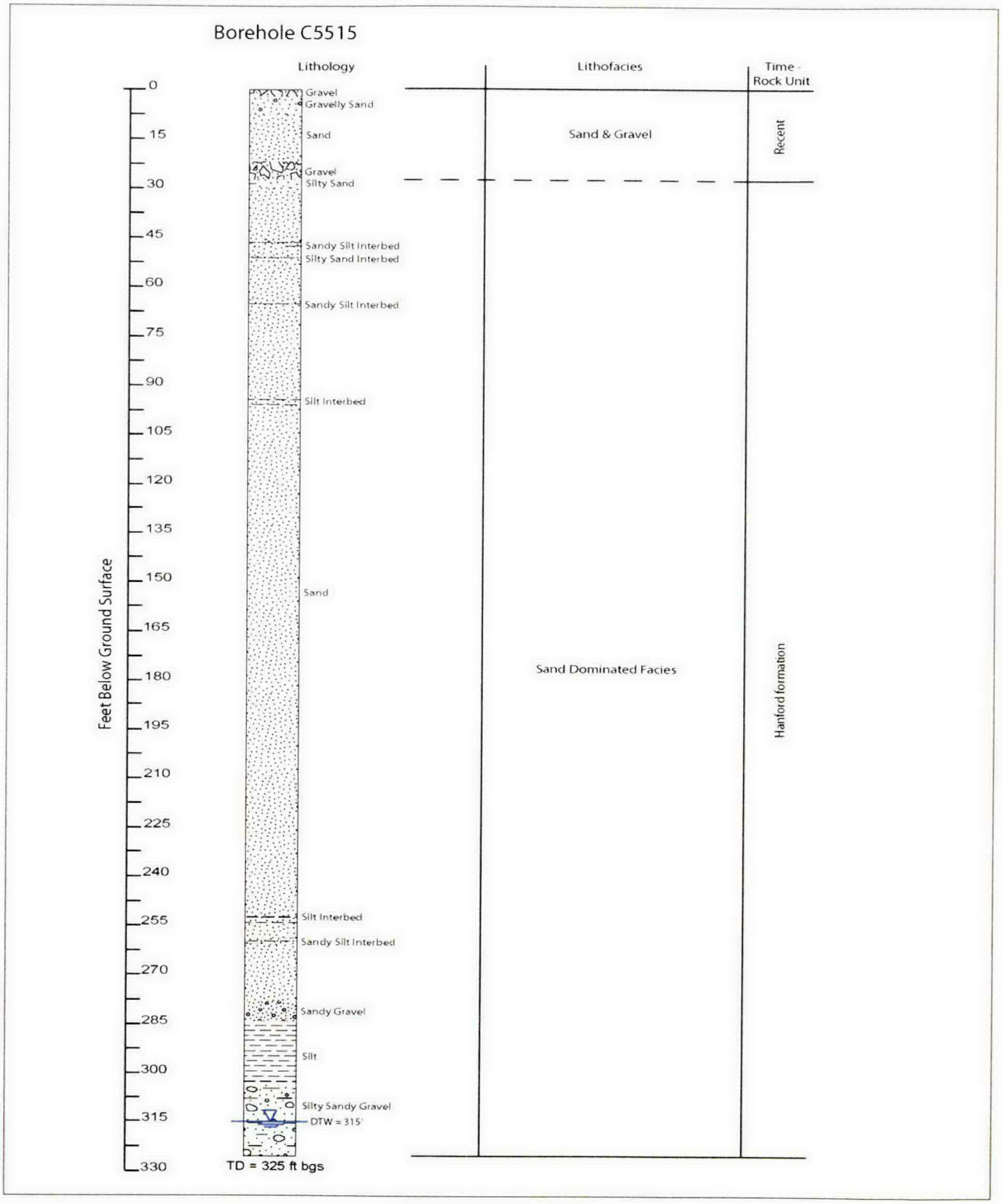
The stratigraphy at the 216-A-4 Crib (Figure 3-4) is based on geologic descriptions of wells 299-E24-54, 299-E24-23 (C5301), borehole C4560, and the stratigraphy described in PNNL-12261. Well 299-E24-23 (C5301) was drilled to approximately 14 m (45 ft) below the water table in sediments of the Hanford formation. Groundwater was encountered at a depth of 95.8 m (314.2 ft) bgs. Borehole C4560 was not drilled to groundwater and was terminated within crib fill material at approximately 7.0 m (23.0 ft) bgs because of unexpectedly high levels of field radioactivity encountered within the 216-A-4 Crib.

At the 216-A-21 Crib, direct push borehole C5571 was installed through the crib to a depth of 18 m (60 ft) bgs. One split-spoon sediment sample was collected at the total depth of the borehole, and consisted of sand and silty sand of the Hanford formation. Groundwater was not encountered because of the relatively shallow depth of the borehole.

At the 200-E-102 Trench, direct push borehole C5302 was installed through the trench to a depth of 17.2 m (56.4 ft) bgs. One split-spoon sediment sample was collected at total depth of the borehole, and consisted of sand and silty sand of the Hanford formation. Groundwater was not encountered because of the relatively shallow depth of the borehole.

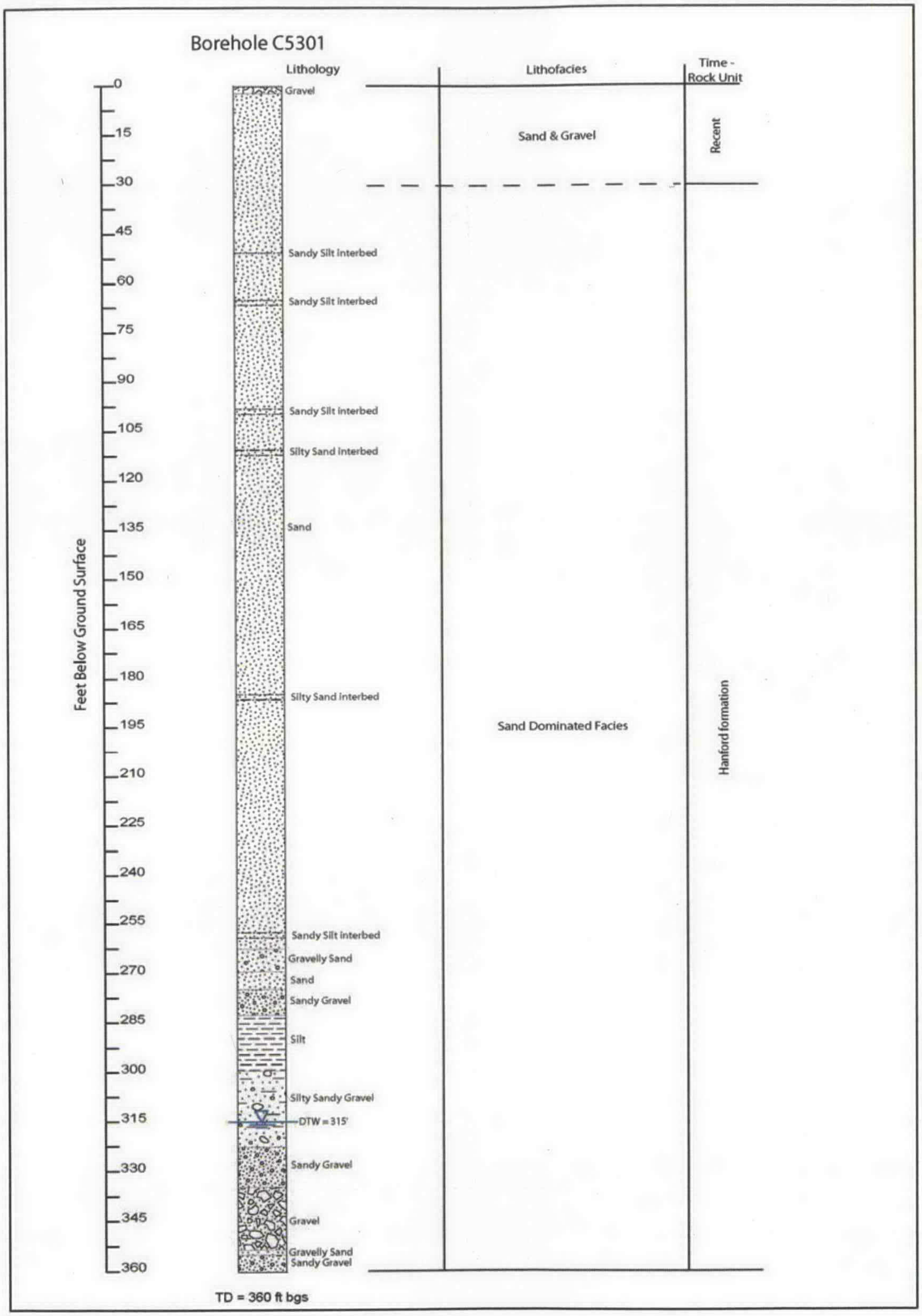
3.5 Soils

In addition to the surficial deposits described in Section 3.4.5, the surficial deposits also include the anthropogenic reworking of surface soil and fill material that was placed in and over the 200-MW-1 OU waste sites during construction, and later as surface cover material. The fill consists of reworked Hanford formation sediments and/or surficial sand and silt.



DTW = depth to water
TD = total depth

Figure 3-3. Stratigraphy in Borehole C5515 at 216-A-2 Crib



DTW = depth to water

TD = total depth

Figure 3-4. Stratigraphy in Borehole C5301 at 216-A-4 Crib

3.6 Hydrogeology

This section describes the hydrogeologic framework in the 200-MW-1 OU area south of the PUREX Plant. The information presented in this section consists of site-specific data (e.g., geologic logs, soil sampling results) collected during recent investigations and existing information derived from 200 Area reports (e.g., DOE/RL-2006-77; the Implementation Plan [DOE/RL-98-28]; and the Work Plan [DOE/RL-2001-65]). Additional information on the hydrogeologic setting of the OU can be found in the Implementation Plan, the Work Plan, PNNL-15955, and other documents cited in the text.

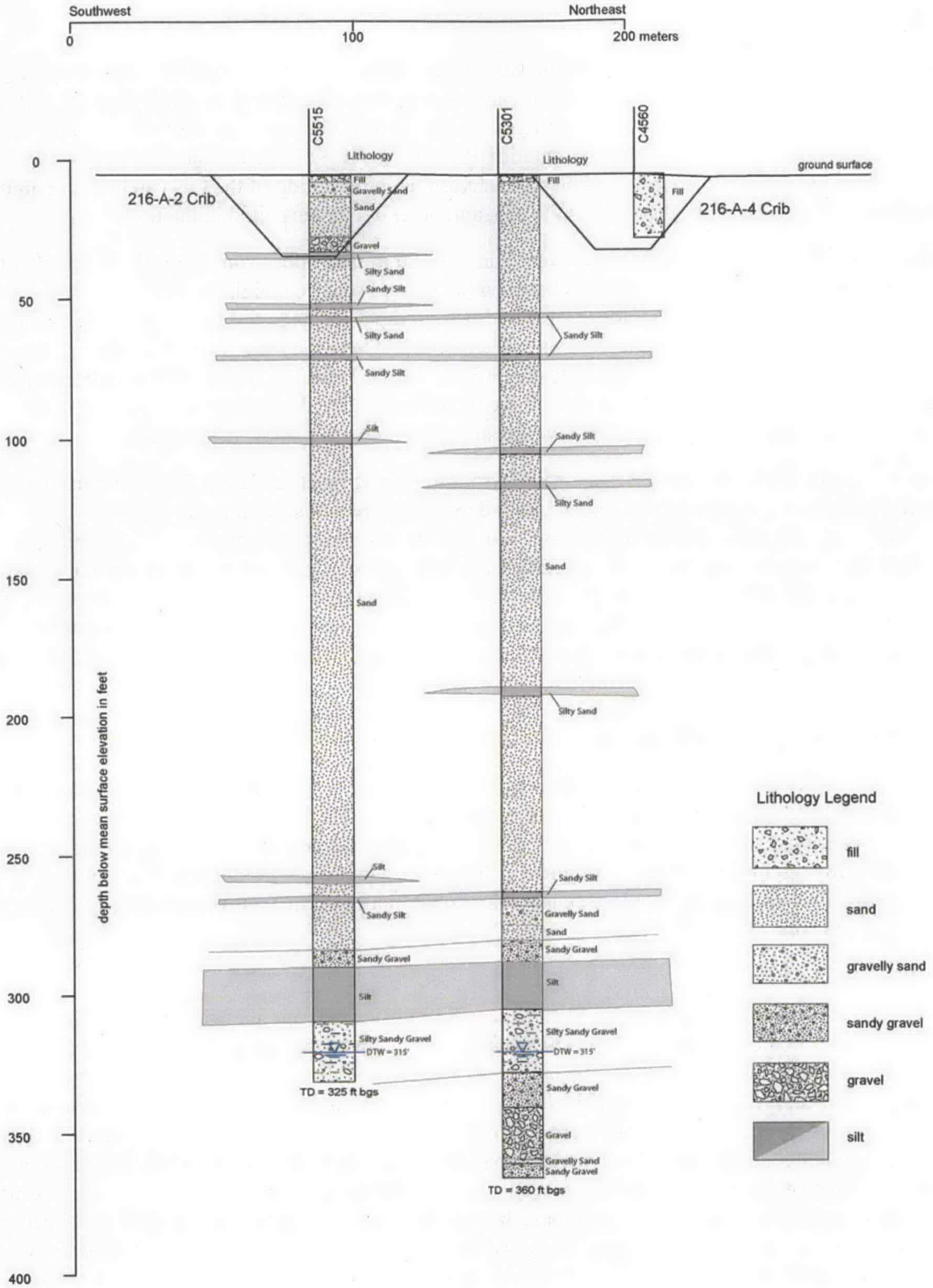
The focus of the RI is on the distribution of contaminants within the vadose zone beneath the four waste sites. The vadose zone is defined as the area between the ground surface and the water table and is approximately 96 m (315 ft) thick. Vadose zone hydrostratigraphic units in the 200-MW-1 OU include the Hanford formation and surficial deposits (see Figure 3-2). Where they occur, the Ringold Formation sediments form the majority of the permeable unconfined aquifer beneath saturated Hanford formation sediments. The base of the unconfined aquifer is the top of basalt (Elephant Mountain Member) throughout much of the 200 East Area where waste sites belonging to the OU are located.

The geologic framework that comprises the vadose zone and uppermost unconfined aquifer beneath the cribs is predominantly unconsolidated, horizontally deposited layers of silt, sand, and gravel. Conceptually, liquid waste disposed to the cribs would move downward, relatively vertically through these relatively permeable sediments. Reduced vertical flow and increased lateral spreading would most likely occur as the layer boundaries are encountered. Fine-grained layers that have reduced permeability will create slower flow conditions for liquids and can cause increased lateral spreading and localized perching. An example of a potential perching layer is the thick silt layer approximately 85 m (280 ft) bgs (Figure 3-5). This thick silt layer is encountered in several of the deep wells and appears fairly continuous beneath the area. The top of this silt unit may create a large area of lateral spreading, potentially creating a mixing interval for liquid waste disposed from other nearby sources.

Small volumes of liquid waste could be completely contained within the thick sequence of vadose zone sediment, thus taking many years to migrate to the water table. Liquid waste that does make it to the water table (uppermost aquifer) would mix with the existing groundwater migrating beneath the site and move laterally downgradient within the saturated sediments. Changes in hydraulic head within the saturated sediments or variations in waste density also could induce vertical movement of the liquid waste within the groundwater.

3.6.1 Vadose Zone

The vadose zone is the unsaturated interval between the ground surface and the water table. The sediments within the vadose zone function as a transport pathway for liquids (i.e., water and related soluble and insoluble materials) between the land surface and the underlying uppermost aquifer. The vadose zone is approximately 96 m (315 ft) thick in the southern section of the 200 East Area near the four waste sites south of the PUREX Plant, and thins to as little as 0.3 m (1 ft) to the north near the West Lake. Sediments in the vadose zone are dominated by the Hanford formation, although the Cold Creek unit and part of the Ringold Formation occur above the water table in the 200 West Area. Because erosion during cataclysmic flooding removed much of the Ringold Formation north of the central part of the 200 East Area, the vadose zone is predominantly comprised of Hanford formation sediments between this area and Gable Mountain to the north. Basalt projects above the water table north of the 200 Areas.



DTW = depth to water
TD = total depth

Figure 3-5. Borehole Hydrostratigraphy in the Vicinity of the 216-A-2 Crib and the 216-A-4 Crib

Figure 3-5 shows the vadose zone lithology encountered beneath the 216-A-2 and 216-A-4 Cribs. Based primarily on borehole geologic and geophysical log interpretations for the two deep boreholes (C5515 and C5301), the lithology beneath the cribs consists of Hanford formation sand extending to a depth of about 84 m (275 ft) bgs. Thin sandy silt and silty sand interbeds are found within this sand interval, with several continuous interbeds traceable between boreholes. These include silty layers located about 17 m (55 ft) bgs, 20 m (67 ft) bgs, 30 m (100 ft) bgs, and 79 m (260 ft) bgs. Sandy gravel of the Hanford formation is encountered at 84 m (275 ft) bgs, and a 3 to 4 m (15 to 20 ft) thick silt unit is encountered at about 86 m (282 ft) bgs. Sediments beneath the silt unit (to the water table encountered 5 to 6 m [15 to 20 ft] beneath the silt) consist of sandy gravels and Hanford formation gravels.

SGW-44795 discusses the issue of whether the thick silt unit at 86 m (282 ft) bgs was ever within the water table, particularly during the time of greatest disposal to waste sites south of the PUREX Plant (i.e., mid-1950s to mid-1960s). Based on limited hydrograph data available for wells in the area, the conclusion is that the silt unit was too shallow to have ever been within the water table, and that contamination found in and directly above the silt unit (see Chapter Four) is more likely related to vertical infiltration of fluids through the vadose zone and horizontal spreading within and above the thick silt layer.

A number of sediment samples were collected from boreholes at the 216-A-2 Crib, 216-A-4 Crib, 216-A-21 Crib, and 200-E-102 Trench to determine moisture content and bulk density.

At the 216-A-2 Crib, moisture content (by weight) was determined for 128 samples (spaced approximately every 0.8 m [2.5 ft] of vertical depth) in the vadose zone. Moisture content for these samples was within the following ranges (depths indicated are the top and bottom depths of the sampled intervals, which are not necessarily coincidental with the top and bottom depths of the sampled stratigraphic unit):

- Crib fill gravel and backfill (4.7 to 7.6 m [15.5 to 25.0 ft] bgs): 3.0 to 7.6 percent
- Hanford formation sand and silty sand (8.8 to 86.1 m [29.0 to 282.5 ft] bgs): 2.1 to 16.3 percent
- Hanford formation silt unit (86.7 to 92.2 m [284.5 to 302.5 ft] bgs): 15.9 to 23.8 percent
- Hanford formation sandy gravel (92.8 to 96.2 m [304.5 to 315.5 ft] bgs): 2.8 to 6.4 percent

One moisture value calculated for the interval from 21.3 to 21.5 m (70 to 70.5 ft) bgs (Hanford formation sand and silty sand) appears to be an outlier, because there is no identified lithologic or geophysical change across this interval that could account for the relatively high moisture content. This interval, with a moisture content of 16.3 percent, is approximately 10 percent higher than the next highest value of 6.6 percent. If this high value is not considered, the range in moisture content for the thick Hanford formation sand and silty sand interval beneath the 216-A-2 Crib varies from only 2.1 to 6.6 percent. Bulk densities were not calculated for sediments at the 216-A-2 Crib.

At the 216-A-4 Crib, moisture content was determined for 110 samples (spaced approximately every 0.8 m [2.5 ft] of vertical depth) in the vadose zone. Moisture content for these samples was within the following ranges:

- Hanford formation sand and silty sand interval (6.7 to 83.2 m [22.0 to 273.0 ft] bgs): 2.1 to 7.4 percent
- Hanford formation sandy gravel interval (83.7 to 85.5 m [274.5 to 280.5 ft] bgs): 2.31 to 2.62 percent
- Hanford formation silt unit (86.1 to 90.6 m [282.5 to 297.5 ft] bgs): 14.3 to 24.3 percent
- Hanford formation sandy gravel interval (91.3 to 96.0 m [299.5 to 315.0 ft] bgs): 3.12 to 4.7 percent

Dry bulk densities were measured at the following four intervals in the vadose zone at the 216-A-4 Crib:

- Hanford formation sand and silty sand (13.1 to 13.9 m [43.0 to 45.5 ft] bgs): 1.74 grams per cubic centimeter (g/cm^3) (0.061422 ounces per cubic inch [$oz/in.^3$])
- Hanford formation sand and silty sand (37.2 to 37.8 m [122.0 to 124.0 ft] bgs): 1.70 g/cm^3 (0.06001 oz/in.)
- Hanford formation sand/silty sand (79.2 to 79.9 m [260.0 to 262.0 ft] bgs): 1.55 g/cm^3 (0.05471 oz/in.)
- Hanford formation silt (86.3 to 86.9 m [283.0 to 285.0 ft] bgs): 1.72 g/cm^3 (0.060716 oz/in.)

At the 216-A-21 Crib, moisture content was determined for the following four samples in the vadose zone:

- Hanford formation sand and silty sand (6.4 to 6.9 m [21.0 to 22.5 ft] bgs): 12 percent
- Hanford formation sand and silty sand (7.7 to 8.1 m [25.1 to 26.6 ft] bgs): 5.8 percent
- Hanford formation sand and silty sand (11.9 to 12.3 m [39.0 to 40.5 ft] bgs): 2.7 percent
- Hanford formation sand and silty sand (17.7 to 18.3 m [58.2 to 59.9 ft] bgs): 3.45 percent

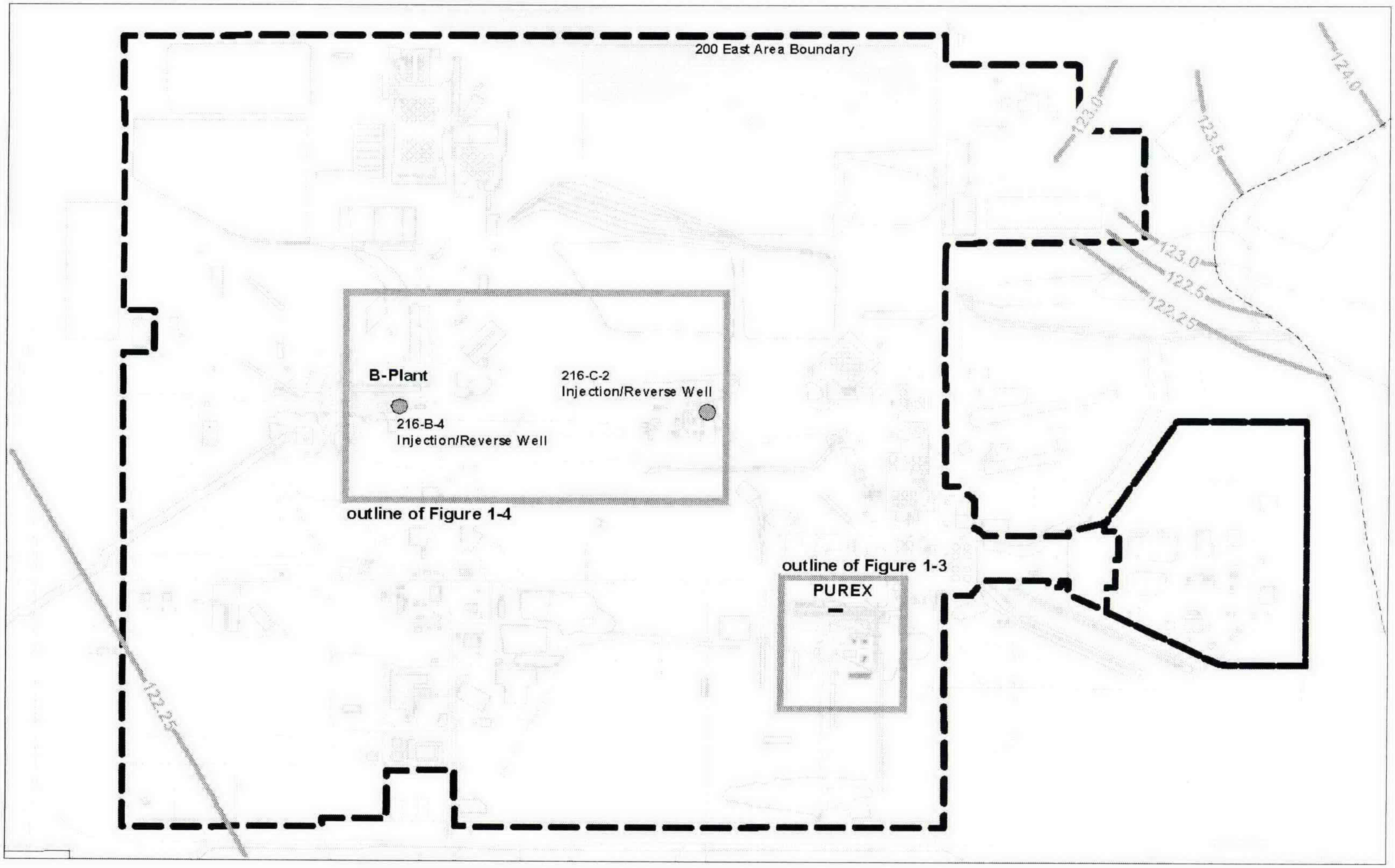
Bulk densities were not determined for these samples.

At the 200-E-102 Trench, moisture content was determined for one sample in the vadose zone, collected at a depth of 16.7 m (55 ft) bgs. The moisture content for this sample, consisting of Hanford formation sand and silty sand, was 5.84 percent. Bulk density was not determined for this sample.

3.6.2 Unconfined Aquifer

The unconfined aquifer in the 200 East Area occurs within the Hanford formation and the underlying Ringold Formation, depending on location. Groundwater in the unconfined aquifer flows from recharge areas where the water table is higher (west of the Hanford Site) to areas where it is lower (near the Columbia River [PNNL-16346, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*]). In the northern half of the 200 East Area, the water table is present within the Hanford formation, except in areas where basalt extends above the water table. Near the B-BX-BY waste management area, the water table occurs within or near a fine-grained sequence of sediments that correlate to the Cold Creek unit. In the central and southwestern sections of the 200 East Area, the water table is located near the contact between the Ringold Formation and the Hanford formation.

Depth to groundwater in and near the 200 East Area ranges from about 54 m (177 ft) near B Pond to about 104 m (340 ft) near the southern portion of the area. The water table across the 200 East Area occurs within the very permeable (highly transmissive) Hanford formation sediments (PNNL-16346), which results in a very flat water table (Figure 3-6), making it difficult to determine current groundwater flow directions based on water-level measurements from monitoring wells. However, based on the configuration of the contaminant plumes mapped in the 200 Area, the direction of groundwater flow is predominantly to the northwest in the northern half of the 200 East Area and to the east/southeast in the southern half of the 200 East Area. Identifying the specific location of the groundwater divide between the northern and southern sections is hampered by the now flat water table and years of past liquid waste disposal to various locations within this area.



Source: PNNL-16346, *Hanford Site Groundwater Monitoring for Fiscal Year 2006.*
PUREX = Plutonium-Uranium Extraction Plant

Figure 3-6. Water Table Contours for the 200-E Area (2006)

When the 200-MW-1 OU liquid waste disposal facilities were operating between 1955 and 1970, localized areas of saturation or near-saturation and an associated rise in the water table (groundwater elevation) were created in the soil column underlying these facilities. After most liquid waste discharges were terminated in the late 1990s, the water table, expressed as an elevated mound, began to decline and flatten; this decline continues today. The most recent calculated rate (PNNL-16346) is about 0.07 m/yr (0.23ft /yr), based on water level measurements collected between March 2005 and April 2006. As expected, this is less than the previous annual decline (0.13 m [0.4 ft]) from March 2004 to March 2005 (PNNL-15670, *Hanford Site Groundwater Monitoring for Fiscal Year 2005*), and is also less than the average rate of decline observed from June 1997 to March 2002 (0.17 m/yr [0.56 ft/yr]) (PNNL-16346). Over time, without the addition of artificial liquid recharge, the water table should resume a very low, west-to-east gradient across the Central Plateau.

Recharge to the unconfined aquifer within the 200 Area in the past has been predominantly from large volume artificial sources and significantly less from natural precipitation. The infiltration from natural sources (rainfall and snow melt) is estimated at 0.004 m/yr (0.16 inches/yr) or 2.4 percent of the average annual precipitation. Infiltration rates are largely dependent on soil texture and the type and density of vegetation. By comparison, PNL-5506, *Hanford Site Water Table Changes 1950 through 1980: Data Observations and Evaluation*, reports that between 1943 and 1980, 6.33×10^{11} L (1.67×10^{11} gal) of liquid wastes were discharged to the soil column in the 200 Areas. Most sources of artificial recharge were terminated in 1995. The artificial recharge that does continue is largely limited to liquid discharges from sanitary sewers, two state-approved land-disposal structures, and 140 small-volume, uncontaminated miscellaneous liquid discharge streams. One of the closest approved land-disposal structures, the Treated Effluent Disposal Facility (a liquid waste disposal facility), is located 3.3 km (2.1 mi) east (and downgradient) of the PUREX 216-A-2 and 216-A-4 Cribs, and receives treated liquid wastes from the 200 East and 200 West Area facilities.

Figure 3-5 shows that the depth to groundwater in the recent characterization boreholes drilled at the 216-A-2 and 216-A-4 Cribs is approximately 96 m (315 ft) bgs. The water table lies within the silty sandy gravel unit of the Hanford formation, approximately 3 to 5 m (10 to 15 ft) below the thick silt unit shown in Figure 3-5, which could create a vertical liquid flow barrier and perching horizon to liquids infiltrating downward beneath the waste sites. This silt horizon, located deep in the lower vadose zone, could have been saturated during high water table conditions created during peak liquid waste disposal periods, but water level measurement records for this area are not available to validate the time and elevation of the highest water table elevation. The lateral extent of this silt unit, while locally continuous beneath the PUREX cribs, has not been mapped outside of the area. Evidence from wells located to the east and west of the PUREX cribs area suggests that the silt unit was never below the top of the saturated zone.

3.7 Water Use

Groundwater beneath the 200 Areas is not currently used, and the level of contaminants present in groundwater precludes its use as a drinking water source for the foreseeable future (DOE/EIS-0222-F). All drinking water for the 200 Areas is supplied by DOE from a treatment plant that draws water from the Columbia River. Based on the risk framework workshops (HAB, 2002), groundwater use inside and outside the industrial (exclusive) use area has been restricted until remediation efforts achieve groundwater cleanup standards. Once the restoration effort is complete (not expected before the year 2150), it is anticipated that unrestricted groundwater use outside the core zone boundary could be allowed. However, long-term groundwater use restrictions inside the industrial (exclusive) use area will likely remain because portions of this area are expected to remain waste management areas for the foreseeable future. The PUREX facility and its immediate surrounding area, which includes many of the 200-MW-1 OU waste sites, will likely reside within the industrial (exclusive) area.

3.8 Ecology

The flora and fauna and species of concern are described in the following subsections.

3.8.1 Vegetation

The dominant plants on the 200 Areas Plateau are big sagebrush, rabbitbrush, cheatgrass, and Sandberg's bluegrass. PNNL-6415 reports that the undisturbed portions of the 200 Areas are characterized by sagebrush/cheatgrass or sagebrush/Sandberg's bluegrass communities. Of the vegetation types found on the Hanford Site adjacent to the 200-MW-1 OU, those with a shrub component (that is, big sagebrush, threetip sagebrush [*Artemisia tripartita*], bitterbrush [*Purshia tridentata*], gray rabbitbrush [*Ericameria nauseousa* previously *Chrysothamnus nauseosus*], green rabbitbrush [*Chrysothamnus viscidiflorus*], black greasewood [*Sarcobatus vermiculatus*], winterfat [*Krascheninnikovia (Ceratoides) lanata*], snow buckwheat [*Eriogonum niveum*], and spiny hopsage [*Grayia (Atriplex) spinosa*]) are considered shrub-steppe. These stands typically have an understory dominated by bunchgrasses, such as bluebunch wheatgrass (*Pseudoroegnaria spicata* previously *Agropyron spicatum*), Sandberg's bluegrass (*Poa sandbergii [secunda]*), needle-and-thread grass (*Hesperostipa comata* previously *Stipa comata*), Indian ricegrass (*Achnatherum hymenoides* previously *Oryzopsis hymenoides*), bottlebrush squirreltail (*Elymus elymoides* previously *Sitanion hysterix*), and prairie junegrass (*Koeleria cristata*), as well as a number of broad-leaf forbs. Heavily grazed or disturbed areas on the Hanford Site often have an understory dominated by cheatgrass.

Disturbance and active management have either completely denuded or significantly reduced the species more typical of undisturbed sites in the 200 Areas at each of the waste sites in the 200-MW-1 OU.

3.8.2 Wildlife

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

The largest mammal potentially frequenting the 200-MW-1 OU is the mule deer. Mule deer collect around the 200 Areas, away from the river, and constitute a grouping named the Central Population. The Rattlesnake Hills herd of elk inhabiting the Hanford Site primarily occupies the Fitzner-Eberhardt Arid Lands Ecology Reserve and private lands adjoining the reserve to the south and west. They are seen occasionally on the 200 Areas Plateau.

Common upland game bird species in shrub and grassland habitat include chukar (*Alectoris chukar*), partridge (*Perdixperdix*), California quail (*Callipepla californica*), and ring-necked pheasant (*Phasianus colchicus*). Chukars are most numerous in the Rattlesnake Hills, Yakima Ridge, Umtanum Ridge, Saddle Mountains, and Gable Mountain areas of the Hanford Site. Less common species include greater sage grouse (*Centrocercu urophasianus*), and scaled quail (*Callipepla squamata*). Greater sage grouse historically were abundant on the Hanford Site; however, populations have declined since the early 1800s.

Among the more common raptor species to use shrub and grassland habitat are the ferruginous hawk (*Buteor egalis*), Swainson's hawk (*B. swainsoni*), and red-tailed hawk (*B. jamaicensis)*. Northern harriers (*Circus cyaneus)*, sharp-shinned hawks (*Accipiter striatus)*, rough-legged hawks (*B. lagopus)*, and golden eagles (*Aquila chrysaetos*) also occur in this habitat, although infrequently.

The side-blotched lizard (*Uta stansburiana*) is the most abundant reptile species occurring on the Hanford Site. Short-horned (*Phrynosoma douglassii*) and sagebrush (*Sceloporus graciosus*) lizards are found on the Hanford Site but occur infrequently. The most common snake species include gopher snake (*Pituophis melanoleucus*), yellow-bellied racer (*Coluber constrictor*), and western rattlesnake (*Crotalus viridis*).

Many species of insects occur throughout the Hanford Site. Butterflies, grasshoppers, and darkling beetles are among the most conspicuous of the approximately 1,500 species of insects identified from specimens collected on the Hanford Site. The actual number of insect species occurring on the Hanford Site may reach as high as 15,500 (PNNL-6415).

3.8.3 Species of Concern

The Hanford Site is home to a number of species of concern, but many of these are associated with the Columbia River and its shoreline, or to steel transmission line towers. No federal- or state-listed endangered or threatened mammals, reptiles, amphibians, or invertebrates are on the Hanford Site. However, three species of fish, five species of birds, and eleven species of plants are listed as threatened or endangered by either the state or the federal government outside of the waste site areas (PNNL-6415).

4 Nature and Extent of Contamination

This chapter evaluates laboratory analysis results from testing of surface and subsurface soil samples at the 200-MW-1 OU waste sites. The primary objective for the evaluation is to refine and update the conceptual site model (CSM) for each of the seven 200-MW-1 OU waste sites. The CSMs illustrate what is known about the waste site while providing a meaningful description of the most probable site conditions and possible variations in those conditions. The CSMs are used in the RI/FS process to define the area and volume of contaminated soil present at each waste site and to aid in the development and evaluation of remedial action alternatives to address the hazards posed to HHE.

The 200-MW-1 OU RI included the drilling of seven new boreholes (Figure 4-1), geophysical logging of selected boreholes (Table 4-1), and laboratory analysis of split-spoon soil and opportunistic grab samples collected at multiple depths at selected boreholes. One borehole (C5515) at the 216-A-2 Crib and a second borehole C5301 (currently Monitoring Well 299-E21-23 at the 216-A-4 Crib) were advanced to depths of 99.1 m (325 ft) and 109.7 m (360 ft) bgs, respectively, or 3.1 m (10 ft) to 13.7 m (45 ft) below the water table. The five remaining boreholes (C5570, C4560, C4671, C5302, and C5571) were advanced to depths of 18.3 m (60 ft) bgs or less. A total of 67 split-spoon samples were collected. This included 37 primary samples, seven duplicate/split samples, and 23 QC samples. A total of 327 opportunistic grab samples were also taken. Appendix A contains analytical data for those samples used to support this document. Specific details of the sampling activity including sample disposition criteria are included in the respective borehole summary reports (SGW-35574, *Borehole Summary Report for 200-MW-1 Operable Unit Boreholes C5515, C5570, and C5571 Drilled in the 216-A-2 and 216-A-21 Cribs*, and SGW-33959, *Borehole Summary Report for Well 299-E24-23 (Borehole C5301) and Borehole C5302 Drilled in the Vicinity of the 216-A-4 Crib and the 216-E-102 Trench*).

The RI included testing for VOCs, SVOCs, PCBs, metals, radionuclides, general chemistry parameters, and physical properties. The laboratory analysis results were validated to ensure that the DQOs were met. Following the data validation step, the results were uploaded into the Hanford Environmental Information System (HEIS) database, and summary tables were prepared for the 200-MW-1 OU waste sites. The laboratory analysis results are tabulated in Appendix A.

The borehole geophysical logging performed by S. M. Stoller Corporation (Stoller) included an SGLS, HRLS, NMLS, and PNLS. The SGLS detects the presence of process uranium, Cs-137, americium, cobalt, europium, and several other radionuclides. The HRLS is used to log zones with extremely high radioactivity. The NMLS qualitatively detects changes in moisture content, while the PNLS is a qualitative tool designed to screen for the presence of plutonium. The borehole geophysical logs are provided in Appendix B.

4.1 Background Concentrations

Some chemical and radionuclide compounds (constituents) occur naturally in environmental media; therefore, the presence of these constituents may not necessarily indicate a hazardous substance release. EPA 540-R-01-003, *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites*, OSWER 9285.7-41, defines background constituents as:

- Anthropogenic – natural and human-made substances present in the environment as a result of human activities (that is, their presence at the site is not specifically related to the CERCLA release in question).
- Naturally occurring – substances present in the environment in forms that have not been influenced by human activity.

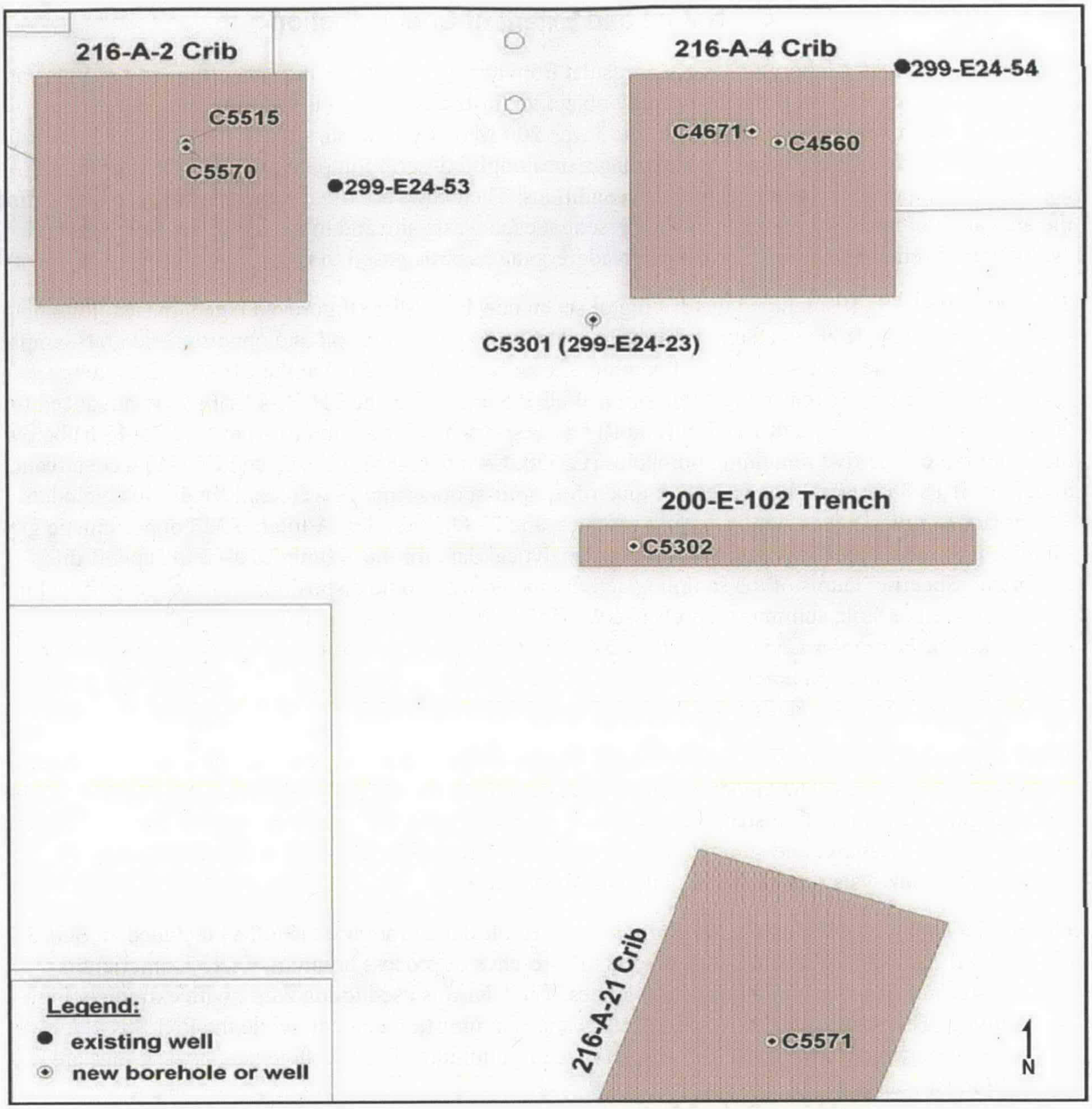


Figure 4-1. 200-MW-1 OU Remedial Investigation New Borehole Location Map

Background concentrations for chemical compounds in soil at the Hanford Site are described in DOE/RL-92-24, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*, Summary Table 2. Background concentrations for radionuclide compounds in soil are described in DOE/RL-96-12, *Hanford Site Background: Part 2, Soil Background for Radionuclides*, Table 5-1. The background concentrations presented in these documents were compared to the 200-MW-1 OU laboratory analysis results to help assess the significance of a contaminant concentration. The background concentrations, more specifically in the BRA, are recommended for use on environmental restoration projects at the Hanford Site to maintain consistency. They have also been peer reviewed for technical credibility. No background sampling was conducted under the 200-MW-1 OU RI.

Table 4-1. Remedial Investigation Summary for the 200-MW-1 OU

New Borehole Name:	**C5515**	**C5570**			**C5301 (299-E24-23)**	**C4560 and C4671**	**C5571**	**C5302**
Existing Borehole Name:			**A5910 (299-E24-53)**	**A5911 (299-E24-54)**				
Location:	216-A-2 Crib (within Crib)	216-A-2 Crib (within Crib)	216-A-2 Crib (outside Crib)15 m to east	216-A-4 Crib (outside Crib)-0.5 m from NE corner	216-A-4 Crib (outside Crib) 2.5 m SW of crib	216-A-4 Crib (within Crib)	216-A-21 Crib (within Crib)	200-E-102 Trench (inside the western third of trench)
Date Installed:	July 2007	May 2007	January 1955	January 1955	January 2007	August 2004	July 2007	October 2006
Total Depth:	98.1 m (322 ft)	10.7 m (35 ft)	15.8 m (52 ft)	31.1 m (102 ft)	108.2 m (355 ft)	C4560 (7 m [23 ft]); C4671 (18.3 m [60 ft])	18.3 m (60 ft)	16.8 m (55 ft)
Depth to Groundwater:	95.7 m (314 ft)	NA	NA	NA	95.7 m (314 ft)	Not available	Not available	Not available
Date of Geophysical Logging:	July and August 2007	May 2007	October 2005	April and October 2005	December 2006 and January 2007	September 2004	August 2007	October 2006
Primary Radionuclides Detected:	Cs-137 from 5.5 to 26.2 m (18 to 86 ft)	Cs-137 from 5.6 m (18.5 ft) to total borehole depth (10.5 m [34.5 ft])	Cs-137 from 8.8 m (29 ft)-total depth (~15.8 m [52 ft]); Co-60 at 9.6 m (31.5 ft) and 11.1–14.8 m (36.5-48.5 ft); Eu-154 at 9.6 m (31.5 ft) and 11.1–12.3 m (36.5-40.5 ft)	Cs-137 from 8.8–11 m (29-36 ft) and 19.5–27.7 m (64-91 ft); Co-60 between 8.8–16 m (29-54 ft) and 19.8–21 m (65-69 ft)	Cs-137 from ground surface to 7 m (23 ft) bgs and 14–23.2 m (46-76 ft) bgs	C4560 was not logged before abandonment. Cs-137 from ground surface to total logged depth (~17.7 m [58 ft]) bgs for C4671	Cs-137 from ground surface to total logged depth (~18 m [59 ft]) bgs	Cs-137 from 11–12.8 m (36-42 ft bgs); Eu-154 from 14.6 m (48 ft) bgs to total logged depth (~54 ft) bgs
Crib Bottom Depth:	8.5 m (28 ft) bgs	8.5 m (28 ft) bgs	8.5 m (28 ft) bgs	7.6 m (25 ft) bgs	7.6 m (25 ft) bgs	7.6 m (25 ft) bgs	5.9 m (19.33 ft) bgs	1.2 m (4 ft) bgs
Peak Activity:	2×10^6 pCi/g at 8.4 m (27.5 ft) bgs; near bottom where gravel sits on native soil	2×10^7 pCi/g at 8.5 m (27.5 ft) bgs; near bottom where gravel sits on native soil	4600 pCi/g at 10.2 m (33.5 ft) bgs (Cs-137); 4 pCi/g at 11.1 m (36.5 ft) bgs (Co-60); 6 pCi/g at 11.1 m (36.5 ft) bgs (Eu-154); 1.7 m (5.5 ft) below crib bottom	55 pCi/g at 20 m (65.5 ft) bgs (Cs-137); 2 pCi/g at 13.9 m (45.5 ft) bgs (Co-60); 9.3 m (30.5 ft) below crib bottom	15 pCi/g at 14.9 m (49 ft) bgs; 7.6 m (25 ft) below crib bottom	2.36×10^8 pCi/g at 6.1 m (20 ft) bgs for C4671; 0.6 m (2 ft) below distribution pipes and 1.5 m (5 ft) above crib bottom	1.3×10^6 pCi/g at 6.4 m (21 ft) bgs; 0.6 m (2 ft) below crib bottom in native soil	112 pCi/g at 11.6 m (38 ft) bgs (Cs-137); 3 pCi/g at 16 m (52.5 ft) bgs (Eu-154)
Notes:	Casing was contaminated and suspected to carry contaminants to greater depth					Casing was contaminated	Casing was contaminated	

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The approach used to define background concentrations, and to compare these values with the 200-MW-1 OU laboratory analysis results, is summarized below. Background concentration values are presented in Table 4-2.

4.1.1 Approach and Comparison with 200-MW-1 Results

Three types of sampling were conducted at the Hanford Site to define background concentrations. Systematic random sampling and judgmental sampling were conducted for inorganic chemicals and naturally occurring radionuclides. Surface sampling was conducted for anthropogenic radionuclides. The composition of the background samples described in DOE/RL-92-24 and DOE/RL-96-12 is representative of the sedimentary facies in the vadose zone at the 200-CS-1 OU sites.

DOE/RL-92-24 recommends using the systematic random-sampling results as the primary data set for inorganic chemical background comparisons. If the chemical does not have sufficient systematic random-sampling background data (or is not different from random-sampling background results), then the judgmental sampling data should be used. For naturally occurring radionuclides, the systematic random-sampling background data are recommended as the primary data set. For anthropogenic radionuclides, the surface-sampling background data are recommended as the primary data set. Some inorganics and radionuclides did not have reported lognormal 90th percentile background values in DOE/RL-92-24, Table 2, or DOE/RL-96-12, Table 5-1. In these cases, other sources were researched. In addition to the DOE reports, background information also was obtained from Ecology Publication 94-115, *Natural Background Soil Metals Concentrations in Washington State*.

Background values and data sources used for the background comparison step are shown in Table 4-2. Table 4-2 also includes other distributional parameters for the systematic random-sampling data set. The lognormal 90th percentile was used first to compare to the maximum detected concentration in each sample. If the maximum concentration was greater than the lognormal 90^{th} percentile background value, the constituent was retained for further evaluation.

A background value for uranium as an inorganic compound (not a radionuclide) is not provided in DOE/RL-92-24. The background value for inorganic uranium, used for comparison purposes, was derived by dividing the lognormal 90th percentile background activity levels for U-234, U-235, and U-238 by the specific activity for each isotope, converting those values from picocuries per gram to milligrams per kilogram, and then summing the calculated values for each isotope to arrive at a total background value (Hoover, 2007, "RE: Background Value Question").

Background concentration values for inorganic chemicals or radionuclides that do not have background values reported in DOE/RL-92-24, DOE/RL-96-12, or other described sources are also identified in Table 4-2. Background concentrations have not been developed for organic chemicals in Hanford Site soils.

Constituents with maximum concentrations less than their respective 90^{th} percentile background value are interpreted as not indicating the presence of a hazardous substance release. Constituents with detected concentrations greater than the 90^{th} percentile background value may indicate the presence of a hazardous substance release.

Table 4-2. Hanford Site-Specific Background Concentrations

Constituent (CAS No.)	Units	Lognormal 90th Percentile Value	90% UCL	Lognormal 95th Percentile Value	Source of Background Values
			Metals		
Aluminum (7429-90-5)	mg/kg	11,800	13,000	13,300	DOE/RL-92-24, V.1, Rev.4
Antimony (7440-36-0)	mg/kg	5	Not available	Not available	Statewide Conc.; WA Pub. #94-115; Oct. 2004
Arsenic (7440-38-2)	mg/kg	6.47	7.38	7.65	DOE/RL-92-24, V.1, Rev.4
Barium (7440-39-3)	mg/kg	132	144	148	DOE/RL-92-24, V.1, Rev.4
Beryllium (7440-41-7)	mg/kg	1.51	1.62	1.65	DOE/RL-92-24, V.1, Rev.4
Cadmium (7440-43-9)	mg/kg	1	~	~	Statewide Conc.; WA Pub. #94-115; Oct. 2004
Calcium (7440-70-2)	mg/kg	17,200	19,700	20,400	DOE/RL-92-24, V.1, Rev.4
Chromium (7440-47-3)	mg/kg	18.5	21.4	22.3	DOE/RL-92-24, V.1, Rev.4
Cobalt (7440-48-4)	mg/kg	15.7	16.9	17.3	DOE/RL-92-24, V.1, Rev.4
Copper (7440-50-8)	mg/kg	22	24.1	24.7	DOE/RL-92-24, V.1, Rev.4
Iron (7439-89-6)	mg/kg	32,600	35,000	35,600	DOE/RL-92-24, V.1, Rev.4
Lead (7439-92-1)	mg/kg	10.2	11.7	12.2	DOE/RL-92-24, V.1, Rev.4
Magnesium (7439-95-4)	mg/kg	7,060	7,620	7,780	DOE/RL-92-24, V.1, Rev.4
Manganese (7439-96-5)	mg/kg	512	550	561	DOE/RL-92-24, V.1, Rev.4
Mercury (7439-97-6)	mg/kg	0.33	0.6	0.7	DOE/RL-92-24, V.1, Rev.4
Molybdenum	mg/kg	2.8-6	~	~	Judgmental samples, DOE/RL-92-24
Nickel (7440-02-0)	mg/kg	19.1	21	21.6	DOE/RL-92-24, V.1, Rev.4
Potassium (7440-09-7)	mg/kg	2150	2440	2520	DOE/RL-92-24, V.1, Rev.4
Silver (7440-22-4)	mg/kg	0.73	1.33	1.52	DOE/RL-92-24, V.1, Rev.4
Sodium (7440-23-5)	mg/kg	690	878	937	DOE/RL-92-24, V.1, Rev.4
Uranium (7440-61-1)	mg/kg	3.21	~	~	Isotopic Activity Conversion based on DOE/RL-96-12 values
Vanadium (7440-62-2)	mg/kg	85.1	93.9	96.4	DOE/RL-92-24, V.1, Rev.4
Zinc (7440-66-6)	mg/kg	67.8	72.1	73.3	DOE/RL-92-24, V.1, Rev.4

Table 4-2. Hanford Site-Specific Background Concentrations

Constituent (CAS No.)	Units	Lognormal 90th Percentile Value	90% UCL	Lognormal 95th Percentile Value	Source of Background Values
Radionuclides					
Americium-241	pCi/g	ND	ND	ND	
Cesium-137 (10045-97-3)	pCi/g	1.05	~	1.51	DOE/RL-96-12, Rev.0
Cobalt-60 (10198-40-0)	pCi/g	0.00842	~	0.0104	DOE/RL-96-12, Rev.0
Europium-152	pCi/g	ND	ND	ND	
Europium-154 (15585-10-1)	pCi/g	0.0334	~	0.0427	DOE/RL-96-12, Rev.0
Europium-155 (14391-16-3)	pCi/g	0.05	~	0.0723	DOE/RL-96-12, Rev.0
Gross beta (12587-47-2)	pCi/g	22.96	~	24.07	DOE/RL-96-12, Rev.0
Nickel-63	pCi/g	ND	ND	ND	
Plutonium-238 (13981-16-3)	pCi/g	0.00378	~	0.0648	DOE/RL-96-12, Rev.0
Plutonium-239/240 (Pu-239/240)	pCi/g	0.0248	~	0.0366	DOE/RL-96-12, Rev.0
Potassium-40 (13966-00-2)	pCi/g	16.6	~	17.9	DOE/RL-96-12, Rev.0
Radium-226 (13982-63-3)	pCi/g	0.815	~	0.928	DOE/RL-96-12, Rev.0
Radium-228 (15262-20-1)	pCi/g	1.32	~	1.47	DOE/RL-96-12, Rev.0
Strontium-90 (10098-97-2)	pCi/g	0.178	~	0.247	DOE/RL-96-12, Rev.0
Technetium-99	pCi/g	ND	ND	ND	
Thorium-228 (14274-82-9)	pCi/g	1.32	~	1.47	DOE/RL-96-12, Rev.0
Thorium-230 (14269-63-7)	pCi/g	1.1	~	1.23	DOE/RL-96-12, Rev.0
Thorium-232 (TH-232)	pCi/g	1.32	~	1.47	DOE/RL-96-12, Rev.0
Total beta radiostrontium (SR-RAD)	pCi/g	0.178	~	0.247	DOE/RL-96-12, Rev.0
Tritium	pCi/g	ND	ND	ND	
Uranium-233/234 (U-233/234)	pCi/g	1.1	~	1.23	DOE/RL-96-12, Rev.0
Uranium-234 (13966-29-5)	pCi/g	1.1	~	1.23	DOE/RL-96-12, Rev.0
Uranium-235 (15117-96-1)	pCi/g	0.109	~	0.153	DOE/RL-96-12, Rev.0
Uranium-238 (U-238)	pCi/g	1.06	~	1.18	DOE/RL-96-12, Rev.0

Table 4-2. Hanford Site-Specific Background Concentrations

Constituent (CAS No.)	Units	Lognormal 90th Percentile Value	90% UCL	Lognormal 95th Percentile Value	Source of Background Values
General Chemistry					
Ammonia (7664-41-7)	mg/kg	9.23	15.1	17.3	DOE/RL-92-24, V.1, Rev.4
Chloride (16887-00-6)	mg/kg	100	182	214	DOE/RL-92-24, V.1, Rev.4
Fluoride (16984-48-8)	mg/kg	2.81	3.7	3.98	DOE/RL-92-24, V.1, Rev.4
Nitrate (14797-55-8)	mg/kg	52	93.4	110	DOE/RL-92-24, V.1, Rev.4
Phosphate (14265-44-2)	mg/kg	0.785	2.87	4.08	DOE/RL-92-24, V.1, Rev.4
Sulfate (14808-79-8)	mg/kg	237	469	566	DOE/RL-92-24, V.1, Rev.4

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.*

UCL = upper confidence limit

ND = not determined

~ = not established

4.2 Contaminant Distribution in Soil at the 200-MW-1 Characterized Waste Sites

The distribution of contaminants in subsurface soil at the 200-MW-1 OU crib sites resulted from the discharge of liquid effluent between 1955 and 1970. Key factors that affected how contaminants were distributed within the crib gravel and underlying soil column included the total effluent discharge volume and instantaneous discharge rate, the form of contaminants present in the effluent discharged to the crib, and the contaminant's affinity for sorption to soil particles.

The total volume of liquid discharged to the cribs ranged from 230,000 L (61,000 gal) at the 216-A-2 Crib to 230 million L (61 million gal) at the 216-A-27 Crib. Instantaneous discharge rates varied depending on whether the crib received effluent from a continuous generating process or a batch process. Water entering the crib exited the pipe at the first available perforations and flowed down to the crib floor before spreading horizontally across the bottom. If the discharge rate to the crib was less than the design infiltration rate, nominally assumed to be 407 L/m^2/day (10 gal/ft^2/day [DOE/RL-98-28]),[3] the effluent would have spread across the bottom, and the liquid level inside the crib would have remained low. Based on the information provided in Table 4-3, it is assumed the discharge rate for each of the 200-MW-1 OU cribs was less than the design infiltration rate; thus, the liquid level would have remained at or near the bottom of the crib unless the crib plugged, such as was the case for the 216-A-4 Crib.

[3] Percolation testing was reportedly done for several cribs with an average design value of 407.2 L/m^2/day (10 gal/ft^2/day), but it is unclear what methods were used to conduct the tests. Engineering documentation on crib design is rare and most likely exists in the specific project documentation for crib construction (DOE/RL-98-28).

Table 4-3. 200-MW-1 OU Reliance Information

Waste Site	Waste Site Configuration, Construction, and Purpose	Current Waste Site Cover/ Vegetation	Site and Discharge History	SIM Inventory (Mean Value)														Effluent Volume (liters)	Notes
				Total U (kg)	Pu (Ci)	Am-241 (Ci)	Cs-137 (Ci)	Sm-151 (Ci)	Te-99 (Ci)	Sr-90 (Ci)	Tritium (Ci)	Sodium (kg)	Phos phate (kg)	Nitrate (kg)	NPH (kg)	K (kg)	TBP (kg)		
200-MW-1 OU Waste Sites																			
216-A-2 Crib	Dates: Jan-1956 to Jan 1963 Crib Dimensions (L x W x D ft): 20 x 20 x 27 Total Perforated Pipe Length (ft): 40 ft. Trapezoid Crib Excavation/Backfill Volume (cubic ft): 5,000	6-inches of crushed rock (1999). Borehole C5515 indicates up to 2 ft of stabilization material	PUREX P1 organic rich waste stream from 202A Blg. Low in salt, neutral to basic.	228	239-7.9 240-1.59 241-6.95	0.18	1.86	27.2	0.026	0.89	0.001	5.97	0	2,370	63.29 0	0	149,160	230,000	
216-A-4 Crib	Dates of Operation: 1955 to 1958 Dimensions (L x W x D ft): 20 x 20 x 27 Total Perforated Pipe Length (ft): 40 ft. Trapezoid Crib Excavation/Backfill Volume (cubic ft): 10,000	6-inches of crushed rock (1999). Borehole C4560 indicates up to 2 ft of stabilization material	PUREX UNH concentrated misc waste stream comprised of laboratory cell drainage from 201A Blg and 291A Stack. Predominantly potassium nitrate.	5,388	239-1.08 240-0.38 241-7.2	0.005	4.86	0.13	0.57	4.14	64.5	447	1,691	95,373	0	75,974	0	6,210,000	
216-A-21 Crib	Dates of Operation: Oct-1957 to June 1965 (out of service for 6 months in 1958 for piping rebuild) Dimensions (L x W x D ft): 20 x 20 x 27 Total Perforated Piping Length (ft): 32 after rebuild V-Shaped Crib Excavation/Backfill Volume (cubic ft): 24,000	6-inches of crushed rock	Sump waste from 293A Blg, laboratory cell drainage from 202A Blg, 291-A1 Stack drainage.	195	239-4.61 240-1.13 241-10	4.61	63.74	0.38	0.008	6.1	49.5	107,488	0	320,298	0	610	0	77,900,000	66,300 kg ammonium
216-A-27 Crib	Dates of Operation: June 1965 to July 1970 Dimensions (L x W x D ft): 200 x 10 x 18.3 Volume: 24,000 cubic ft^3		Sump waste from 293A Blg, laboratory cell drainage from 202A Blg, 291-A1 Stack drainage. Low salt, neutral to basic.	65	239-6.49 240-2.27 241-43.1	0.03	29.35	0.79	0.009	24.8	0.05	1,861	3,502	11,234	0	8,525	0	23,100,000	
E-102 Trench	Dates of Operation:1958 Dimensions (L x W x D ft): 60 x 10 x 4 Volume: 2,400 cubic ft^3	1-ft of clean soil and 6-inch of crushed rock (1999)	Contaminated soil from 216-A-4 Crib overflow.	NA	239-NA 240-NA 241-NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	
216-B-4 Reverse Well	Dates of Operation: April 1945 to Dec 1949 Dimensions (Diameter x D ft): 0.67 x 110 Slotted Interval: 85 to 110 ft bgs		291-B Stack drainage. After Aug 1947 received floor drainage from 292-B Blg. Neutral to basic and low salt with < 1 Ci beta. Possible TRU fission products.	0.0005	239-5.6E-6 240-5.6E-7 241-1.0E-6	1.7E-6	0.01	0.0005	4.9E-6	0.001	1.2E-5	0.08	0.01	0.12	0	0.004	0	10,000	

Table 4-3. 200-MW-1 OU Reliance Information

Waste Site	Waste Site Configuration, Construction, and Purpose	Current Waste Site Cover/ Vegetation	Site and Discharge History	SIM Inventory (Mean Value)														Effluent Volume (liters)	Notes
				Total U (kg)	Pu (Ci)	Am-241 (Ci)	Cs-137 (Ci)	Sm-151 (Ci)	Te-99 (Ci)	Sr-90 (Ci)	Tritium (Ci)	Sodium (kg)	Phos phate (kg)	Nitrate (kg)	NPH (kg)	K (kg)	TBP (kg)		
216-C-2 Reverse Well	Dates of Operation: 1953 to 1988 Dimensions (Diameter x D ft): 1 x 40 Slotted Interval: 15 to 40 ft bgs		291-C Stack drainage and seal water from stack ventilation filters. Low salt, neutral/basic < 1 Ci beta.	0.001	239-0.0001 240-4.1E-5 241-0.0007	0	0.009	0	0	0.08	0	1.29	0	2.86	0.29	0.3	0	3,150,000	
216-A-5 Crib	Dates: Dec 1955 to Nov 1961 Dimensions (L x W x D ft): 35 x 35 x 29 Volume: 35,525 cubic ft^3		202A Big condensate (acid process condensate. After 1961 216-A-10 Crib backup.	198	239-32.59 240-6.55 241-28.8	43	11.81	29.99	0.31	30.33	17.078	16.650	0	1.071.0 70.581	-0	0	0	1.63 billion	

NC = not calculated

The contaminants in the liquid effluent discharged to the crib were present either as dissolved solids or in a particulate form. Dissolved solids were distributed through the crib gravel and underlying soil column by the liquid effluent. Particulate contaminants would tend to settle out from the liquid effluent in proportion to effluent flow velocity changes (Stokes's Law) and, thus, would likely be concentrated near the center of square cribs or at the head end of rectangular cribs.

A contaminant's affinity for sorption (adsorption and absorption) to soil is another important characteristic that affects its distribution in soil. Contaminants can either attach to the surface of a soil particle (absorption) or diffuse into the pore space (adsorption) of individual particles. A contaminant's affinity for sorption is measured by its soil-water distribution coefficient (K_d), which is influenced by the soil pH and mineral content. Contaminants with higher K_d values, such as strontium ($K_d = 22$), cesium (K_d=2000), and plutonium (K_d=600), have a higher affinity for soil and, therefore, would tend to concentrate in soil in proximity to the crib bottom. Because contaminants with low K_d values, such as nitrate (K_d=0), tritium (K_d=0), and Tc-99 (K_d=0) have less affinity for soil, they tend to distribute throughout the soil column within the area wetted by the liquid effluent discharge. This trend is the primary determining factor for evaluating depths of contamination.

4.2.1 216-A-2 Crib

The RI characterization drilling (see borehole log for borehole C5515 in SGW-35574) indicates that the bottom of the crib is 8.2 m (27 ft) bgs, and the top of the crib gravel is 6.4 m (21 ft) bgs. The borehole log also shows 0.31 m (1 ft) of stabilization material at the ground surface. These depths are consistent with the information on drawing H-2-56050, *Underground Rock Cribs 216-A-2 216-A-3 216-A-4 216-A-5*.

4.2.1.1 Primary Sources and Waste Characteristics

The 230,000 L (61,000 gal) of liquid effluent discharged to the 216-A-2 Crib originated from the 202-A Building (PUREX) and was characterized as an organic-rich (PUREX P1 waste stream [RPP-26744]). The monthly operating reports (HW-57649, *Radioactive Contamination in Liquid Wastes Discharged to Ground at Separations Facilities Through June 1958*, Table III) described the waste as "spent organic extraction." The waste stream was low in salt content with a neutral to basic pH (RHO-CD-673). The 216-A-2 Crib was also associated with the 241-A-15 diversion box and the 200-E103 underground radioactive material (URM) area. The pipelines associated with this crib are site code 200-E-183 PL and 200-E-184-PL (WIDS, 2008).

The liquid effluent (Table 4-3) discharged to the crib contained tri-butyl phosphate (TBP), and normal paraffin hydrocarbons (NPH) with potentially no aqueous component. The key constituents present in the effluent and their reported inventory (RPP-26744) included TBP at 149,200 kg (328,900 lb) and NPH at 63,920 kg (140,900 lb). Based on the density of TBP and NPH, the volume of TBP is estimated at 153,400 L (40,500 gal) and 85,200 L (22,500 gal) for NPH, which total 238,600 L (63,000 gal). Thus, the entire effluent volume of 230,000 L (61,000 gal) discharged to the crib is accounted for by the volume of TBP and NPH. Thus the aqueous component of the liquid effluent discharged to this crib is low.

The inorganic compounds with the largest inventory (RPP-26744) discharged to the crib (Table 4-3) included nitrate at 2,370 kg (5,220 lb) and uranium at 228 kg (503 lb). The radionuclides with the largest inventories discharged to the crib included: Sm-151 (27.2 Ci), Pu-239 (7.9 Ci), Pu-241 (6.9 Ci), Cs-137 (1.9 Ci), and Pu-240 (1.6 Ci).

4.2.1.2 Field Investigation Activities

Two boreholes (C5570 and C5515) were drilled at the 216-A-2 Crib to complement an existing borehole (299-E24-53) completed as a vadose zone well in 1955. Shallow borehole C5570 was drilled in May 2007 within the crib's footprint to a depth of 10.7 m (35 ft) bgs. This borehole was then geophysically logged from ground surface to its total depth to improve the sampling design for borehole C5515.

Deep borehole C5515 was drilled in July 2007 through the crib, adjacent to borehole C5570, to a total depth of 98.1 m (322 ft). Groundwater was encountered at a depth of 95.9 m (314.7 ft) bgs. Twelve split-spoon soil samples and one water sample were collected for laboratory analysis. This borehole was geophysically logged from ground surface to its total depth.

4.2.1.3 Borehole Geophysical Logging Summary – Shallow Borehole C5570

Logging was performed in July 2007 and again in August 2007. SGLS and HRLS geophysical logging detected Cs-137 at depths between 5.6 and 10.5 m (18.5 to 34.5 ft) bgs with a peak concentration of approximately 20 million pCi/g observed at a depth of 8.4 m (27.5 ft) bgs, or approximately 15 cm (6 in.) above the crib bottom. The logging report (Appendix B) noted that a majority of the activity was concentrated in an approximately 15 cm (6 in.) thick or less interval. The logging report also indicated that the maximum observed value may be underestimated. This occurs because the instruments are calibrated assuming an infinite, uniform radionuclide distribution, which does not allow for accurate quantification across thin zones of contamination.

4.2.1.4 Borehole Geophysical Logging Summary – Deep Borehole C5515

At deep borehole C5515, geophysical logging was initially performed inside a 25 cm (10 in.) diameter casing to a depth of 25.9 m (85 ft). Cs-137 was detected at depths between 5.5 and 26.2 m (18 to 86 ft) bgs with a peak concentration of about 2 million pCi/g observed (Figure 4-2) at a depth of 8.4 m (27.5 ft) bgs. The maximum observed value also appeared to be confined within a thin interval of about 15 cm (6 in.) located just below the bottom of the crib. The logging report (Appendix B) also noted that Cs-137 detected at depths below 8.5 m (28 ft) bgs may be due to casing contamination (external and internal drag-down) rather than radionuclide contamination present in the soil column. The borehole was subsequently deepened by telescoping a 20 cm (8 in.) diameter casing to 98.2 m (322 ft). HRLS and SGLS logging was performed between 25.6 and 98.2 m (84 and 322 ft). The presence of drag-down contamination during the initial run was confirmed by the second logging run, which noted a significant drop-off in activity at the bottom of the 25 cm (10 in.) casing.

The NMLS at deep borehole C5515 revealed several intervals with slightly elevated moisture content. A zone of elevated moisture from 86 to 92 m (282 to 302 ft) bgs coincides with a layer of silt (also reflected in the gamma log by elevated natural K-40, U 238, and Th-232 concentrations) observed between these depths. The elevated moisture peak detected at 8.4 m (27.5 ft) bgs may not be accurate because the NMLS sonde can be influenced by extremely high gamma activity, which was present at the bottom of the crib. The elevated moisture levels detected from 26 to 28 m (85 to 92 ft) bgs most likely correlate with residual moisture associated with swabbing of the 25 cm (10 in.) diameter casing prior to the geophysical logging.

The PNLS indicated approximately 100 counts per second (cps) at 8.4 m (27.5 ft) bgs. This cps rate is believed to be influenced by the high gamma activity present at the bottom of the crib rather than representing the existence of alpha-emitting radionuclides (plutonium).

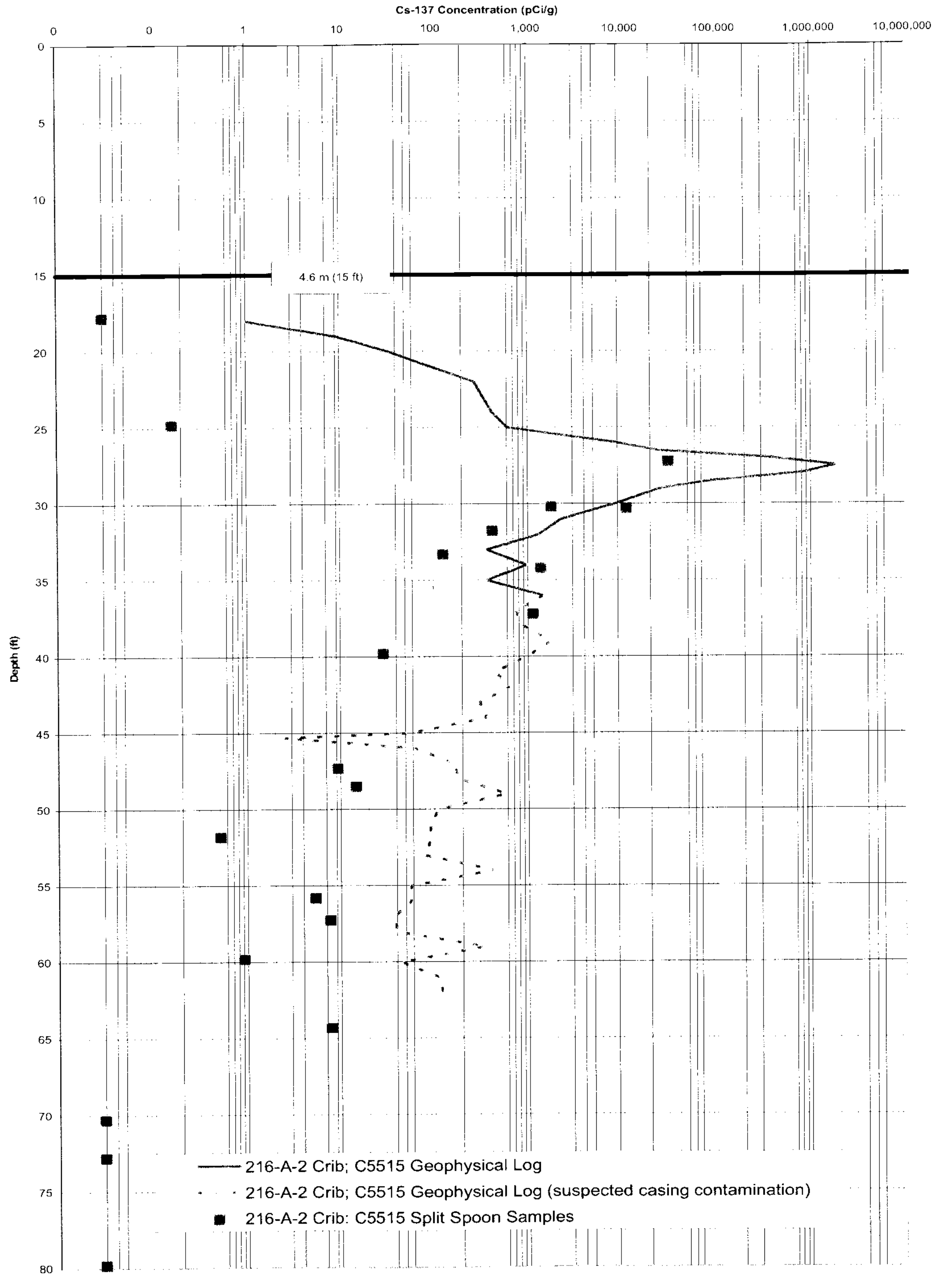


Figure 4-2. Geophysical Log for Deep Borehole C5515 at the 216-A-2 Crib

4.2.1.5 Borehole Geophysical Logging Summary – Well 299-E24-53

Borehole geophysical logging was performed at existing Well 299-E24-53, located 15 m (49 ft) east of the 216-A-2 Crib, in 1999 and again in October 2005. Cs-137 was detected from 8.8 m (29 ft) to the bottom of the logging run at 15.8 m (52 ft) bgs with the highest activity observed between 8.8 and 12.2 m (29 to 40 ft) bgs. The peak concentration of 4,600 pCi/g was detected at 10.2 m (33.5 ft) bgs.

The geophysical logging report (Appendix B) also indicates that Co-60 is likely present from 9.8 to 11.1 m (32 to 36.5 ft) bgs. Eu-154 was detected at 9.6 m (31.5 ft) bgs and again from 11.1 to 12.3 m (36.5 to 40.5 5 ft) bgs, with a peak concentration of about 6 pCi/g observed at 11.1 m (36.5 ft) bgs. Eu-154 also may be found at higher concentrations from 9.8 to 11.1 m (32 to 36.5 ft) bgs.

Gamma activity indicates the presence of processed uranium contamination at depths between 11.4 and the bottom of the well at 15.7 m (37.5 to 51.5 ft) bgs. Although no detections of processed uranium occurred in the high activity zone between 8.8 to 11.1 m (29 to 36.5 ft) bgs, it is likely to be present there as well.

Neutron logging shows significant moisture variability with a peak concentration of 22 percent detected at 14.9 m (49 ft) bgs. The logging report (Appendix B) noted that these data are in agreement with the SGLS and moisture data acquired in 1999 using the Radionuclide Logging System. Additionally, comparison with a total gamma log acquired by PNNL in 1982 shows no significant changes (either vertically or in contaminant magnitude) over the past 23 years.

4.2.1.6 Deep Borehole C5515 Laboratory Analysis Results

The split-spoon soil samples collected from deep borehole C5515 were tested for a broad suite of radionuclide and chemical constituents. Laboratory testing of the samples detected the presence of radionuclides and chemical constituents to a depth of 97.4 m (319.5 ft) bgs. The maximum detected concentrations are summarized in Table 4-4 (radionuclides) and Table 4-5 (non-radionuclides), and the complete results are tabulated in Appendix A.

The grab samples collected from deep borehole C5515 were tested by ESL for radionuclides and a subset of chemical constituents. The ESL data are used with limitations because QA/QC samples (for example, duplicates and splits) were not provided with the grab samples shipped to the ESL. However, the ESL data meet all other DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Document*, requirements and are included, where appropriate, on borehole contaminant distribution charts (that is, where ESL data correspond to commercial laboratory data with regard to analytical method and medium). The ESL laboratory data provide a useful source of constituent distribution data where there are no other laboratory results reported or available (that is, to fill in data gaps in the vadose profiles). The ESL data add valuable information used to trend the data and evaluate the geochemical contaminant signature in the vadose zone below the crib.

Shallow Soil. Radionuclide and chemical constituents were not detected at concentrations greater than background in the split-spoon sample collected at a depth between 4.1 and 4.7 m (13.5 to 15.5 ft).

Deep Soil. The maximum observed concentrations of radionuclide and chemical constituents, and their depth of occurrence in the deep soil samples are summarized in Table 4-4 and Table 4-5, respectively. These results are associated with testing of five split-spoon samples collected beneath the crib's footprint at depths between 8.4 and 17.4 m (27.5 and 57 ft), one sample collected between 40.4 and 41.2 m (132.5-135 ft), and three samples collected at depths between 76.2 and 97.4 m (250 and 319.5 ft).

Table 4-4. Maximum Detected Radionuclide Concentrations at 216-A-2 Crib Borehole C5515

Radionuclide	Lognormal 90th Percent Background Concentration (pCi/g)	Maximum Detected Concentration (pCi/g)	Depth of Maximum Concentration (ft-bgs)
Americium-241	ND	94,000	8.2–8.4 m (27–27.5 ft)
Cesium-137	1.05	31,000	8.2–8.4 m (27–27.5 ft)
Cobalt-60	0.0842	0.382	8.8–9.6 m (29–31.5 ft)
Europium-154	0.0334	1.28	9.8–10.5 m (32–34.5 ft)
Nickel-63	ND	10.6	9.8–10.5 m (32–34.5 ft)
Plutonium-238	0.00378	120	9.8–10.5 m (32–34.5 ft)
Plutonium-239/240	0.0248	426,000	8.2–8.4 m (27–27.5 ft)
Technetium-99	ND	6.27	8.8–9.6 m (29–31.5 ft)
Strontium-90	0.178	125,000	8.2–8.4 m (27–27.5 ft)
Tritium	ND	2,860	86.9–87.5 m (285–287 ft)
Uranium-233/234	1.1	43.2	9.8–10.5 m (32–34.5 ft)
Uranium-235	0.109	4.28	8.8–9.6 m (29–31.5 ft)
Uranium-238	1.06	56.6	9.8–10.5 m (32–34.5 ft)

N = background concentration not determined

bgs = below ground surface

Table 4-5. Maximum Detected Non-Radionuclide Concentrations at 216-A-2 Crib Borehole C5515

Non-Radionuclide Constituent	Lognormal 90th Percent Background Concentration (mg/kg)	Maximum Detected Concentration (mg/kg)	Depth of Maximum Concentration (ft-bgs)
Chromium (trivalent)	18.5	23.6	86.9–87.5 m (285–287 ft)
Chromium (hexavalent)	ND	0.247	40.4–41.1 m (132.5–135 ft)
Copper	22	23.3	86.9–87.5 m (285–287 ft)
Lead	10.2	10.3	86.9–87.5 m (285–287 ft)
Selenium	ND	0.786	86.9–87.5 m (285–287 ft)
Uranium (total)	3.21	147	8.8–9.6 m (29–31.5 ft)
Cyanide	ND	0.230	8.8–9.6 m (29–31.5 ft)
Nitrate as N	52	57.1	86.9–87.5 m (285–287 ft)
Nitrite as N	ND	2.56	8.8–9.6 m (29–31.5 ft)

Table 4-5. Maximum Detected Non-Radionuclide Concentrations at 216-A-2 Crib Borehole C5515

Non-Radionuclide Constituent	Lognormal 90th Percent Background Concentration (mg/kg)	Maximum Detected Concentration (mg/kg)	Depth of Maximum Concentration (ft-bgs)
Phosphate	0.785	313	8.8–9.6 m (29–31.5 ft)
Methylene Chloride	ND	0.0037	9.8–10.5 m (32–34.5 ft)
Styrene	ND	0.009	9.8–10.5 m (32–34.5 ft)
Toluene	ND	0.00057	9.8–10.5 m (32–34.5 ft)
2,4-Dimethylheptane	ND	0.24	8.8–9.6 m (29–31.5 ft)
2,6-Dimethylheptane	ND	0.15	9.8–10.5 m (32–34.5 ft)
Bis(2-ethylhexyl) phthalate	ND	0.047	9.8–10.5 m (32–34.5 ft)
Di-n-butylphthalate	ND	0.038	9.8–10.5 m (32–34.5 ft)
Heptane, 2,5-dimethyl	ND	0.18	9.8–10.5 m (32–34.5 ft)
Tributyl Phosphate	ND	0.12	8.8–9.6 m (29–31.5 ft)
Aroclor-1254	ND	0.052	8.8–9.6 m (29–31.5 ft)

ND = background concentration not determined

bgs = below ground surface

4.2.1.7 Summary and Discussion

The concentration and vertical distribution of radionuclide and non-radionuclide constituents detected above background in the soil samples collected from interior borehole C5515 are shown on Figure 4-3 to Figure 4-6, and the CSM is presented in Figure 4-7. The vertical distribution profiles presented in Figure 4-4 and Figure 4-6 contain some anomalies where non-detect results occur. These anomalies result from detection limits that vary between the laboratories performing the analyses, and elevated detection limits that result from sample dilution effects.

Laboratory analysis results from testing of soil samples collected from interior boring C5515 and geophysical logging of the perimeter borehole 299-E24-53 were used to draw conclusions on the nature of radionuclide and non-radionuclide constituents present in subsurface soil beneath the 216-A-2 Crib. These conclusions include:

- Radionuclides – The highest concentrations were observed in the samples collected immediately below the crib bottom at depths of 8.2 to 10.5 m (27 to 34.5 ft). The primary constituents detected included Am-241 (94,000 pCi/g), Cs-137 (31,000 pCi/g), Pu-238 (21,000 pCi/g), Pu-239/240 (426,000 pCi/g), and Sr-90 (125,000 pCi/g). Sm-151, which had the highest discharge inventory, was not tested for in the soil samples. Maximum detected radionuclide concentrations were within the depth interval 8.2 to 12.2 m (27 to 40 ft) bgs for all radionuclide constituents except tritium.
- Transuranic Radionuclides – Am-241 at 94 nCi/g, Pu-238 at 1.05 x 10-5 nCi/g, and Pu-239/240 at 426 nCi/g were detected at a total concentration of 520 nCi/g. The maximum detected concentrations were present in samples collected from the 8.4 to 9.2 m (27.5 to 30.25 ft) depth interval.

- Tritium – Tritium was detected in soil samples collected at depths between 40.9 to 97 m (134 to 318 ft) bgs. The maximum detected concentration of 2,860 pCi/g was observed in the sample taken at 87.2 m (286 ft) bgs. With a reported inventory of 0.001 Ci, tritium is not a significant component of the waste inventory discharged to the crib (Table 4-3).
- Non-radionuclides – The highest concentrations were detected in soil samples collected immediately below the crib bottom at depths of 8.2 to 10.5 m (27 to 34.5 ft). Phosphate at 313 mg/kg was present at the highest concentration in a sample collected at a depth of approximately 9.1 m (30 ft). The phosphate is likely related to the TBP discharged to the crib (TBP was detected at 0.12 mg/kg). The highest concentration of uranium metal (147 mg/kg) was also detected in the sample collected at a depth of 9.1 m (30 ft). Several other constituents detected at concentrations slightly higher than background levels included hexavalent chromium (0.247 mg/kg), copper (23.3 mg/kg), lead (10.2 mg/kg) and nitrate (57.1 mg/kg). These constituents were observed in soil samples collected at depths of 40.4 to 41.1 m (132.5 to 135 ft) and 86.7 to 87.5 m (285 to 287 ft).

Geophysical and split-spoon laboratory analysis results from the two borings located within the crib boundary (C5515 and C5570) and one boring immediately adjacent to the crib (299-E24-53) were used to delineate the vertical and lateral extent of radionuclides at the 216-A-2 Crib. This information indicates that the maximum observed concentration for most contaminants occurs near the bottom of the crib at 8.2 to 8.5 m (27 to 28 ft) bgs, with concentrations decreasing rapidly between the bottom of the crib and a depth of 19.7 m (64.5 ft) bgs. The lateral extent of contaminants is estimated to extend outward 10.4 m (34 ft) from the center of the crib.

Although both tritium and nitrate were encountered at the top and within a thick silt unit found at a depth of about 87 m (285 ft) bgs, the small discharge volumes at the 216-A-2 Crib and the low reported inventories of tritium and nitrate (0.001 Ci and 2,370 kg, respectively [RPP-26744]) make it unlikely that the contaminants encountered at the top of the silt layer are associated with this crib. Sampling results for the 216-A-2 Crib and at the nearby 216-A-4 Crib suggest that the deep silt layer unit forms at least a partial barrier to deeper contaminant transport. It is more likely that the tritium and nitrate are related to discharges from another currently unidentified site(s). The nitrate and tritium groundwater plumes are more regional in nature, with multiple potential sources present in the area south of the PUREX Plant.

4.2.2 216-A-4 Crib

The RI characterization drilling at borehole C5301 shows 0.31 m (1 ft) of surface stabilization material is present. Drilling observations at borehole C4560 indicate that the top of the crib gravel is 5.8 m (19 ft) bgs. These depths are consistent with the information shown on drawing H-2-56050. Boring logs and well completion diagrams are included in SGW-35574 and SGW-38891.

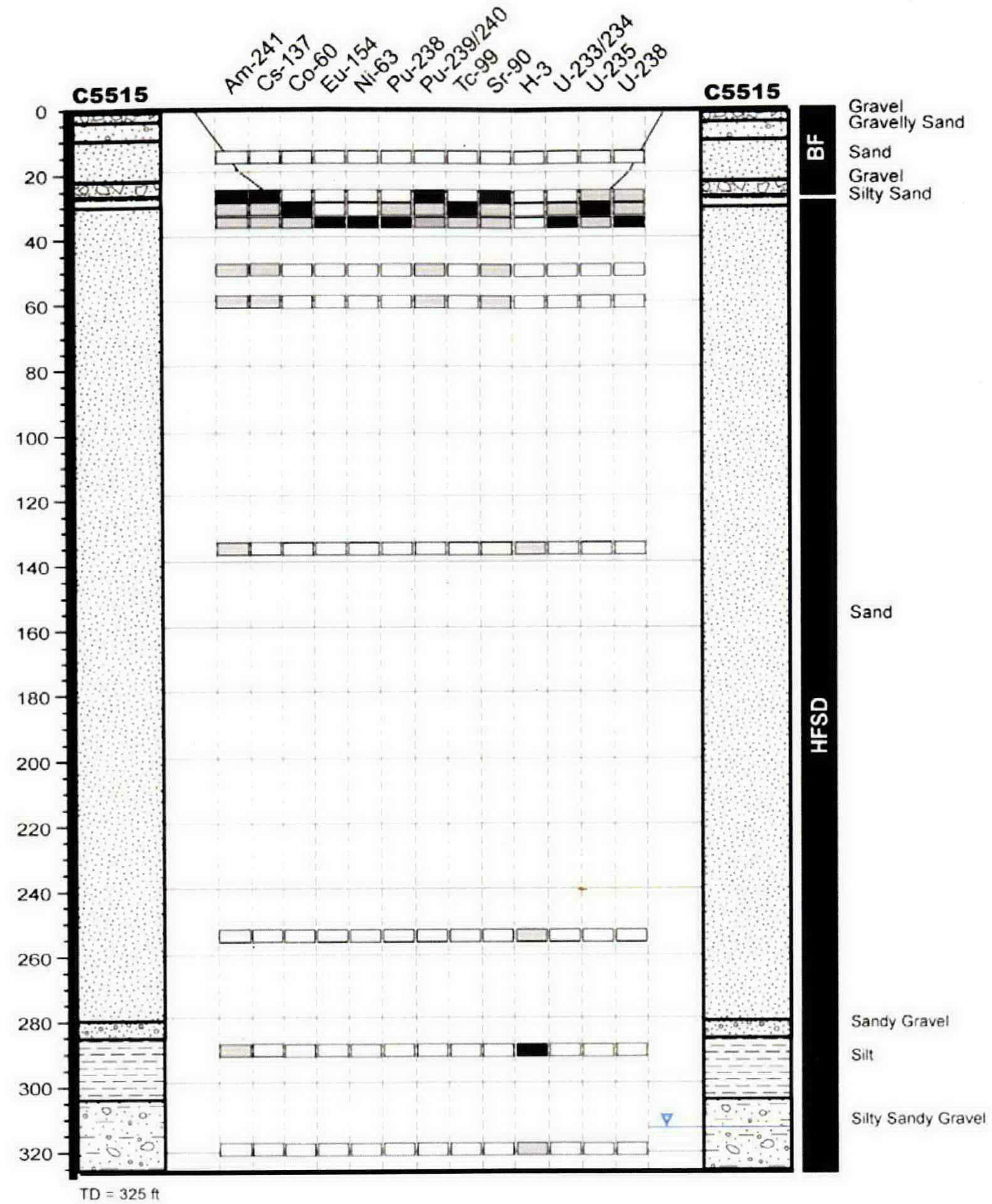
4.2.2.1 Primary Sources and Waste Characteristics

WIDS reports that the 6.21 million L (1.64 million gal) of liquid effluent discharged to the 216-A-4 Crib originated from 202-A Building (PUREX) laboratory cell drainage, and possibly drainage from the 291-A Stack. In December 1958, HW-59359 (Table V) described the waste stream as "Lab. cell and drain waste from 202-A December 1955 to date." The 291-A-1 Stack sources include stack drain, stack liner drain after neutralization in Tank 216A-TK1, sampler house sink and floor drain, stack gas filter drain, stack gutter drains, and the stack pit plenum.

The 216-A-4 Crib was also associated with the 241-A-151 diversion box, PUREX Laboratories, unplanned releases (UPRs) UPR-200-E-15 and UPR-200-E-103, and the 200-E-103 PUREX Stabilized Area. The site has also been identified as receiving drainage from pipelines 200-E-185-PL and 200-E-196-PL. Other waste streams reportedly discharged to the crib (DOE/RL-2006-47, p. 1-5) originated from the ventilation fans (fan bearing, fan turbine condensate, and control house drain), 202-A-U3, and the 202-A-U4 neutralization tanks (TK-U3 and TK-U4).

The 216-A-4 liquid effluent waste stream was categorized (RPP-26744) as a miscellaneous PUREX uranium nitrate hexahydrate and laboratory waste stream containing potassium nitrate solution with minor amounts of sodium, calcium, phosphate and fluoride. However, the reported sources and waste stream characteristics are suspect for several reasons:

- The crib plugged in 1958 after only 36 months of operation, leading to an overflow. It is the only 200-MW-1 OU crib that reportedly plugged, and the wastes described above are not expected to have caused a plugging problem.
- From borehole geophysical logging and soil samples taken during advancement of the RI characterization boreholes, the crib appears to contain Cs-137 (and perhaps other radionuclides) at much higher concentrations than the above waste streams would likely have contained.



216-A-2 Crib - Borehole C5515 Radionuclides Exceeding Background or No Background[1]													
A-2 Sample Depths	Am-241 (pCi/g)	Cs-137 (pCi/g)	Co-60 (pCi/g)	Eu-154 (pCi/g)	Ni-63 (pCi/g)	Pu-238 (pCi/g)	Pu-239/240 (pCi/g)	Tc-99 (pCi/g)	Sr-90 (pCi/g)	H3 (pCi/g)	U-233/234 (pCi/g)	U-235 (pCi/g)	U-238 (pCi/g)
13.0 - 15.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	BB	BB	BB
27.0 - 27.5	**94000**	**31000**	ND	ND	--	ND	**426000**	--	**125000**	--	--	1.97	47.4
29.0 - 31.5	1140	3700	**0.382**	ND	ND	78.1	5350	**6.27**	18700	ND	42.1	**4.28**	49.7
32.0 - 34.5	1420	130	0.356	**1.28**	**10.6**	**120**	6360	4.56	1700	ND	**43.2**	3.9	**56.6**
47.5 - 49.5	0.12	14.5	ND	ND	ND	ND	0.56	ND	2.2	ND	BB	ND	BB
54.5 - 57.0	0.37	5.31	ND	ND	ND	ND	1.8	ND	3.5	ND	BB	BB	BB
132.5 - 135.0	0.041	ND	ND	ND	ND	ND	ND	ND	ND	14.4	BB	BB	BB
250.5 - 253.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	196	BB	ND	BB
285.0 - 287.0	0.021	ND	ND	ND	ND	ND	ND	ND	ND	**2860**	BB	BB	BB
317.0 - 319.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	73	BB	BB	BB

1 Background values are provided in Tables 4-2
BB Value detected was below background
ND Not detected
NA not available
NR no result reported

Am Americium
Cs Cesium
Co Cobalt
Eu Europium
Ni Nickel
Pu Plutonium
Tc Technetium
Sr Strontium (total beta)
H-3 Tritium
U Uranium

[box] Maximum Concentrations

Discussion of RI-derived radionuclide data and comparison to existing information for the 216-A-2 Crib

- The 216-A-2 Crib was not considered in the Work Plan (DOE/RL-2001-65) as it was subsequently added to the OU. According to the Hanford Soil Inventory Model (RPP-26744), 207,000 L of organic-rich effluent were discharged to the 216-A-2 Crib, containing 27.3 Ci of Sm-151, 16.6 Ci of plutonium, 0.9 Ci of Sr-90, and 1.9 Ci of Cs-137.
- A recent study by PNNL (Appendix A) states that measured Cs-137 Kds are much higher than calculations from waste stream compositions indicate. These high Kds should lead to limited Cs-137 mobility in the vadose zone; however, geophysical logging in borehole C5515 (drilled through the crib) and proximal borehole 299-E24-53 show significant lateral migration of Cs-137 for at least 50 ft, coupled with vertical migration of detectable Cs-137 to 86 ft in depth. PNNL suggests that this may be related to high levels of organics in the effluent, potentially modifying viscosity and other flow parameters.
- A direct comparison of effluent volume versus available pore volume (DOE/RL-96-81) suggests that the vadose zone could have been completely saturated to a depth of about 90 ft bgs, which compares favorably with the depth of 86 ft bgs to which Cs-137 is detected in geophysical logging.
- The maximum levels of most radionuclides detected in laboratory analyses were found just beneath the bottom of the crib (27 – 35 ft bgs), as expected. The maximum level of tritium, however, was found at a depth of about 285 ft bgs near the upper margin of a 20-foot thick silt layer, although tritium has a Kd of 0. Effluent volume to pore volume considerations suggest that it is unlikely that any tritium discharged at the 216-A-2 Crib would have migrated to this depth. This, coupled with the small amount of tritium reportedly discharged at the crib (0.0014 Ci) suggests that the tritium comes from a different source and may not be related to the 216-A-2 Crib.
- PNNL-16346, shows that tritium and I-129 are detected above the maximum contaminant level (MCL) beneath the 216-A-2 Crib. Based on vadose zone characterization data obtained from borehold C5515, it is unlikely that the effluent discharged to the 216-A-2 Crib impacted groundwater.

FORMATION LEGEND	STRATIGRAPHIC LEGEND	CONSTITUENT LEGEND
BF - Backfill CG - Cemented Gravel G - Gravel HFSD - Hanford formation: Sand Dominated S - Sand to Silt SG - Sandy Gravel Si - Silt	Backfill Sand Silt Silty Sand Sandy Gravel Gravelly Sand Gravel	Highest Values ≥ Background < Background or PAL[1] [1] DOE/RL-2006-47 and DOE/RL-2006-77

Crib Construction Diagram (typical)

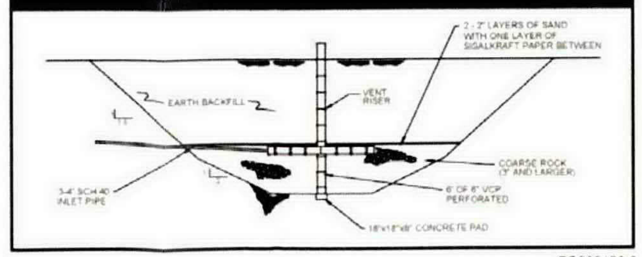


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Figure 4-3. Stratigraphy and Radionuclides Detected at the 216-A-2 Crib

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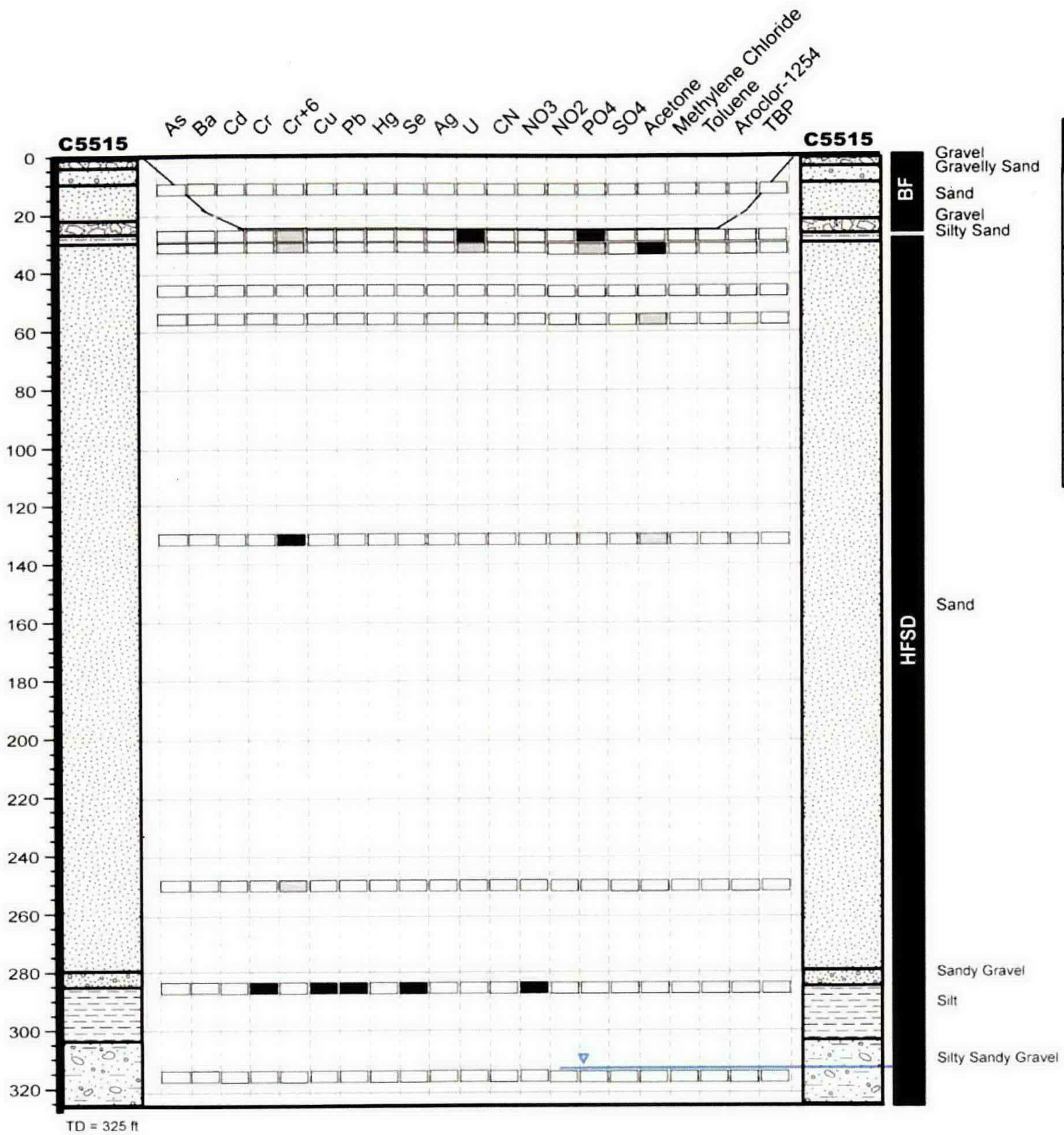

FORMATION LEGEND	**STRATIGRAPHIC LEGEND**	**CONSTITUENT LEGEND**
BF - Backfill	Backfill	Highest Values
CG - Cemented Gravel	Sand	> Background
G - Gravel	Silt	< Background or PAL[1]
HFSD - Hanford formation: Sand Dominated	Silty Sand	[1] DOE/RL-2006-47 and DOE/RL-2006-77
S - Sand to Silt	Sandy Gravel	
SG - Sandy Gravel	Gravelly Sand	
Si - Silt	Gravel	

216-A-2 Crib - Borehole C5515 Non-Radionuclides Exceeding Background or PAL[1]

A-2 Sample Depths	As (mg/kg)	Ba (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Cr+6 (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	Hg (mg/kg)	Se (mg/kg)	Ag (mg/kg)	U (mg/kg)	CN (mg/kg)	N03 (mg/kg)	NO2 (mg/kg)	PO4 (mg/kg)	SO4 (mg/kg)	Acetone (mg/kg)	Methylene Chloride (mg/kg)	Toluene (mg/kg)	Aroclor - 1254 (mg/kg)	TBP (mg/kg)
13.0 - 15.5	BB	BB	ND	BB	---	BB	BB	ND	ND	ND	BB	ND	BB	ND	ND	BB	ND	ND	ND	ND	ND
29.0 - 31.5	BB	BB	ND	BB	0.220	BB	BB	BB	ND	BB	**147.0**	BB	BB	BB	**313**	BB	ND	ND	ND	BB	BB
32.0 - 34.5	BB	BB	BB	BB	0.100	BB	BB	BB	ND	BB	106.0	BB	BB	BB	197	BB	**0.0082**	BB	BB	BB	BB
47.5 - 49.5	BB	BB	ND	BB	ND	BB	BB	ND	ND	ND	BB	ND	BB	ND	ND	BB	ND	ND	ND	ND	ND
54.5 - 57.0	BB	BB	ND	BB	ND	BB	BB	ND	BB	ND	BB	ND	BB	ND	ND	BB	0.0070	ND	ND	ND	ND
132.5 - 135.0	BB	BB	BB	BB	**0.247**	BB	BB	ND	BB	ND	BB	ND	BB	ND	ND	BB	0.0064	ND	ND	ND	ND
250.5 - 253.0	BB	BB	ND	BB	0.240	BB	BB	ND	ND	ND	BB	ND	BB	ND	ND	BB	ND	ND	ND	ND	ND
285.0 - 287.0	BB	BB	BB	**23.6**	ND	**23.30**	**10.30**	ND	**0.786**	BB	BB	ND	**57.1**	ND	ND	BB	ND	ND	ND	ND	ND
317.0 - 319.5	BB	BB	ND	BB	ND	BB	BB	ND	BB	ND	BB	ND	BB	ND	ND	BB	ND	ND	ND	ND	ND

1 Background values are provided in Table 4-2.
BB Value detected was below background
ND Not detected
NA not available
NR no result reported

TCE Trichloroethene
▭ Maximum Concentrations

Discussion of RI-derived non-radionuclide data and comparison to existing information for the 216-A-2 Crib

- The 216-A-2 Crib was not considered in the Work Plan (DOE/RL-2001-65) as it was subsequently added to the OU. According to the Hanford Soil Inventory Model (RPP-26744), 207,000 L of organic-rich effluent were discharged to the 216-A-2 Crib, containing 228 kg of uranium, 2,370 kg of nitrate, 149,200 kg of tributyl phosphate (TBP), and 63,920 kg of normal paraffin hydrocarbon (NPH).
- Analytical laboratory data from borehole C5515, drilled through the 216-A-2 Crib, shows maximum levels of many non-radionuclide contaminants are found immediately beneath the crib, or at a depth of about 285 ft bgs at the top of a thick silt layer. Most low-mobility (i.e., high Kd) contaminants have maxima near the bottom of the crib (29 – 35 ft bgs), as might be expected. However, the maximum level of phosphate, which is considered a high mobility contaminant (i.e., low Kd) is also found just beneath the crib, although nitrate, with a similar low Kd is found at the top of the silt layer at 285 ft bgs. This suggests that nitrate may have a different source than the 216-A-2 Crib. Several metals are also found with maxima at the top of the silt layer. The concentrations of these metals are low and these analyses may be related to in-situ metallic minerals within the sediments of the Hanford formation.
- A direct comparison of effluent volume versus available pore volume (DOE/RL-96-81) suggests that the vadose zone could have been completely saturated to a depth of about 90 ft bgs. Hexavalent chromium, which is quite mobile, has a maximum analytical concentration at a depth of 132.5 ft, perhaps indicating a different source than the 216-A-2 Crib for this contaminant.
- PNNL-13646, the most recent groundwater report, shows that nitrate is detected above the maximum contaminant level (MCL) beneath the 216-A-2 Crib. Based on the vadose zone characterization data obtained from borehole C5515, it is unlikely that the effluent discharged to the 216-A-2 Crib impacted groundwater.

Crib Construction Diagram (typical)

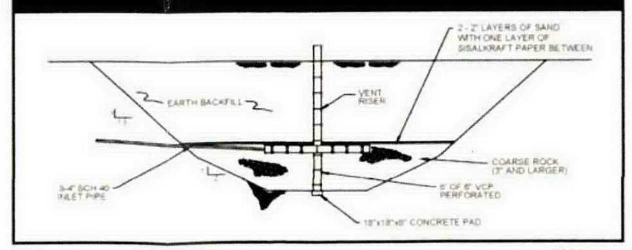

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Figure 4-4. Stratigraphy and Non-Radionuclides Detected at the 216-A-2 Crib

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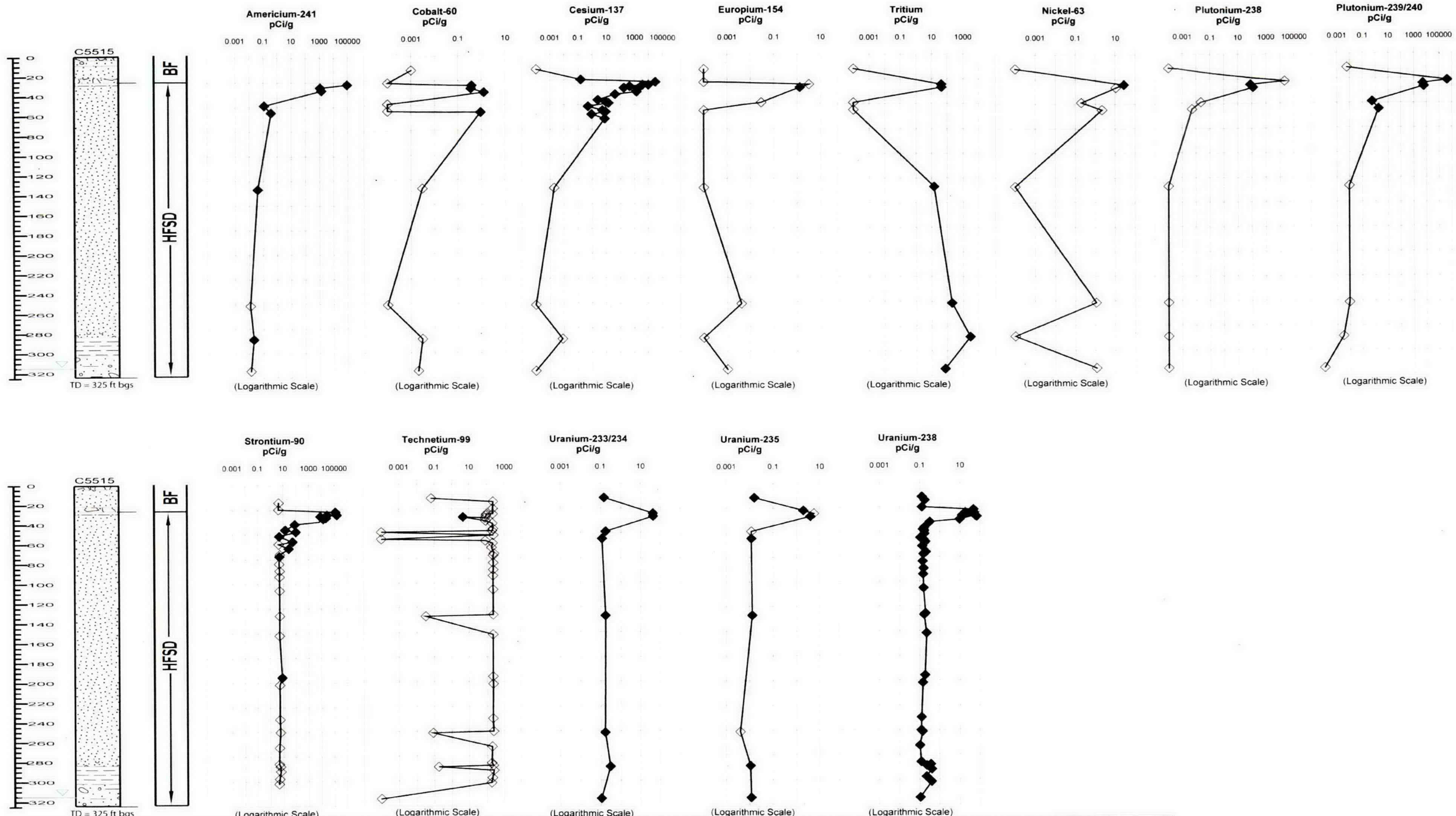

216-A-2 Crib - Borehole C5515

BF - Backfill Material
HFSD - Hanford formation Sand Dominated
RE - Ringold Formation, Unit E
TD - Total Depth

Concentration Legend

Rad Analyte	Background (pCi/g)	Non-Rad Analyte	Background (µg/kg)	Non-Rad Analyte	Background (µg/kg)
Americium - 241	N/A	Acetone	N/A	Nitrite	N/A
Cesium - 137	1.05	Aroclor-1254	N/A	Phosphate	790
Cobalt - 60	0.00842	Arsenic	6,470	Selenium	780
Europium - 154	0.0334	Barium	132,000	Silver	730
Nickel - 63	N/A	Cadmium	810	Sulfate	237,000
Plutonium - 238	0.00378	Chromium	18,500	Toluene	N/A
Plutonium - 239/240	0.0248	Copper	22,000	Tribuytl Phosphate	N/A
Strontium - 90	0.178	Cyanide	N/A	Uranium	3210
Technetium - 99	N/A	Hexavalent Chromium	N/A		
Tritium	N/A	Lead	10,200		
Uranium - 233/234	1.1	Mercury	330		
Uranium - 235	0.109	Methylene Chloride	N/A		
Uranium - 238	1.06	Nitrate	52,000		

Borehole Legend

Gravel
Gravelly Sand
Sand
Silty Sand
Sandy Gravel
Silt
Silty Sandy Gravel
Static Water Line
Non-detect
Positive Detect

Figure 4-5. Vertical Distribution of Radionuclides in Borehole C5515 at the 216-A-2 Crib

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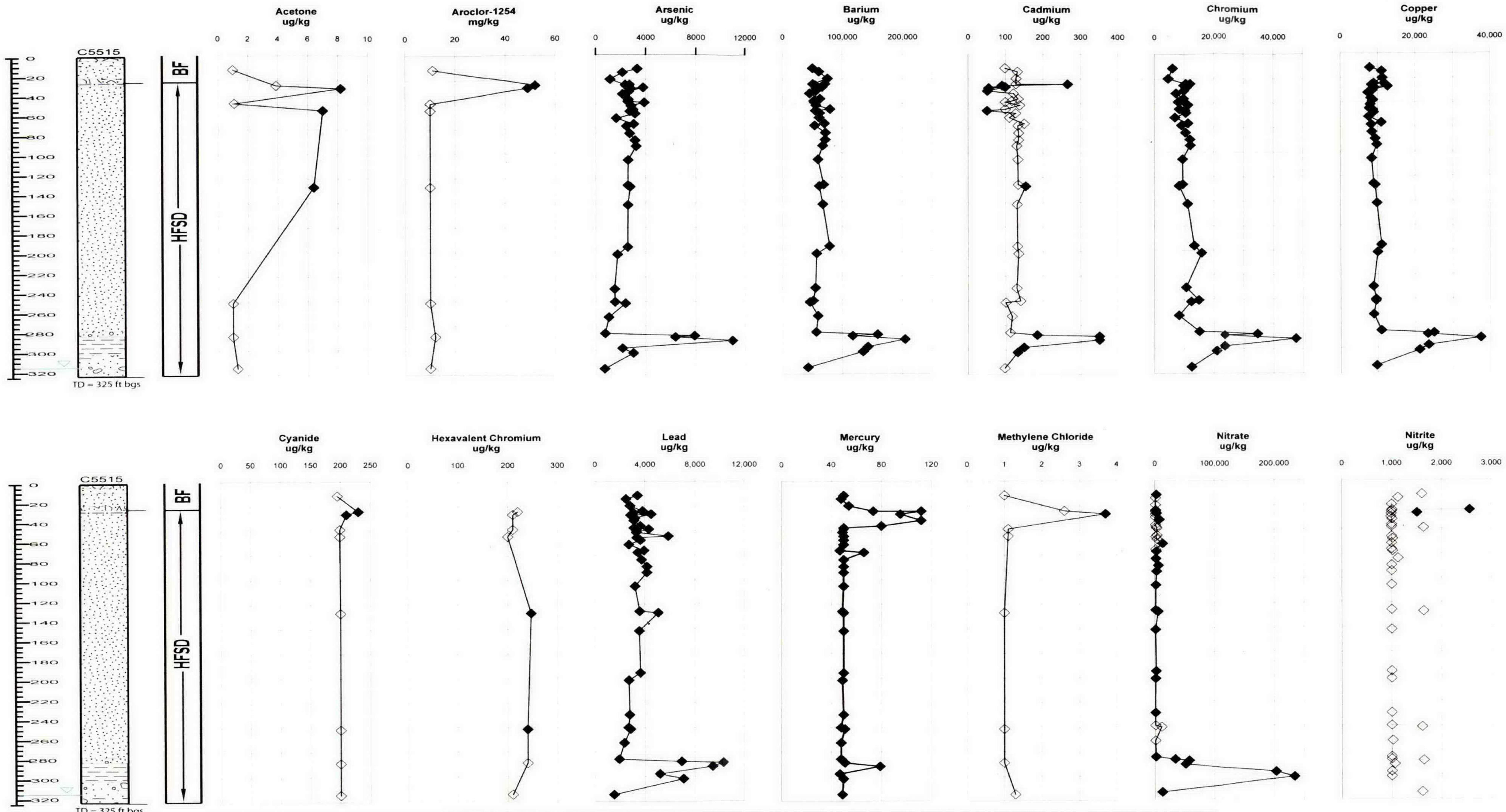

216-A-2 Crib - Borehole C5515

BF - Backfill Material
HFSD - Hanford formation Sand Dominated
RE - Ringold Formation, Unit E
TD - Total Depth

Concentration Legend

Rad Analyte	Background (pCi/g)	Non-Rad Analyte	Background (µg/kg)	Non-Rad Analyte	Background (µg/kg)
Americium - 241	N/A	Acetone	N/A	Nitrite	N/A
Cesium - 137	1.05	Aroclor-1254	N/A	Phosphate	790
Cobalt - 60	0.00842	Arsenic	6,470	Selenium	780
Europium - 154	0.0334	Barium	132,000	Silver	730
Nickel - 63	N/A	Cadmium	810	Sulfate	237,000
Plutonium - 238	0.00378	Chromium	18,500	Toluene	N/A
Plutonium - 239/240	0.0248	Copper	22,000	Tribuytl Phosphate	N/A
Strontium - 90	0.178	Cyanide	N/A	Uranium	3210
Technetium - 99	N/A	Hexavalent Chromium	N/A		
Tritium	N/A	Lead	10,200		
Uranium - 233/234	1.1	Mercury	330		
Uranium - 235	0.109	Methylene Chloride	N/A		
Uranium - 238	1.06	Nitrate	52,000		

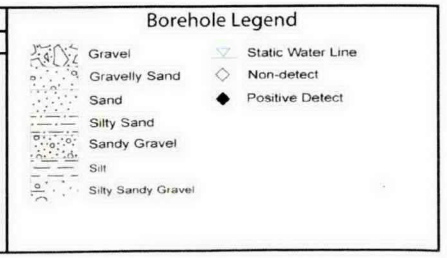

Figure 4-6. Vertical Distribution of Non-Radionuclides in Borehole C5515 at the 216-A-2 Crib

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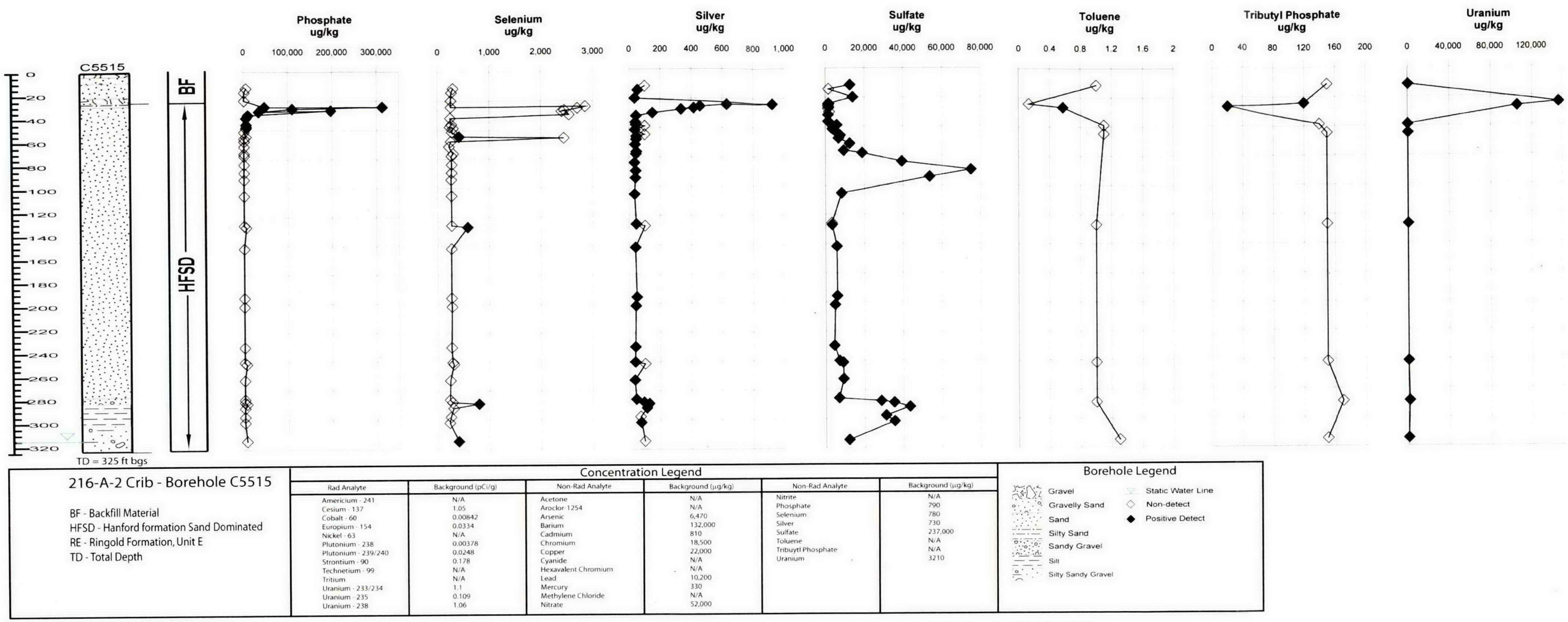

Figure 4-6. Vertical Distribution of Non-Radionuclides in Borehole C5515 at the 216-A-2 Crib

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200-MW-1 Operable Unit

216-A-2 Crib

200 East Area

HISTORY

The 216-A-2 crib is an inactive liquid waste disposal site that received liquid organic wastes from the 202-A Building (PUREX). The waste was low in salt, neutral to basic, and contained organics, mainly tri-butyl phosphate (TBP) and normal paraffin hydrocarbons (NPH).

Construction: The site is a square, gravel-filled crib with a soil and gravel cover. The bottom dimensions are 20 ft x 20 ft. The maximum depth from original grade is 27 ft. The sides are sloped 2:1 from the bottom to 21 ft-bgs and at 1.5:1 to the surface. The bottom 6 ft is filled with coarse gravel, and the remainder with native soil (gravelly sand). Distribution pipes at 21 ft-bgs (top of the gravel) discharged the effluent to the crib gravel.

Waste Volume: 230,000 liters (60,800 gallons).

Duration: The 216-A-2 Crib was activated in January 1956, and deactivated in January 1963 (WIDS), when the specific retention capacity was reached. SIM (RPP-26744) reports the crib was active from 1956 to 1960. The unit was replaced by the 216-A-31 Crib.

Inventory of High/Mobility Constituents:

Constituent	Units	Inventory Mean	Inventory Low	Inventory High
Tc-99	Ci	0.027	0.015	0.039
Tritium	Ci	0.001	0.001	0.002
N03	kg	2370	1,857	3,000

Low = 5th percentile
High = 95th percentile

Inventory of Low Mobility Constituents:

Constituent	Units	Inventory Mean	Inventory Low	Inventory High
Cs-137	Ci	1.86	1.0	2.7
Pu-239/240	Ci	9.47	4.86	15.7
Sr-90	Ci	0.89	0.49	1.3
U- Metal	kg	228	86.5	432

Low = 5th percentile
High = 95th percentile

BASIS OF KNOWLEDGE

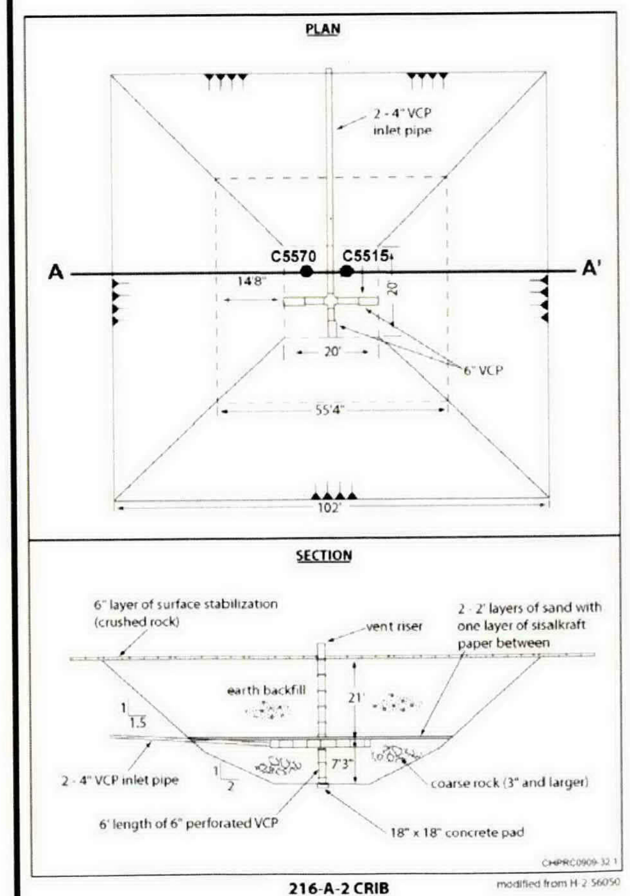
- Process History (Drawings and WIDS)
- SIM (RPP-26744)
- Sampling and Analysis
- Borehole Geophysical Logging
- Geologic Logs

CHARACTERIZATION SUMMARY

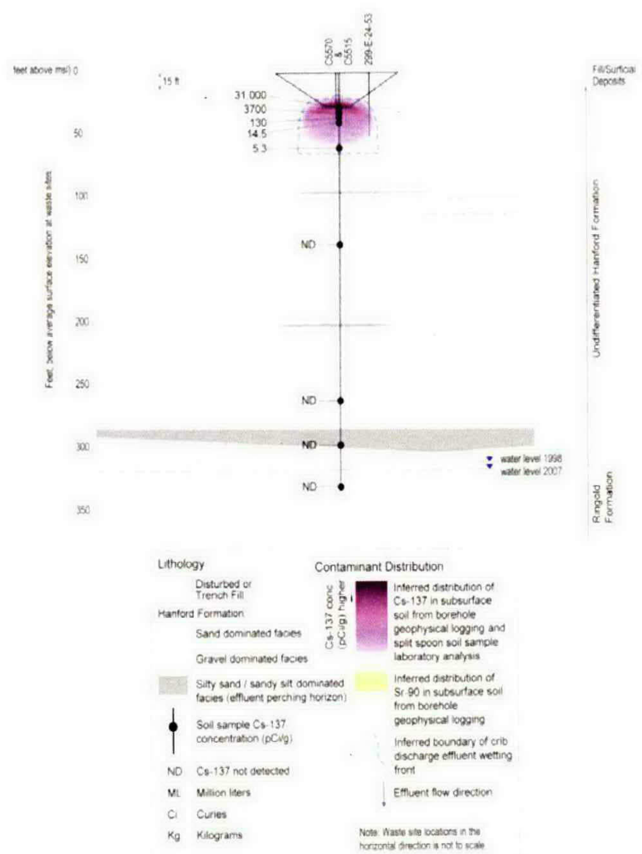
- C5570 -Direct push borehole advanced to 35 ft bgs and geophysically logged.
- C5515: borehole advanced to 322 ft bgs with twelve split spoon soil samples collected between 13 and 319.5 ft bgs in addition to geophysical logging.
- 299-E24-52: Existing vadose zone monitor well installed to 52 ft bgs, geophyscially logged three times between 1999 and 2005

Waste Site: 216-A-2 Crib

Site Construction



Contaminant Distribution



Potential Viable Alternatives

● NO ACTION ● ICs/MNA ● REMOVE, TREAT, DISPOSE

UNCERTAINTY SUMMARY

The site is well characterized by three boreholes, with the deepest installed through the center of the crib to the water table located at a depth of 315 ft.

NATURE AND EXTENT

Medium/low mobility radionuclide contaminants beneath the 216-A-2 crib are concentrated primarily within the zone extending from the base of the crib (27 ft bgs) to a depth of 40 ft bgs. Comparison of peak Cs-137 activity in geophysical logs at the center of the crib (borehole C5570) and near the edge of the crib (299-E-24-53) indicates a majority of the radionuclide activity lies within the crib footprint.

Direct Exposure: Radionuclide and non-radionuclide contaminants were not detected above screening levels in the split spoon samples collected from 0 to 15 ft bgs. Based on these findings, the direct contact (industrial land use) exposure pathway is not complete.

Ecological Exposure: The ecological exposure pathway is incomplete. Active management controls and lack of biological activity within shallow soil (0 to 15 ft bgs) preclude exposure.

Groundwater Protection: Uranium metal concentrations in soil at the 216-A-2 Crib are greater than their respective soil to groundwater protection screening concentrations. A groundwater sample collected from deep borehole C5515 detected uranium at 11 µg/L well below its 30 µg/L MCL value.

- Tritium and nitrate were encountered within a thick silt unit present at a depth of about 285 ft bgs. uranium was not detected. The small effluent discharge volume at the 216-A-2 Crib and the low reported tritium and nitrate (0.001 Ci and 2,370 kg, respectively) inventory make it unlikely that the groundwater concentrations are associated with this crib. Nitrate and tritium concentrations are declining in the area south of PUREX (see Appendix A).
- RESRAD modeling under a restricted land use shows that radionuclides do not impact above MCL values within a 1,000 year timeframe.
- RESRAD modeling under an unrestricted land use shows Tc-99 reaching groundwater within the 1,000 year simulation period. The modeled concentration of 4 pCi/L in year 781 is below its MCL value of 900 pCi/L.

Figure 4-7. Conceptual Site Model for the 216-A-2 Crib

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- The high concentrations of Cs-137 and Sr-90 evident from the field gamma activity monitoring, and observed in the few soil samples collected inside the crib footprint, are thought to have originated from higher concentration waste streams that inadvertently passed to the crib through the 241-A-151 diversion box.

Three accounts of the crib plugging and overflow event have been described:

- The liquid effluent backed up into the 291-A Turbine House through the floor drains. The backup also flooded an area of soil and blacktop outside the 291-A Turbine House. The floor of the turbine house was reportedly contaminated to a level corresponding to 20 rad/hr at a distance of 25.4 cm (10 in.). The ground was contaminated to a level corresponding to 8 rad/hr at an unspecified distance (WIDS 2008: UPR-200-E-13).
- The crib plugged, contaminating an area of soil (and perhaps blacktop) between the 291-A Stack and the crib. The soil was scraped up and placed in the 200-E-102 Trench (HW-60807, p. 18; DOE/RL-2001-65, p. 2-16).
- The crib plugged, flooding the ground surface and contaminating surface soil (DOE/RL-2001-65, p. 3-3).

The radionuclides with the largest inventories (Table 4-3) disposed to the 216-A-4 Crib included tritium (64.5 Ci), Pu-241 (7.2 Ci), Cs-137 (4.86 Ci), Sr-90 (4.14 Ci), and Pu-239 (1.08 Ci). The inorganic compounds in the liquid effluent discharged to the crib and their reported (RPP-26744) inventory included nitrate at 95,370 kg (210,300 lb), potassium at 75,970 kg (167,500 lb), uranium at 5,388 kg (11,880 lb) and phosphate at 1,691 kg (3,728 lb).

4.2.2.2 Field Investigation Activities

Three boreholes were drilled at the 216-A-4 Crib to complement existing borehole 299-E24-54, completed as a vadose zone well in 1955. Shallow borehole C4560 was drilled within the crib footprint between July and August 2004 and terminated at a depth of 7.6 m (25 ft) after a high level of field radioactivity was unexpectedly encountered. Most of the temporary casing and some drilling tools were left in the borehole. Three soil samples were collected from this borehole for laboratory analysis.

Shallow borehole C4671 was drilled 1.1 m (4 ft) away from C4560 and advanced to a total depth of 18.3 m (60 ft). This borehole was then geophysically logged in September 2004 from ground surface to its total depth.

Deep borehole C5301 was drilled 2.5 m (8.2 ft) outside the crib footprint's southwest corner. Drilling was initiated in November 2006 and completed in March 2007 (SGW-33959). The borehole was advanced to a total depth of 109.7 m (360 ft) bgs. Groundwater was encountered at a depth of 95.7 m (314.1 ft) bgs. Six split-spoon soil samples and one water sample were collected for laboratory analysis. The borehole was also geophysically logged from ground surface to its total depth.

4.2.2.3 Borehole Geophysical Logging Summary – Shallow Borehole C4671

The logging sensors used by the contractor (Stoller) included SGLS, HRLS, NMLS, and PNLS. The SGLS and HRLS logging detected Cs-137 at depths between ground surface and 17.7 m (58 ft) bgs, with a peak concentration of 240 million pCi/g observed at a depth of 6.1 m (20 ft) bgs, or approximately 1.5 m (5 ft) above the crib's floor. The logging report (Appendix B) noted that the zone of maximum activity appeared to be less than 30 cm (12 in.) thick. At depths between ground surface and 3.7 m (12 ft) bgs, Cs-137 concentrations ranged from 36 to 86 pCi/g (Figure 4-8).

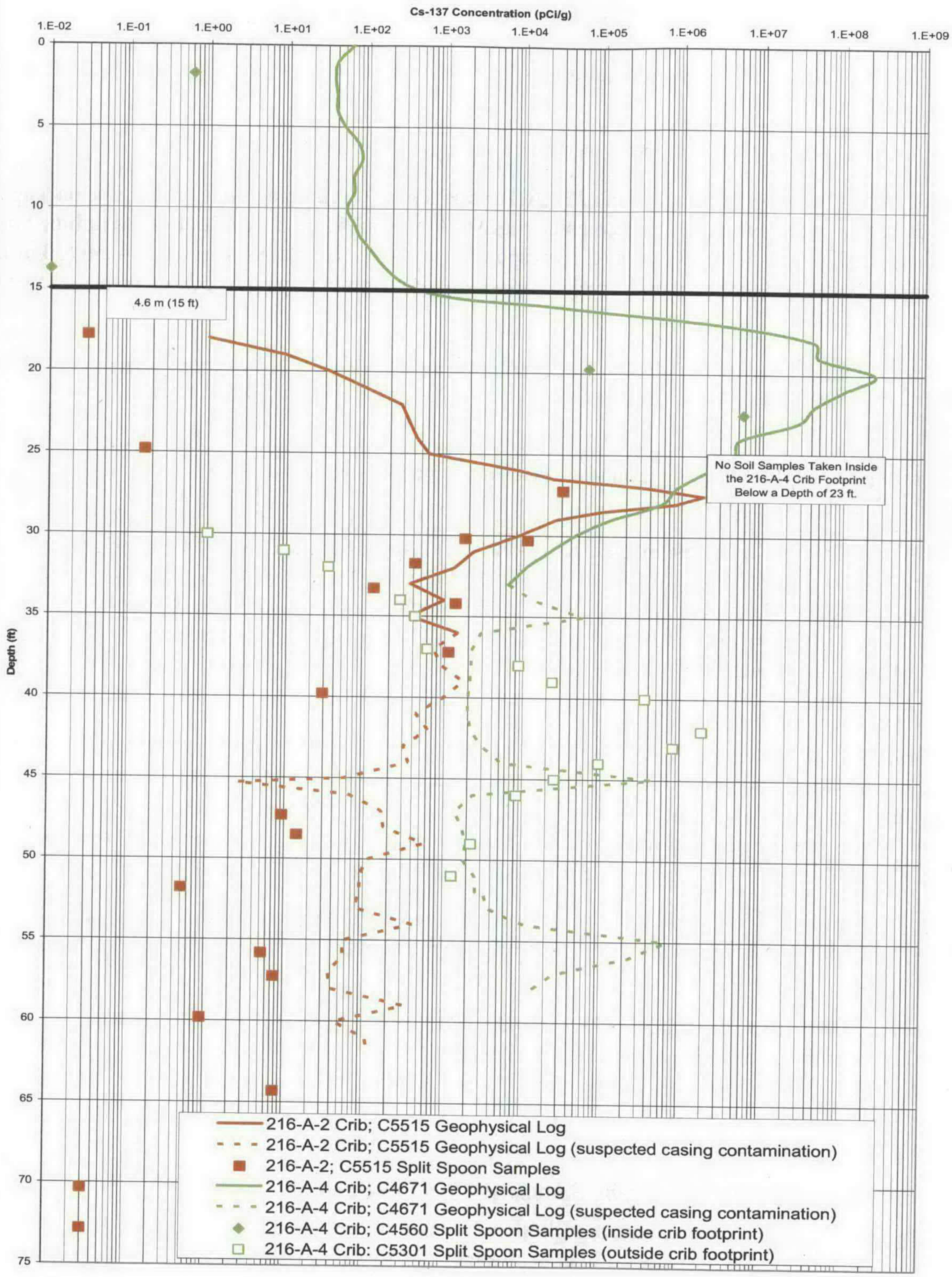


Figure 4-8. Geophysical Log for Shallow Borehole C4671 at the 216-A-4 Crib

As discussed further in Appendix B, much of the Cs-137 observed at depths below 6.1 m (20 ft) may be associated with casing contamination as evidenced by the sharp uniformly spaced, repeating peaks (Figure 4-8) noted at 3.1 m (10 ft) intervals at depths of 10.7 m (35 ft), 13.7 m (45 ft) and 16.8 m (55 ft).

4.2.2.4 Borehole Geophysical Logging Summary – Deep Borehole C5301

Geophysical logging at deep borehole C5301, located just outside the crib footprint, was initially performed inside a 25 cm (10 in.) diameter casing to a depth of 25.9 m (85 ft). The borehole was then deepened by telescoping a 20 cm (8 in.) diameter casing to a depth of 108.2 m (355 ft). The logging sensors used by the contractor (Stoller) included SGLS, HRLS, NMLS, and PNLS.

Cs-137 was detected from ground surface to a depth of 7 m (23 ft), and from depths of 14 to 23.2 m (46 to 76 ft) bgs at concentrations between 0.1 and 15 pCi/g with the peak concentration of 15 pCi/g observed at a depth of 14.9 m (49 ft) bgs. NMLS logging detected the same elevated moisture zone observed at borehole C5515 (216-A-2 Crib) between a depth of 86 to 90.2 m (282 to 296 ft) bgs. This zone coincides with the silt layer encountered from 86 to 91.1 m (282 to 299 ft) bgs.

4.2.2.5 Borehole Geophysical Logging Summary – Well 299-E24-54

Vadose zone Well 299-E24-54 (A5911), located 0.5 m (1.5 ft) outside the crib boundary to the northeast, was logged in April 2005. The logging detected Cs-137 at depths between 8.8 and 11 m (29to 36 ft) bgs and between 19.5 and 27.7 m (64 to 91 ft) bgs. A peak Cs-137 concentration of approximately 55 pCi/g was detected at depths of 9.5 m (31 ft) and 20 m (65.5 ft) bgs. Geophysical logging of boreholes C5301 and A5911 indicate very little lateral migration beyond the crib's footprint, even though a zone of highly concentrated Cs-137 occurs directly beneath the crib.

4.2.2.6 Laboratory Analysis Results for Shallow Borehole C4560

Three split-spoon soil samples were collected from the shallow borehole that was drilled and terminated inside the 216-A-4 Crib footprint. The samples were collected at depths of 0.2 to 0.9 m (0.5 to 3 ft), 3.7 to 4.4 m (12 to 14.5 ft), and from 5.5 to 6.3 m (18 to 20.5 ft). The maximum detected concentrations are summarized in Table 4-6 (radionuclides) and Table 4-7 (non-radionuclides), and the complete results are tabulated in Appendix A.

Shallow Soil. Three radionuclide constituents were detected at concentrations near background levels (Table 4-6) in the shallow soil samples collected at depths of less than 4.6 m (15 ft).

Deep Soil. Several radionuclide constituents, most notably Cs-137 and Sr-90, were detected in the samples collected at depths between 4.6 and 6.4 m (15 and 21 ft). Cs-137 was detected at a concentration of 63,600 pCi/g, Sr-90 at 3.86 million pCi/g, and Pu-239/240 at 21,400 pCi/g (Table 4-6). The maximum observed concentrations were present in the sample collected at a depth of 5.6 to 6.4 m (18.5 to 21 ft). Non-radionuclide constituents detected above background levels (Table 4-7) included bismuth (144 mg/kg), uranium metal (1,970 mg/kg), and oil and grease (197 mg/kg). These constituents were detected in the soil samples collected at 5.6 to 6.4 m (18.5 to 21 ft) bgs. This depth interval is near the top of the crib rock at a depth of 5.5 m (18 ft) bgs.

4.2.2.7 Deep Borehole C5301 (Outside Crib Footprint) Laboratory Analysis Results

Six soil samples were collected from the deep borehole drilled outside the crib footprint. These samples were taken at depths of 8.8 to 9.6 m (29 to 31.5 ft), 13 to 13.7 m (42.5 to 45 ft), 37.3 to 38.1 m (122.5 to 125 ft), 48.8 to 49.5 m (160 to 162.5 ft), 79.3 to 80 m (260 to 262.5 ft), and 86.1 to 86.9 m (282.5 to 285 ft). The maximum detected concentrations are summarized in Table 4-8 (radionuclides) and Table 4-9 (non-radionuclides), and the complete results are tabulated in Appendix A.

The laboratory analysis summary does not include data from the grab samples (ESL analysis) because field QA/QC samples (duplicates and splits) were not included.

Shallow Soil. No shallow soil samples were collected between the ground surface and a depth of 4.6 m (15 ft).

Deep Soil. Several radionuclides were detected at concentrations near background levels (Table 4-8) with tritium detected at a concentration of 1,100 pCi/g at a depth of 86.3 to 86.9 m (283 to 285 ft). Non-radionuclide constituents detected at concentrations above background levels (Table 4-9) included primarily nitrate at 185 mg/Kg, phosphate at 4.2 mg/kg, and oil and grease at 250 mg/kg.

4.2.2.8 Summary and Discussion

The concentration and vertical distribution of radionuclides detected above background in the soil samples collected from borehole C4560 (inside the crib) and borehole C5301 (outside the crib) are shown on Figure 4-9 and Figure 4-10, respectively. The concentration and vertical distribution of non-radionuclide constituents are shown on Figure 4-11 and Figure 4-12, respectively. A CSM for the 216-A-4 Crib is presented in Figure 4-13.

Table 4-6. Maximum Detected Radionuclide Concentrations at 216-A-4 Crib Borehole C4560

Radionuclide	Lognormal 90th Percent Background Concentration (pCi/g)	Maximum Detected Concentration (pCi/g)	Depth of Maximum Concentration (bgs)
Shallow Soil			
Americium-241	ND	0.088	3.8–4.6 m (12.5–15 ft)
Plutonium-239/240	0.0248	0.45	3.8–4.6 m (12.5–15 ft)
Strontium-90	0.178	0.37	3.8–4.6 m (12.5–15 ft)
Deep Soil			
Americium-241	ND	3,810	5.6–6.4 m (18.5–21 ft)
Cesium-137	1.05	63,600	5.6–6.4 m (18.5–21 ft)
Cobalt-60	0.0842	14.3	5.6–6.4 m (18.5–21 ft)
Europium-154	0.0334	179	5.6–6.4 m (18.5–21 ft)
Plutonium-238	0.00378	209	5.6–6.4 m (18.5–21 ft)
Plutonium-239/240	0.0248	21,400	5.6–6.4 m (18.5–21 ft)
Strontium-90	0.178	3,860,000	5.6–6.4 m (18.5–21 ft)
Uranium-233/234	1.1	478	5.6–6.4 m (18.5–21 ft)
Uranium-238	1.06	683	5.6–6.4 m (18.5–21 ft)

ND = background concentration not determined
bgs = below ground surface

Table 4-7. Maximum Detected Non-Radionuclide Concentrations at 216-A-4 Crib Borehole C4560

Non-Radionuclide	Lognormal 90th Percent Background Concentration (mg/kg)	Maximum Detected Concentration (mg/kg)	Depth of Maximum Concentration (bgs)
Antimony	5	0.66	5.6–6.4 m (18.5–21 ft)
Bismuth	ND	144	5.6–6.4 m (18.5–21 ft)
Mercury	0.33	0.92	5.6–6.4 m (18.5–21 ft)
Silver	0.73	2.20	5.6–6.4 m (18.5–21 ft)
Uranium (total)	3.21	1,970	5.6–6.4 m (18.5–21 ft)
Methylene Chloride	ND	0.011	5.6–6.4 m (18.5–21 ft)
Styrene	ND	0.00041	5.6–6.4 m (18.5–21 ft)
Aroclor-1254	ND	0.056	5.6–6.4 m (18.5–21 ft)
Aroclor-1260	ND	0.047	5.6–6.4 m (18.5–21 ft)
Oil and Grease	ND	197	5.6 6.4 m (18.5–21 ft)

Note: Results are for deep soil. No constituents were detected above background levels in shallow soil.

ND = background concentration not determined

bgs = below ground surface

Table 4-8. Maximum Detected Radionuclide Concentrations at 216-A-4 Crib Borehole C5301

Radionuclide	Lognormal 90th Percent Background Concentration (pCi/g)	Maximum Detected Concentration (pCi/g)	Depth of Maximum Concentration (ft – bgs)
Americium-241	ND	0.045	37.2–37.8 m (122.0–124.0 ft)
Iodine-129	ND	1.04	86.3–86.9 m (283–285 ft)
Potassium-40	16.6	17.1	13.1–13.9 m (43.0–45.5 ft)
Plutonium-239/240	0.0248	0.067	37.2–37.8 m (122.0–124.0 ft)
Strontium-90	0.178	0.44	13.1–13.9 m (43.0–45.5 ft)
Tritium	ND	1,100	86.3–86.9 m (283.0–285.0 ft)

Note: Results are for deep soil. Samples were not collected from shallow soil.

ND = background concentration not determined

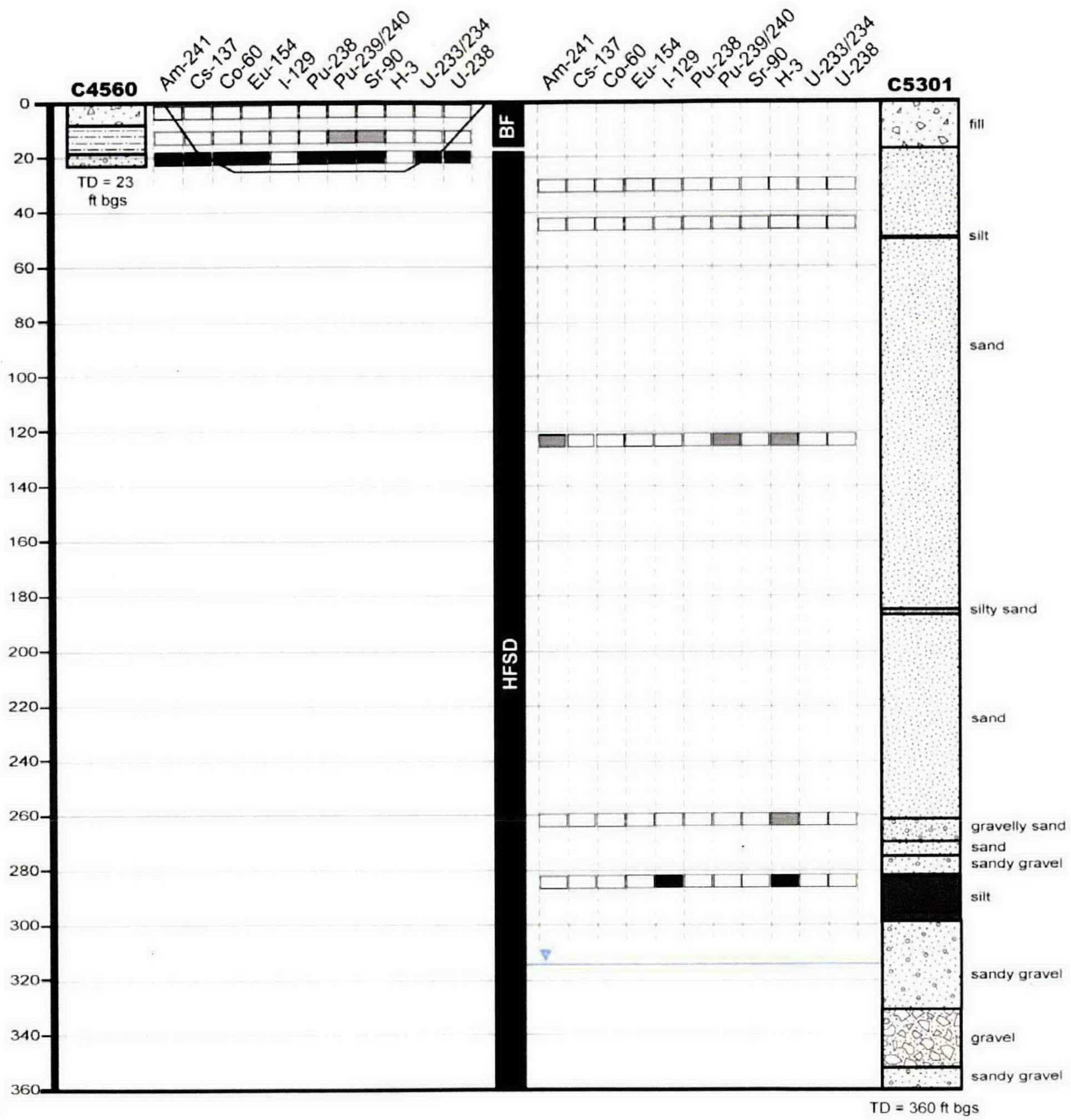
bgs = below ground surface.

Table 4-9. Maximum Detected Non-Radionuclide Concentrations at 216-A-4 Crib Borehole C5301

Non-Radionuclide Constituent	Lognormal 90th Percent Background Concentration (mg/kg)	Laboratory-Detected Maximum Concentration (mg/kg)	Depth of Maximum Concentration (bgs)
Chromium (trivalent)	18.5	25	86.3–86.9 m (283.0–285.0 ft)
Cyanide	ND	0.89	8.8–9.6 m (29.0–31.5 ft)
Nitrate (as N)	52	185	86.3–86.9 m (283.0–285.0 ft)
Nitrite (as N)	ND	0.427	13.1–13.9 m (43.0–45.5 ft)
Phosphate	0.785	4.2	13.1–13.9 m (43.0–45.5 ft)
Oil and Grease	ND	250	8.8–9.6 m (29.0–31.5 ft)

ND = background concentration not determined

bgs = below ground surface



FORMATION LEGEND	STRATIGRAPHIC LEGEND	CONSTITUENT LEGEND
BF - Backfill	Backfill	Highest Values
CG - Cemented Gravel	Sand	> Background
G - Gravel	Silt	< Background or PAL[1]
HFSD - Hanford formation: Sand Dominated	Silty Sand	[1] DOE/RL-2006-47 and DOE/RL-2006-77
S - Sand to Silt	Sandy Gravel	
SG - Sandy Gravel	Gravelly Sand	
Si - Silt	Gravel	

216-A-4 Crib - Borehole C4560 & C5301 - Radionuclides Exceeding Background or No Background [1]

A-4 Sample Depth	Am-241	Cs-137	Co-60	Eu-154	I-129	Pu-238	Pu-239/240	Sr-90	H-3	U-233/234	U-238
ft bgs	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
Borehole C4560											
0.5-3	BB	BB	ND	ND	ND	ND	BB	BB	ND	BB	BB
12.5-14.5	0.088	ND	ND	ND	ND	ND	0.45	0.37	ND	ND	ND
18.5-20.5	3,810	63,600	14.3	179	ND	209	21,400	3,860,000	ND	478	683
Borehole C5301											
29-31.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	BB	BB
43-45.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	BB	ND
122-124	0.045	ND	ND	ND	ND	ND	0.067	ND	13.1	BB	BB
260-262	ND	ND	ND	ND	ND	ND	BB	ND	511	BB	BB
283-285	ND	ND	ND	ND	1.04	ND	ND	ND	1,100	BB	BB

1 Background values are provided in Table 4-2
BB Value detected was below background
ND Not detected
NA not available
NR no result reported

Am Americium; Cs Cesium; Co Cobalt; Eu Europium; I Iodine; Pu Plutonium; Tc Technetium; Sr Strontium (total beta); H-3 Tritium; U Uranium

[box] Maximum Concentrations

Comparison of RI-derived radionuclide data to Work Plan (DOE/RL-2001-65) conceptual distribution model

- According to the Work Plan, the liquid discharged to the waste site contained low-concentration radionuclides including: Cs-137, Cobalt-60, Pu-238, Pu-239/240 and Sr-90. The RI-characterization data from the C4560 borehole, which was completed through the crib, showed higher concentrations for Am-241, Cs-137, Cobalt-60, Pu-238, Pu-239/240 and Sr-90 than anticipated based on the effluent waste stream characteristics. Data from Borehole C5301, completed outside the crib, showed low concentration detections of Am-241, Pu-239/240, I-129, and H-3, as would be expected from the high volume, low concentration discharge. The Hanford Soil Inventory Model (RPP-26744) shows a site-waste inventory of approximately 64.5 Ci of tritium, 8.8 Ci of plutonium, 4.1 Ci of Sr-90, 4.9 Ci of Cs-137, and 1.8 Ci of U-238.
- The Work Plan conceptual contaminant distribution model indicates that waste constituents were expected to migrate vertically beneath the crib after release. Some lateral spreading of liquids and contaminants was expected, based on the data provided in a prior geophysical log completed in nearby well 299-E24-54. No distinct lithologic horizons associated with the spreading were identified at that the time this logging was conducted. The RI-characterization data from borehole C5301 indicates that minor lateral spreading of effluent has occurred underneath the crib within the sand-dominated sequence of the Hanford formation. The extent of vertical contaminant migration directly below the crib has not been determined, due to the termination of borehole C4560 at 23 ft bgs. The vertical extent of the contaminants of concern adjacent to the crib, as noted in borehole C5301, was as expected, with high mobility contaminants like H-3 and I-129 detected at a greater depth.
- Contaminants such as Cs-137 and the Plutonium isotopes with high distribution coefficients (Kd) normally adsorb strongly onto shallow zone sediments. These less mobile contaminants would be detected near points of release in the vadose zone. Contaminants with low Kd values (e.g.: tritium and I-129) are not readily adsorbed on soil particles and migrate to greater depth within the vadose zone. Tritium with a Kd value equal to 0 will migrate vertically with the wetting moisture front. Data provided from boreholes C4560 and C5301 support this assumption. Borehole C4560 showed that low mobility constituents (Am-241, Cs-137, Pu-239/240, Sr-90) were concentrated near the base of the crib, close to their point of release. Due to the shallow termination of borehole C4560, evaluation of the distribution of high mobility contaminants directly below the crib was not completed. High mobility contaminants (H-3 and I-29) were detected within the C5301 borehole at approx. 283 ft bgs. concentrated at the top of a silt interval. Low concentrations of less mobile constituents Am-241 and Pu-239/240 were found at a deeper depth than was expected.
- The conceptual contaminant distribution model presented in the work plan indicated that immobile contaminants were expected to be detected high above the water in the vadose zone. The concentration of high Kd contaminants would generally decrease with depth. Mobile contaminants were expected to be detected at very low concentrations throughout the vadose zone, and their concentrations could actually increase with depth. Based on the RI-characterization data of the C4560 and C5301 boreholes these assumptions are generally supported.
- Based on existing groundwater data, contaminants detected above maximum contaminant levels in the groundwater near this waste site are tritium and I-129. Based on the RI-characterization data obtained from borehole C5301, the effluent discharge to the 216-A-4 crib has not impacted groundwater.

Crib Construction Diagram (typical)

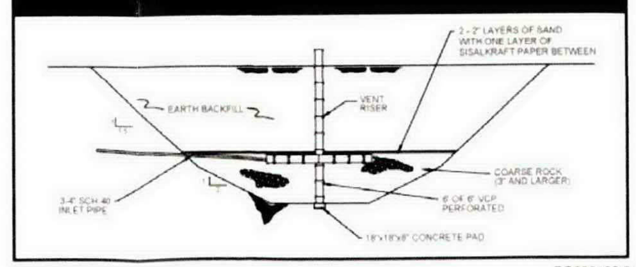


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Figure 4-9. Stratigraphy and Radionuclide Constituents at the 216-A-4 Crib

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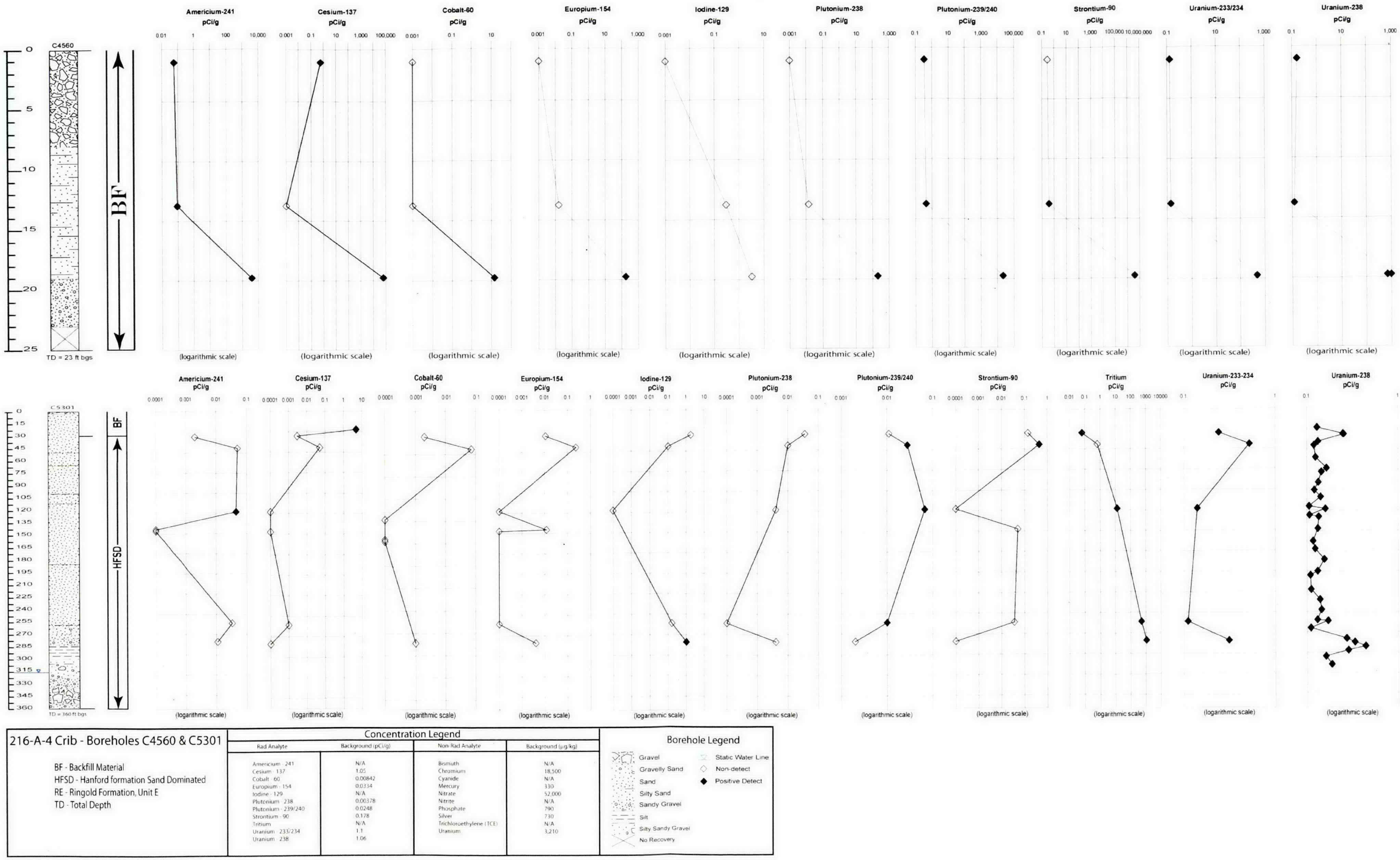

Figure 4-10. Vertical Contaminant Distribution (Radionuclides) in Borehole C4560 and Borehole C5301 at the 216-A-4 Crib

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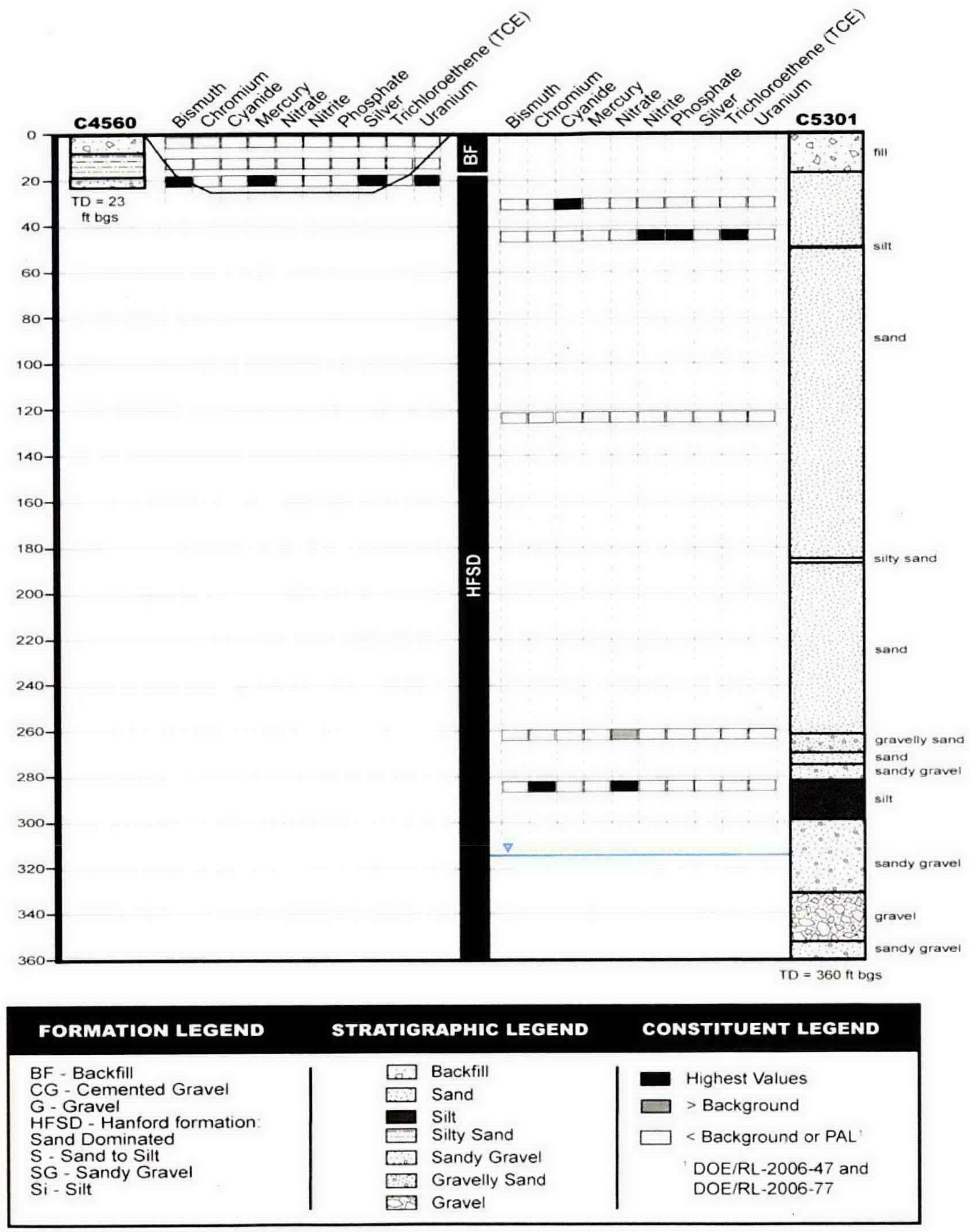


216-A-4 Crib - Borehole C4560 and C5301 - Non-Radionuclides Exceeding Background or PAL[1]

A-4 Sample Depth ft bgs	Bismuth mg/kg	Chromium mg/kg	Cyanide mg/kg	Mercury mg/kg	Nitrate mg/kg	Nitrite mg/kg	Phosphate mg/kg	Silver mg/kg	TCE mg/kg	Uranium mg/kg
Borehole C4560										
0.5 - 3	ND	BB	ND	ND	BB	ND	ND	ND	ND	ND
12.5 - 14.5	ND	BB	ND	ND	ND	ND	ND	ND	ND	ND
18.5 - 20.5	144	BB	ND	0.920	BB	ND	ND	2.20	ND	1,970
Borehole C5301										
29 - 31.5	NA	BB	0.890	ND	ND	ND	ND	ND	ND	BB
43 - 45.5	NA	BB	ND	ND	BB	0.427	4.20	ND	ND	BB
122 - 124	NA	BB	ND	ND	BB	ND	ND	ND	ND	BB
260 - 262	NA	BB	ND	ND	92.50	ND	ND	ND	ND	BB
283 - 285	NA	25	ND	ND	185	ND	ND	ND	ND	BB

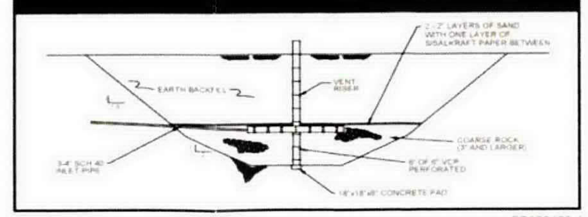
1 Background values are provided in Table 4-2
BB Value detected was below background
ND Not detected
NA not available
NR no result reported

TCE Trichloroethene
[boxed] Maximum Concentrations

Comparison of RI-derived non-radionuclide data to Work Plan (DOE/RL-2001-65) conceptual distribution model

- According to the Work Plan, which is based on DOE-RL 1997 ("Waste Site Grouping for 200 Areas Soil Investigations"), the liquid discharged to the waste site contained low-concentration non-radionuclides, including nitrate and dichromate. The more recent Hanford Soil Inventory Model (RPP-26744) indicates that the waste stream contained significant quantities of potassium, nitrate, and uranium. RI characterization data from borehole C4560, drilled to a depth of 7 m (23 ft) within the crib, showed elevated concentrations of non-radionuclides including bismuth. Characterization data from borehole C5301, drilled to a depth of 110 m (360 ft) just outside the crib boundary, showed elevated concentrations of nitrate.
- The Work Plan conceptual contaminant distribution model indicates that waste constituents were expected to migrate vertically beneath the crib after release. Limited lateral spreading was expected, based on geophysical logging in well 299-E24-54 which is located just beyond the crib boundary to the northeast. Recent geophysical logging in borehole C5301 confirmed little lateral migration of contaminants. The extent of vertical contaminant migration beneath the crib has not been completely characterized since borehole C4560 was terminated at a shallow depth and borehole C5301 was not optimally located to penetrate the crib. However, vertical contaminant migration in borehole C5301 is generally consistent with that predicted in the conceptual contaminant distribution model, showing elevated concentrations of the mobile non-radionuclide constituent nitrate at a depth of 285 ft bgs.
- Borehole C4560 showed that strongly sorbed, low-mobility contaminants such as bismuth are detected in the bottom portion of the crib fill material. This is consistent with the conceptual contaminant distribution model, which predicted that immobile contaminants would be found near the point of release. However, trivalent chromium shows a maxima at the top of the silt layer at 285 ft bgs. Since trivalent chromium has a low mobility (i.e., high Kd), and since the concentration in question is only slightly above the background, it is possible that the source may be in-situ metallic minerals within the Hanford formation sediments.
- Although later work shows that the inventory presented in the Work Plan is inappropriate, the conceptual contaminant distribution model is generally supported, with immobile contaminants found near the point of discharge and mobile contaminants found at considerable depth within the vadose zone.
- PNNL-16346, the most recent groundwater report, shows that nitrate is detected above the maximum contaminant level (MCL) near the 216-A-4 Crib. Based on the RI characterization data obtained from borehole C5301, the effluent discharged to the 216-A-4 Crib may have impacted groundwater.

Crib Construction Diagram (typical)



FG080123.1

DOE/RL-96-81, *Waste Site Grouping for 200 Areas Soil Investigations*
PNNL-16346, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*

DOE/RL-96-81, *Waste Site Grouping for 200 Areas Soil Investigations*
PNNL-16346, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*

Figure 4-11. Stratigraphy and Non-Radionuclide Constituents at the 216-A-4 Crib

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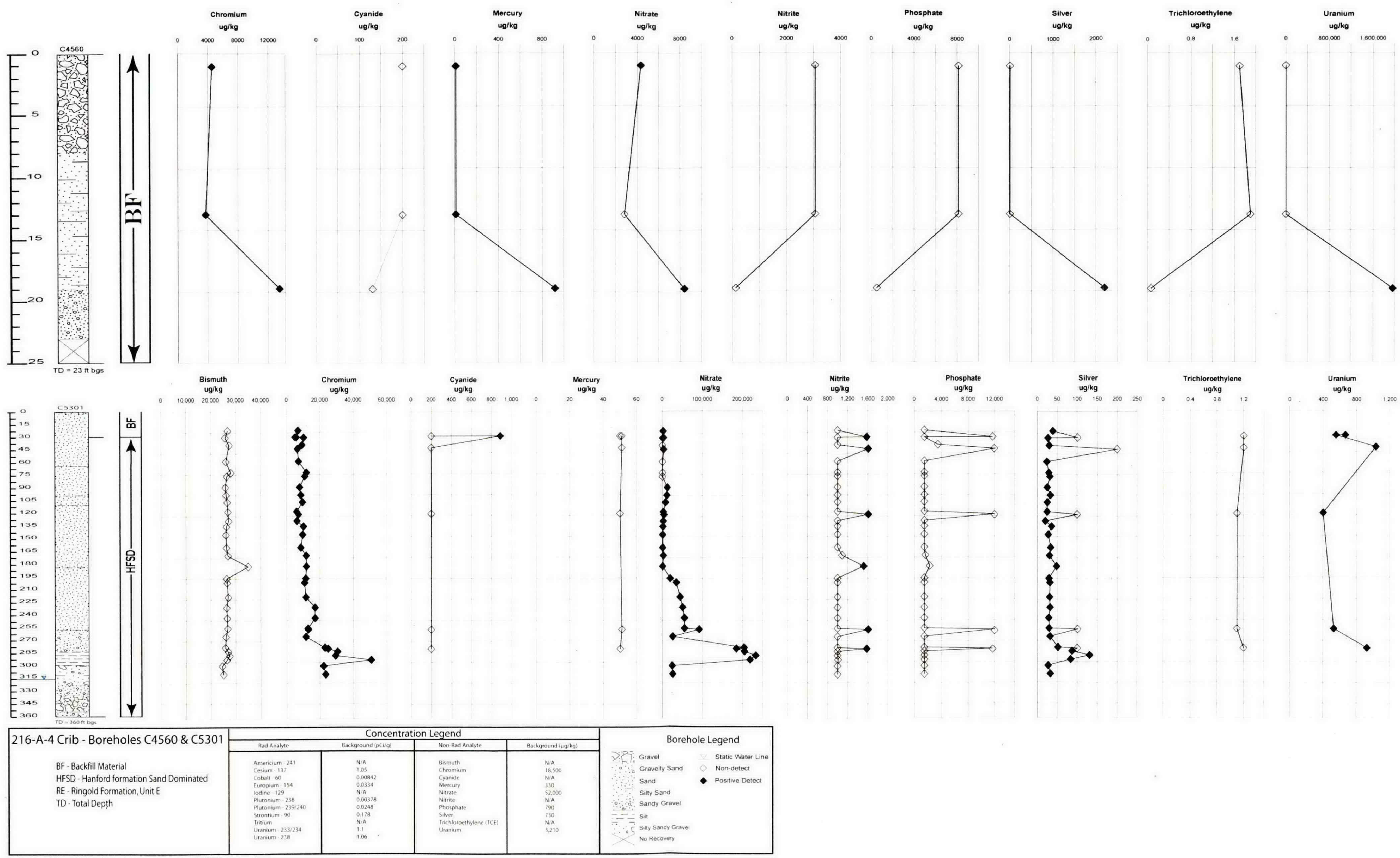

Figure 4-12. Vertical Contaminant Distribution (Non-Radionuclides) in Borehole C4560 and Borehole C5301 at the 216-A-4 Crib

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200-MW-1 Operable Unit

216-A-4 Crib

200 East Area

HISTORY

The 216-A-4 crib is an inactive liquid waste disposal site that received liquid waste including laboratory cell drainage from the 202-A Building (PUREX). Liquid drainage from the 291-A-1 stack may have also been discharged to this crib. The waste was low in salt, with a neutral to basic pH. In 1958, the crib plugged causing liquid effluent to flood an area between the crib and the 291-A-1 Stack. Contaminated soils and asphalt were removed and placed in the adjacent 200-E-102 Trench, which lies along the crib's southern boundary.

Construction: The site is a square, gravel-filled crib with a soil and gravel cover. The bottom dimensions are 20 ft. x 20 ft. The maximum depth from original grade is 26 ft. The sides are sloped 2:1 from the bottom to 18 ft bgs and at 1.5:1 to the surface. The bottom 8 ft is filled with coarse gravel, the remainder with soil (gravelly sand). Distribution pipes at 18 ft bgs (top of the gravel) discharged liquid effluent to the crib gravel.

Waste Volume: 6,210,000 liters (1,640,700 gallons)

Duration: December 1955 to December 1958. The crib was replaced by the 216-A-21 crib.

Inventory of High Mobility Constituents:

		Inventory		
Constituent	Units	Mean	Low	High
Tritium	Ci	64	32	99
Tc-99	Ci	0.57	0.32	0.84
N03	kg	95,400	73,500	121,800

Low = 5th percentile
High = 95th percentile

Inventory of Low Mobility Constituents:

		Inventory		
Constituent	Units	Mean	Low	High
Cs-137	Ci	4.9	1.7	9.0
Pu-239/240	Ci	1.5	0.3	3.6
Sr-90	Ci	4.1	1.4	7.7
U- Metal	kg	5,400	1,839	10,400

Low = 5th percentile
High = 95th percentile

BASIS OF KNOWLEDGE

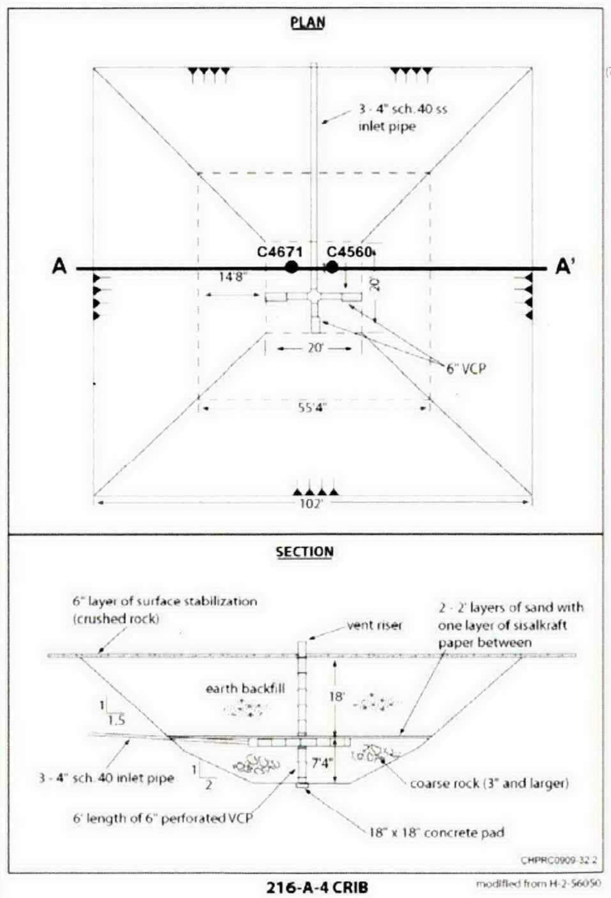
- Process History (Drawings and WIDS)
- SIM (RPP-26744)
- Sampling and Analysis
- Borehole Geophysical Logging
- Geologic Logs (GL)

CHARACTERIZATION SUMMARY

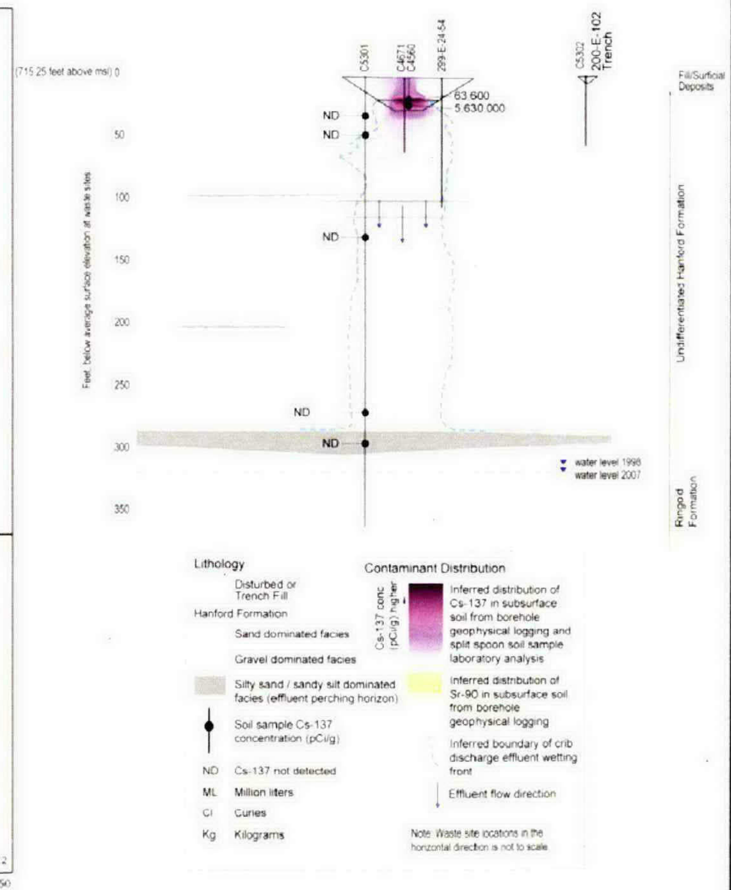
- C4560: Direct push borehole through crib center to a depth of 23 ft bgs. Three split spoon samples collected.
- C4671: A direct push borehole through crib center to a depth of 60 ft bgs. Geophysically logged.
- 299-E24-23 (C5301): Monitor well installed outside crib footprint to a 360 ft bgs. Split spoon sampling and geophysical logging.
- 299-E24-54: Existing 100 ft deep vadose zone monitor well installed near the NW corner of the crib. Geophysically logged.

Waste Site: 216-A-4 Crib

Site Construction



Contaminant Distribution



Potential Viable Alternatives

● NO ACTION ● ICs/MNA ● BARRIER ● REMOVE, TREAT, DISPOSE

UNCERTAINTY SUMMARY

The primary uncertainty at the 216-A-4 crib is the concentration of contaminants present beneath the crib footprint. Boring C4560, which was advanced through the center of the crib, had to be terminated at a depth of 23 ft bgs due to unexpectedly high field radionuclide activity levels. Direct push boring C4671, installed as a replacement, provides geophysical logging data only. There is also uncertainty on the contaminant concentrations present within soil at 0 to 15 ft bgs because geophysical logging detected Cs-137 activity while analytical soil sampling did not.

NATURE AND EXTENT

Medium/low mobility radionuclide contaminants beneath the 216-A-4 crib are concentrated within the zone extending from the base of the crib to a depth of 40 ft bgs. Radionuclides may also occur at lower concentrations within shallow soil (0-15 ft bgs) as evidenced by borehole geophysical logging data. Laboratory analysis of soil samples collected near the edge of the crib indicate that the lateral extent of radionuclides occurs primarily within the crib footprint.

Direct Exposure: Radionuclide and non-radionuclide contaminants were not detected above screening levels in the split spoon samples collected from 0 to 15 ft bgs. However, geophysical logging indicated Cs-137 may occur within this zone. Based on these findings, the direct exposure (industrial land use) pathway may be complete.

Ecological Exposure: Based on laboratory analysis of the split spoon samples, the direct contact exposure pathway for ecological exposure is incomplete. Active management controls and lack of biological activity within the 0 to 15 ft bgs depth interval precludes exposure. However, there may be some exposure potential as described in the Uncertainty section above.

Groundwater Protection: Uranium metal and nitrate concentrations in soil at the 216-A-4 Crib were greater than their respective soil to groundwater protection screening concentrations. Groundwater sampling performed at C5301 detected uranium metal at 79.5 µg/L. The absence of Uranium in the silty 15 feet above the water table, appears to indicate the 216-A-4 Crib is not the source of the uranium.

- Nitrate was not evaluated further because concentrations are declining in the area south of PUREX (Appendix A).
- RESRAD modeling was not performed because contaminant levels in soil beneath the crib were not detected.

Figure 4-13. Conceptual Site Model for the 216-A-4 Crib

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Soil data from the one boring located within the crib boundary (C4560) and one boring immediately adjacent to the crib (C5301 for Well 299-E24-23) were used to evaluate the distribution of contaminants present in soil. The primary findings from these two boreholes include:

- Results for interior borehole C4671 indicate that the December 1958 plugging event resulted in contamination of the soil overlying the crib rock with Cs-137. Geophysical logs for C4671 show Cs-137 concentrations ranging from 36 to 84 pCi/g between ground surface and a depth of 3.6 m (12 ft) bgs. However, soil data for shallow samples collected from crib borehole C4560 are not consistent with geophysical results from C4671. Cs-137 was not detected in the soil samples collected at depths between 0.15 to 0.9 m (0.5 to 3 ft) bgs and from 3.7 to 4.6 m (12 to 15 ft) bgs.

- Geophysical logs for interior borehole C4671 showed Cs-137 concentrations up to 236 million pCi/g near the top of the crib rock at 6 m (20 ft) bgs. Consistent with this result, Cs-137 concentrations detected in soil samples from borehole C4560 were 63,600 pCi/g at a depth of 6 m (19.75 ft) bgs and 5,630,000 pCi/g at a depth of 6.9 m (22.5 ft) bgs. This is the highest observed Cs-137 concentration detected in any soil samples collected from the 200-MW-1 OU waste sites. The vertical distribution of contaminants at 216-A-4 Crib differs from that observed at other 200-MW-1 OU in that the highest observed concentrations occur within the crib rock rather than just below the bottom of the crib rock.

- The level of Cs-137 detected in borehole C4671 below the bottom of the crib (8.2 m [27 ft] bgs) is uncertain due to probable internal casing contamination (Stoller report DOE-EM/GJ827-2005, *C4671 Log Data Report*). The sharp peaks observed at depths of 10.7, 13.7, and 16.8 m (35, 45, and 55 ft) bgs probably represent contamination accumulated at the casing joints. The Cs-137 levels appear to range from 60,000 to 700,000 pCi/g in the vicinity of these peaks. Part, and perhaps all, of this contamination is believed to be internal casing contamination.

- Outside the crib footprint at borehole 299-E24-54, the 2005 geophysical logging detected Cs-137 at three primary depth intervals. At depths between 0.76 and 1.7 m (2.5 and 5.5 ft) bgs, Cs-137 was detected at concentrations between 0.7 and 1.16 pCi/g. This may be a result of the plugging and flooding of the crib in 1958. At depths between 8.8 and 11 m (29 and 36 ft) bgs, Cs-137 concentrations ranged from approximately 0.7 to 50 pCi/g. At depths between 19.5 and 27.7 m (64 and 91 ft) bgs, Cs-137 concentrations ranged from approximately 0.18 to 55 pCi/g.

- In the same 2005 logs, Co-60 was detected at two depth intervals, between 8.8 and 16.4 m (29 and 54 ft) bgs and between 19.8 and 21 m (65 and 69 ft) bgs. The maximum observed concentration of approximately 2 pCi/g was detected at a depth of 13.9 m (45.5 ft) bgs.

- The geophysical log for borehole C5301 (Well 299-E24-23) also detected Cs-137. Concentrations ranging from 2.5 to 6 pCi/g were detected in the 0.3 to 2 m (1 to 6 ft) bgs depth interval. At depths between 14 and 23 m (46 and 76 ft) bgs, Cs-137 concentrations ranged from approximately 1 to 15 pCi/g, with the maximum concentration occurring at 14.6 m (48 ft) bgs.

- The 216-A-4 Crib reportedly received 4.14 Curies of Sr-90 and 4.86 Curies of Cs-137 in 6.21 million L of liquid effluent. These inventories correspond to an estimated effluent concentration (decayed to January 1, 2001) of 73,600 pCi/L of Sr-90 and 86,300 pCi/L for Cs-137. Assuming Kd values of 22 mL/g for Sr-90 and 2000 mL/g for Cs-137, the estimated concentration for these constituents in soil based on the predicted effluent concentrations would be 1600 pCi/g for Sr-90 and 170,000 pCi/g for Cs-137. SGW-44795 indicates that the ionic strength of the solutions discharged at the 216-A-4 Crib would have been about three times greater than for the solutions discharged at the 216-A-2 Crib potentially allowing for greater migration of Cs-137 at the 216-A-4 Crib. In addition, the total effluent volume was about 27 times greater than discharged to the 216-A-2 Crib, with the total effluent discharge volume exceeding the estimated pore volume by a factor of 6 times (DOE/RL-96-81, Table 1).

- The tritium concentration of 1,100 pCi/g observed at the top of the silt unit encountered at a depth of 87 m (285 ft) bgs was similar to the 2,960 pCi/g observed at 216-A-2 Crib borehole C5515.

4.2.3 216-A-21 Crib

The RI characterization drilling at the 216-A-21 Crib did not include sampling to confirm crib construction information.

4.2.3.1 Primary Sources and Waste Characteristics

WIDS (WIDS 2008) reports that the 216-A-21 Crib received 77,900,000 L (20,600,000 gal) of sump waste from the 293-A Building, laboratory cell drainage from the 202-A Building, and drainage from the 291-A Stack. The SIM reports the crib received 70,100,000 L (18,500,000 gal) of liquid waste. The waste stream was characterized as predominately a sodium nitrate solution with significant amounts of calcium, ammonium, carbonate, and chloride. The 216-A-21 Crib is also associated with the 202-A Facility, 291-A, 293-A, and 200-E-103. Pipeline 200-E-193-PL is associated with this crib.

The inorganic compounds with the largest inventory (Table 4-3) discharged to the crib included nitrate at 320,000 kg (704,000 lbs), ammonium at 66,300 kg (145,860), calcium at 28,100 kg (61,820), and iron at 8,160 kg (17,950). The radionuclides with the largest inventory discharged to the crib included 63.7 Ci of Cs-137, 49.5 Ci of tritium, 10 Ci of Pu-241, 6.1 Ci of Sr-90, and 4.6 Ci of Am-241.

4.2.3.2 Field Investigation Activities

A single direct-push borehole C5571 was advanced to a total depth of 18.3 m (60 ft) bgs within the crib footprint. Five split-spoon samples were collected at depths of 5.8 to 6.3 m (19.1 to 20.8 ft) bgs, 6.4 to 6.9 m (21.0 to 22.5 ft) bgs, 7.7 to 8.1 m (25.1 to 26.6 ft) bgs, 11.9 to 12.3 m (39.0 to 40.5 ft) bgs, and 17.7 to 18.3 m (58.2 to 59.9 ft) bgs. Following installation, the borehole was geophysically logged.

4.2.3.3 Borehole Geophysical Logging Summary

Geophysical logging of borehole C5571 was performed between August 1 and 6, 2007 using SGLS, HRLS, NMLS, and PNLS sensors (Appendix B). Cs-137 was detected throughout the borehole (Figure 4-14) with a peak concentration of 1.3 million pCi/g observed at a depth of 6.4 m (21 ft) bgs, which is about 0.5 m (1.5 ft) below the bottom of the crib. Cesium-137 concentrations decreased to less than 100 pCi/g at a depth of about 11.3 m (37 ft) bgs.

4.2.3.4 Borehole C5571 Laboratory Analysis Results

Table 4-10 summarizes the maximum detected concentrations for two of the five samples analyzed at the laboratory. The table does not include analyses from the ESL because the laboratory results do not include the required QA/QC samples (e.g., duplicates and splits). Appendix A provides the complete laboratory analysis results.

Shallow Soil. No samples were collected in the shallow zone interval from ground surface to a depth of 4.6 m (15 ft).

Deep Soil. Two organic compounds, 2-methyl butane and toluene, were detected at concentrations of 5.6 µg/kg and 0.56 µg/kg, respectively. Radionuclides with concentrations greater than background or without an available background were not detected in the split-spoon samples collected at depths below 4.6 m (15 ft).

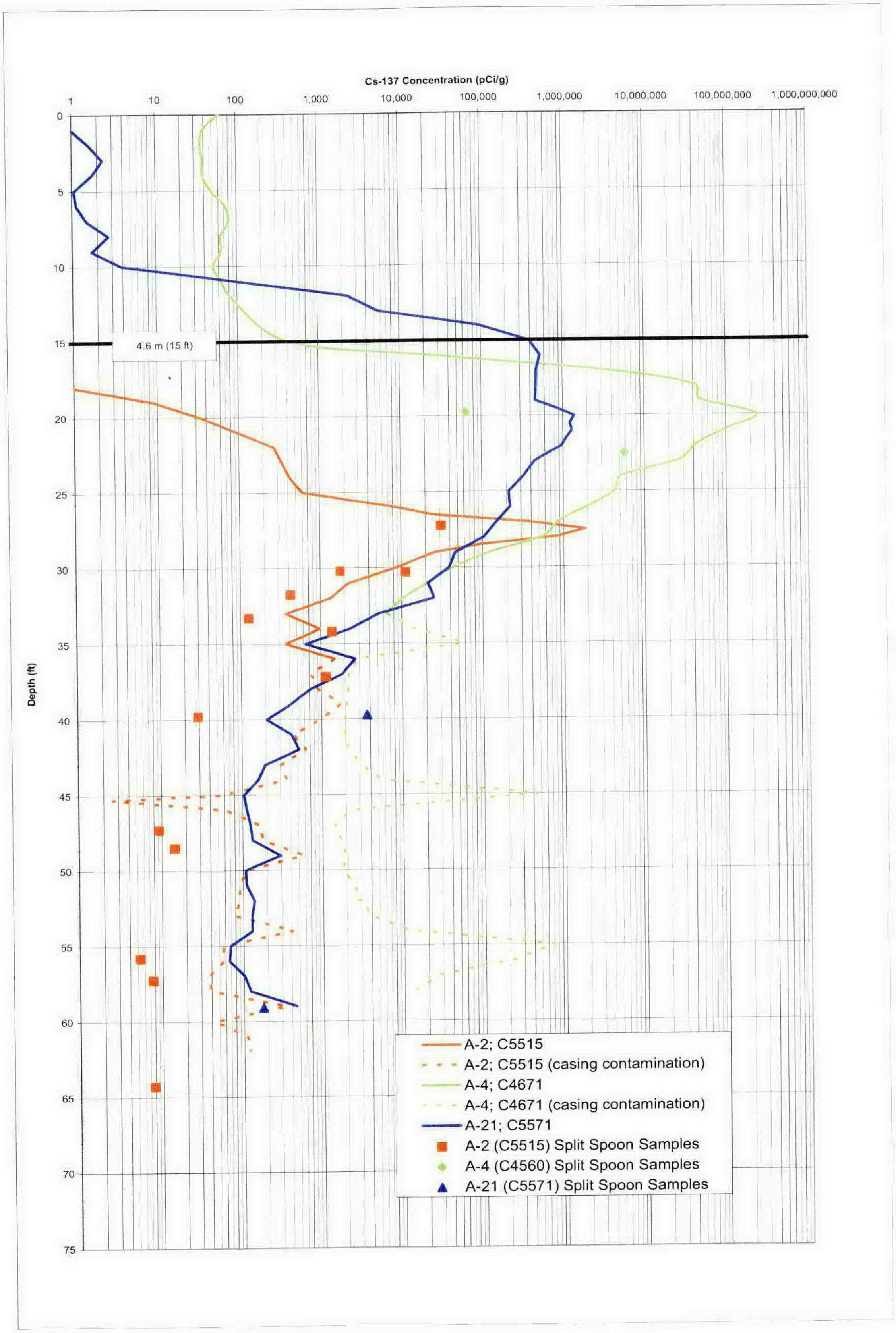

Figure 4-14. Geophysical Log for Borehole C5571 at the 216-A-21 Crib

Table 4-10. Non-Radionuclides Detected in 216-A-21 Crib Borehole C5571 Deep Soil Samples

Non-Radionuclide Constituent	Lognormal 90th Percent Background Concentration (µg/kg)	Maximum Detected Concentration (µg/kg)	Depth of Maximum Concentration (ft-bgs)
Butane, 2-methyl	ND	5.6	7.7–8.1 m (25.1–26.6 ft)
Toluene	ND	0.56	7.7–8.1 m (25.1–26.6 ft)

Notes: These analyses do not have available background values.
bgs = below ground surface

4.2.3.5 Summary and Discussion

The concentration and vertical distribution of radionuclide and non-radionuclide constituents detected above background in the soil samples collected from borehole C5571 are shown on Figure 4-15. A CSM is presented in Figure 4-16.

Two borehole grab samples tested by ESL contained Cs-137. The sample collected at 11.9 to 12.3 m (39.0 to 40.5 ft) bgs contained Cs-137 at 3,700 pCi/g. The sample collected at 17.7 to 18.3 m (58.2 to 59.9 ft) bgs, contained Cs-137 at 180 pCi/g, a value that is generally consistent with the geophysical log.

The vertical extent of Cs-137 at the 216-A-21 Crib appears consistent based on the estimated K_d value and the large volume of fluid disposed. There are no other boreholes near the 216-A-21 Crib that could be used to assess the lateral contaminant distribution.

The 216-A-21 Crib reportedly received an order of magnitude more Cs-137 than the 216-A-2 and 216-A-4 Cribs, with an estimated 63.7 Ci discharged. This crib also has the highest inventories of nitrate, sodium, ammonium, calcium, iron, chloride, and carbonate. The ionic strength of the solution discharged to the crib is estimated to be about three times lower than the solution discharged to the 216-A-4 Crib. The lower ionic strength of the liquid effluent would tend to reduce the amount of lateral spreading that would occur. Thus, the estimated lateral extent of contaminant distribution is expected to be less than observed at the 216-A-4 Crib.

4.2.4 200-E-102 Trench

This trench was not originally designed as a waste site. Instead, this waste site was created as a repository for contaminated soil from 216-A-4.

4.2.4.1 Primary Sources and Waste Characteristics

The 200-E-102 Trench was used for disposal of contaminated soil caused by plugging of the 216-A-4 Crib in 1958. WIDS (WIDS, 2008) reports that the trench is 24.4 m (60 ft) in length, 3.1 m (10 ft) wide, and 1.2 m (4 ft) deep and that the contaminated soil was covered with 0.3 m (1 ft) of clean soil. WIDS describes the excavation as a "slit trench," perhaps because the trench was excavated with a bulldozer. Little information is available about the waste that was placed in the trench. WIDS reports that contaminated soil and blacktop located outside the 2191-A Turbine House (where the floor drains flooded when the 216-A-4 Crib plugged) was contaminated to 8 rads per hour as measured from a distance of 25.4 cm (10 in.). The material placed in the trench is assumed to contain this level of activity.

4.2.4.2 Field Investigation Activities

One direct-push borehole (C5302) was installed within the trench's reported footprint. Drilling was commenced on October 25, 2006, and the borehole decommissioning was completed on November 7, 2006. The total borehole depth was 17.2 m (56.4 ft) bgs. One split-spoon sample was collected at a depth of 16.7 to 17.2 m (54.9 to 56.4 ft) bgs; thus, the material placed in the trench was not directly sampled. Following installation, geophysical logging of the borehole was performed.

4.2.4.3 Borehole Geophysical Logging Summary

The geophysical logging showed a narrow zone of Cs-137 (Appendix B) at a depth extending from 11.0 to 12.8 m (36.0 to 42.0 ft) bgs with a peak concentration of 112 pCi/g observed at 11.m (38.0 ft) bgs. A small amount of Eu-154, approximately 3 pCi/g, was also reported between a depth of 14.5 to 16.5 m (48.0 and 54.0 ft) bgs. There is also an indication of bremsstrahlung radiation between 12.2 and 14.3 m (40.0 to 47.0 ft) bgs that might indicate the presence of Sr-90 (Appendix B).

4.2.4.4 Borehole C5302 Laboratory Analysis Results

No commercial laboratory analysis results were reported for the soil sample collected from this borehole.

4.2.4.5 Summary and Discussion

Based on geophysical logging, Cs-137 and Eu-154 are present at depths of 11.0 to 16.5 m (36.0 to 54 ft) bgs. This distribution does not agree with the disposal history of the trench because the material placed in the trench consisted of contaminated soil from the 216-A-4 Crib. The trench bottom is reported to be only 1.2 m (4 ft) deep, which is well above the depth at which the above radionuclides were detected.

The SGLS log for this borehole showed no radioactivity from the ground surface to a depth of 11.0 m (36.0 ft) bgs. Radionuclides at shallow depths should clearly be detectable if the contaminated soil was spread throughout the trench's length. Because it is possible that borehole C5302 was drilled in a location where no contaminated soil was placed, the distribution of contaminated soil in the trench may not be completely understood. Figure 4-17 presents a CSM for the trench.

4.3 Contaminant Distribution in Soil for the 200-MW-1 Uncharacterized Waste Sites

As described in Section 4.1, the supplemental RI did not include characterization at the 216-A-27 Crib. Therefore, information obtained from another waste site (216-A-5 Crib) which is not part of the 200-MW-1 OU, was used to assist in developing CSMs for this 200-MW-1 OU waste site. The 216-B-4 and 216-C-2 Reverse Wells were not sampled; however, process and construction knowledge was used to assess these waste units.

4.3.1 216-A-27 Crib

Based on design drawing H-2-57509, *Crib Details 216-A-27*, the bottom 1.6 m (5.3 ft) of the crib contains layers of varying gravel size. A distribution pipe 3.0 m (10 ft) bgs, just below the top of the crib rock, distributed the effluent. The crib rock is covered with a 0.1 m (0.2 ft) layer of sand, a polyethylene barrier, and earth backfill. The crib site is covered with crushed rock surface stabilization material (WIDS, 2008). The crib dimensions are 3 by 61 m (10 by 200 ft) at the bottom, 8.0 by 65.9 m (26 by 216 ft) at the top of the gravel, and 18.3 by 76.2 m (60 by 250 ft) at the ground surface.

The CSM for the 216-A-27 Crib is presented in Figure 4-18. The CSM is described briefly in this section, and is followed by a discussion of specific information and data used to develop the CSM. These include information on contaminant sources, SIM waste inventory estimates, and the estimated nature and extent of contamination.

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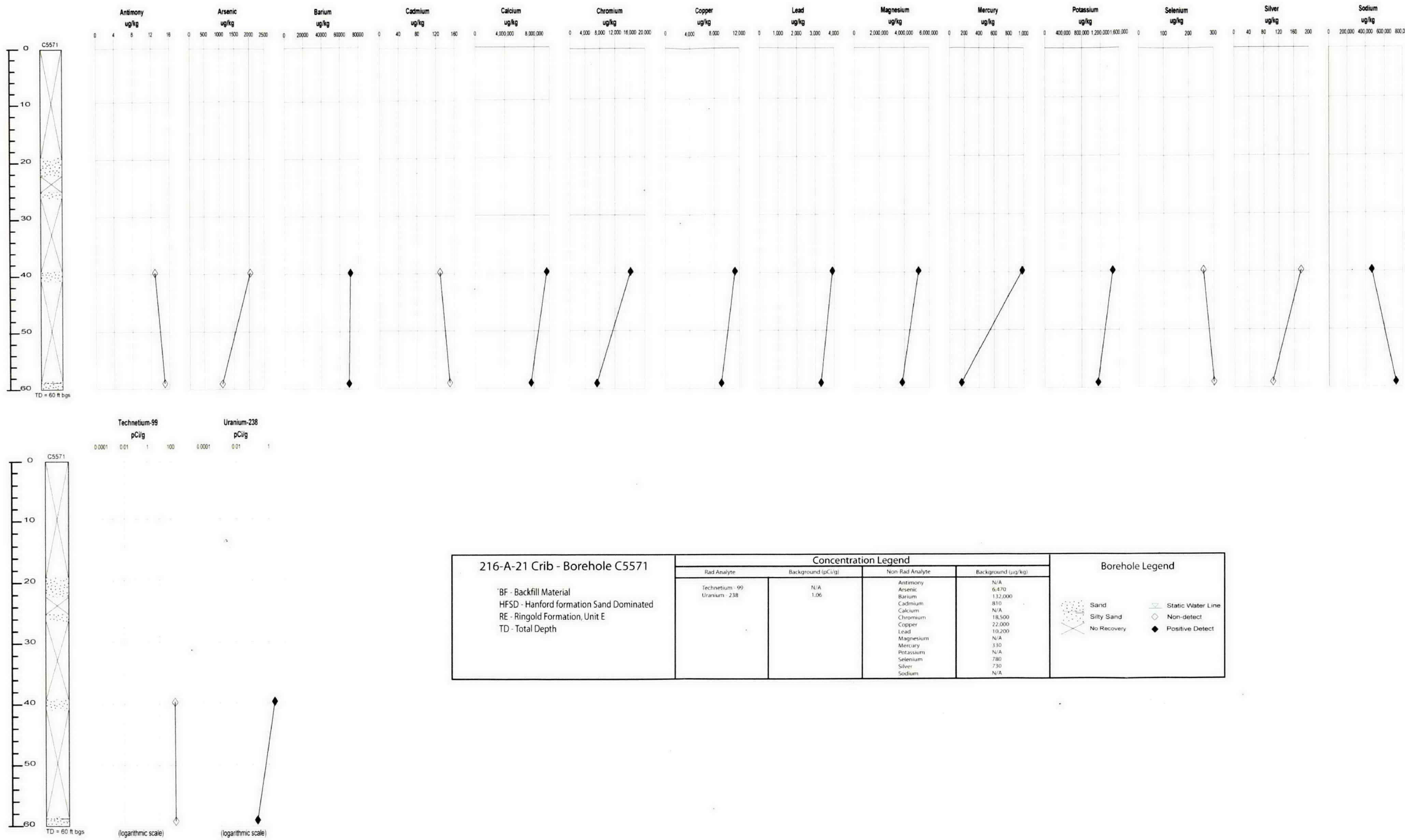

Figure 4-15. Vertical Contaminant Distribution (Radionuclides and Non-Radionuclides) in Borehole C5571 at the 216-A-21 Crib

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200-MW-1 Operable Unit | **216-A-21 Crib** | **200 East Area**

HISTORY

The 216-A-21 crib is an inactive liquid waste disposal site that received sump waste from the 293-A Building, laboratory cell drainage from the 202-A Building (PUREX), and 291-A-1 Stack drainage. SIM (RPP-26744) indicates the waste stream did not contain organics and was predominantly a sodium nitrate solution with significant amounts of calcium, ammonium, carbonate, and chloride.

Construction: The site is a V-shaped trench, 19.4 ft deep, 18 ft wide at the top of the gravel (13.4 ft bgs), and 50 ft long. The sides are sloped 1.5:1 from the bottom to the surface. The lower 6 ft is filled with coarse gravel, the remainder with native soil (gravelly sand). The distribution piping includes a horizontal section approximately 7 ft bgs and vertical (drain) pipes extending into the underlying gravel.

Waste Volume: 77,900,000 liters (20,580,000 gallons)

Duration: October 1957 to June 1965. Taken out of service for approximately 6 months in 1958 for distribution piping re-build. The site replaced the 216-A-4 crib and was in turn replaced by the 216-A-27 crib.

Inventory of High Mobility Constituents:

Constituent	Units	Inventory Mean	Low	High
Tritium	Ci	49	20	88
Tc-99	Ci	0.018	0.003	0.01
N03	kg	320,300	302,800	338,400

Low = 5th percentile
High = 95th percentile

Inventory of Low Mobility Constituents:

Constituent	units	Inventory Mean	Low	High
Cs-137	Ci	64	24	120
Pu-239/240	Ci	5.7	2.2	10.5
Sr-90	Ci	6.1	2.4	11
U- Metal	kg	195	37	460

Low = 5th percentile
High = 95th percentile

BASIS OF KNOWLEDGE

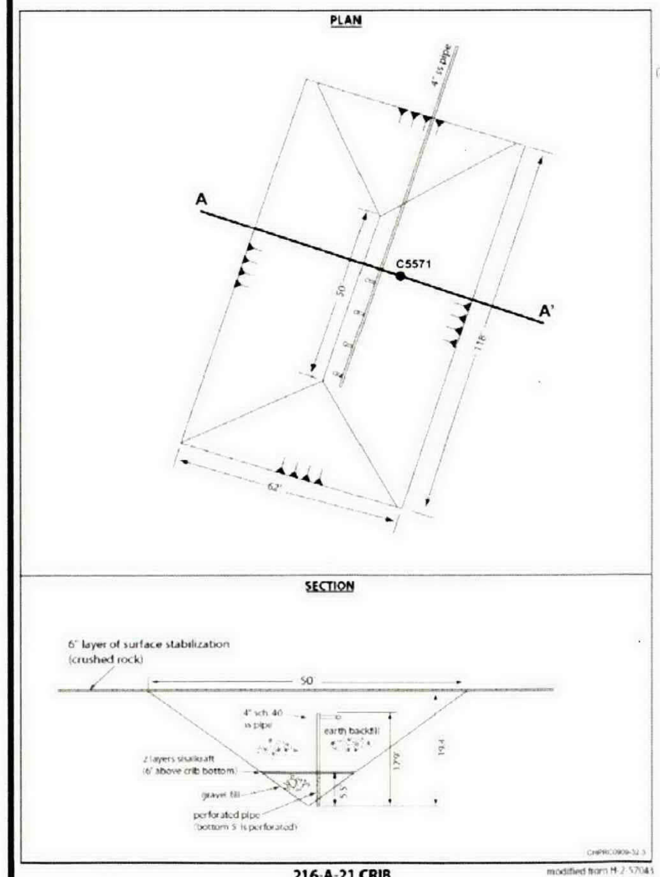
- Process History (Drawings and WIDS)
- SIM (RPP-26744)
- Limited Sampling and Analysis
- Borehole Geophysical Logging
- Geologic Logs

CHARACTERIZATION SUMMARY

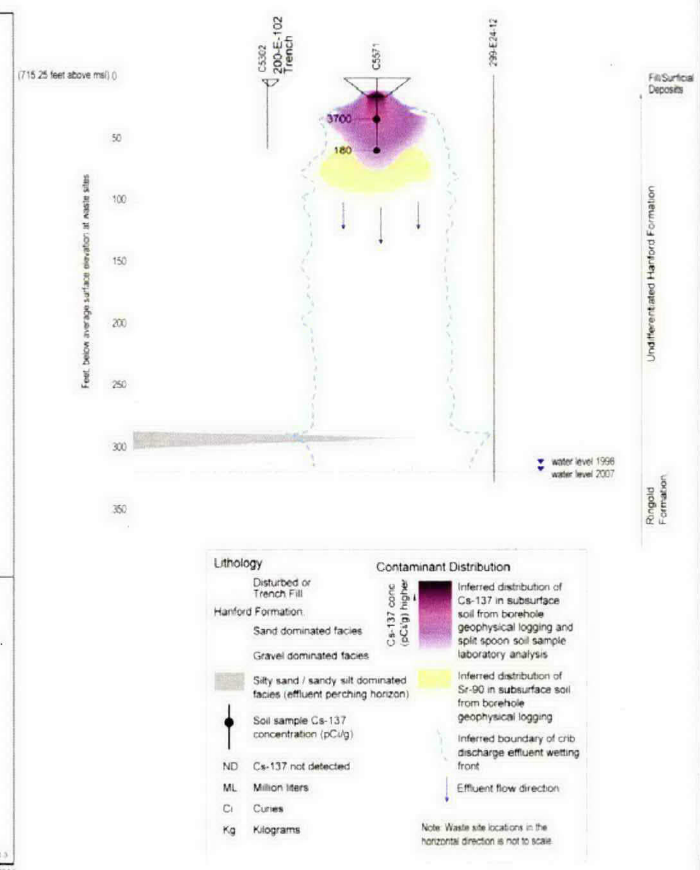
- C5571: A direct push borehole advanced through the center of the crib to a depth of 60 ft bgs. Five split spoon samples were collected between depths of 19.1 ft and 59.9 ft bgs and the borehole geophyscially logged.
- 299-E24-12: Monitor well located adjacent to crib footprint and installed to groundwater table.

Waste Site: 216-A-21 Crib

Site Construction



Contaminant Distribution



Potential Viable Alternatives

● NO ACTION ● ICs/MNA ● BARRIER ● REMOVE, TREAT, DISPOSE

UNCERTAINTY SUMMARY

The primary uncertainty is that no 0 to 15 ft bgs soil samples were collected from borehole C5571, and limited data is available to delineate the lateral and vertical contaminant distribution. Geophysical logging provides information for radionuclides through the center of the crib to a depth of 60 ft bgs.

NATURE AND EXTENT

Borehole geophysical logging detected Cs-137 near background levels at depths between 0 and 10 ft bgs, with activity steadily increasing to a peak value of 1.4 million pCi/g at a depth of 20 ft bgs just below the bottom of the crib. Cs-137 activity declines rapidly below the crib bottom stabilizing at about 100 pCi/g at a depth of 40 to 60 ft bgs. Based on similarities with the 217-A-27 crib, a zone of Sr-90 is inferred to be present below the base of the Cs-137 contaminated zone. The discharge volume to the 216-A-21 crib is the highest of any of the 200-MW-1 waste sites. Comparison to the 216-A-5 crib (not part of the 200-MW-1 OU), which had a much higher discharge volume, suggests that lateral contaminant spreading is limited to an area within the crib's footprint.

Direct Exposure: Soil samples were not collected from the 0 to 15 ft bgs depth interval to assess direct exposure. However, borehole geophysical logging detected Cs-137 at concentrations up to 400,000 pCi/g at depths between 10 and 15 ft bgs. Therefore, it is presumed there is potential for direct exposure risk at this waste site.

Ecological Exposure: Active management controls and a lack of biological activity currently preclude exposure. However, there is potential for ecological exposure in the 10 to 15 ft bgs depth interval if these controls are discontinued.

Groundwater Protection: RESRAD modeling performed for the 216-A-2 and 216-A-5 Cribs showed that only under unrestricted land use conditions only carbon-14 is transported to groundwater at concentrations that could exceed its MCL value. Because unrestricted land use is not expected, Carbon-14 will not exceed MCL in groundwater. Because the SIM estimate for carbon-14 at the 216-A-21 Crib is lower, adverse radionuclide groundwater quality impacts are not expected. Although the 216-A-21 Crib had nitrate and tritium inventories similar to or greater than other 200-MW-1 OU waste sites, nitrate and tritium concentrations in groundwater in the area south of PUREX are decreasing (see Appendix A). Therefore, future water quality impacts are expected to be less than historical.

Figure 4-16. Conceptual Site Model for the 216-A-21 Crib

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200-MW-1 Operable Unit

200-E-102 Trench

200 East Area

HISTORY

The 200-E-102 trench is an inactive waste disposal site that received contaminated soil and debris associated with plugging of the 216-A-4 crib. The plugging event flooded a portion of the 291-A Turbine House floor (when the floor drains flooded) and an area of pavement and soil outside the building. The soil was reported to have been contaminated at up to 8 rad per hour measured at a distance of 10 inches.

Construction: The site is a v-shaped, rectangular trench with an unlined bottom, and a soil and gravel cover. WIDS describes the excavation as a "slit trench". The bottom dimensions are reported to be 10 ft x 60 ft (assumed at the top of the contaminated soil). The maximum depth from original grade is approximately 4 feet. The sides are assumed to be sloped 1.5:1 from a depth of 4 ft to the surface. The bottom 3 ft is filled with contaminated material, the remainder with native soil (gravelly sand). A gravel cover of 0.5 to 1 ft in thickness overlies the contaminated soil.

Waste Volume: Not reported. No information is available on the amount of waste placed in the trench. However, from the trench dimensions, up to 1,200 cubic feet (44 cubic yards) of contaminated soil may be present.

Duration: 1958 (one time unplanned release).

Inventory of High Mobility Constituents:
Unknown

Inventory of Low Mobility Constituents:
Unknown

BASIS OF KNOWLEDGE

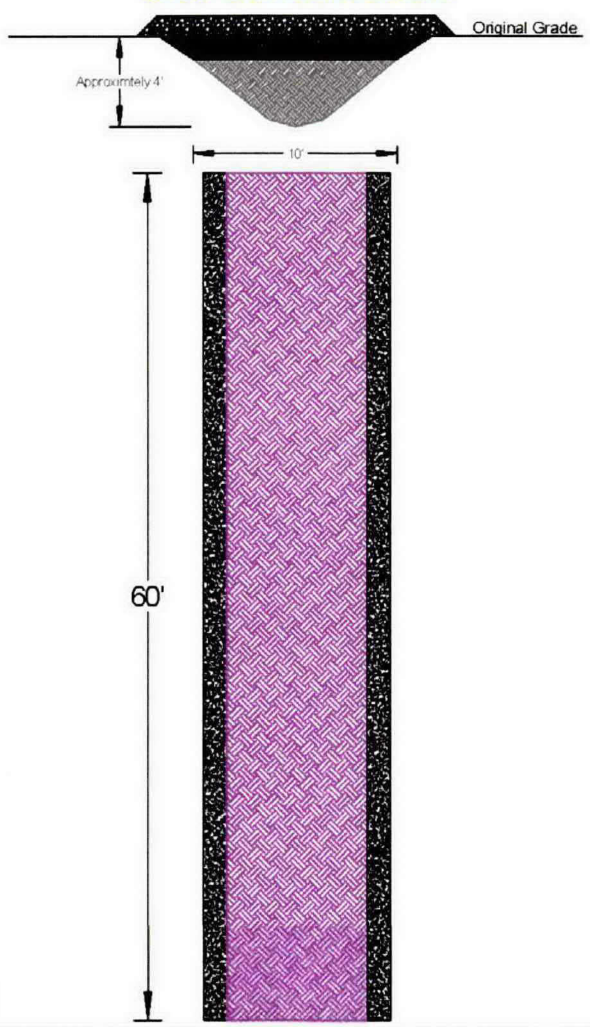
- Process History (Drawings and WIDS)
- Sampling and Analysis
- Borehole Geophysical Logging
- Geologic Logs

CHARACTERIZATION SUMMARY

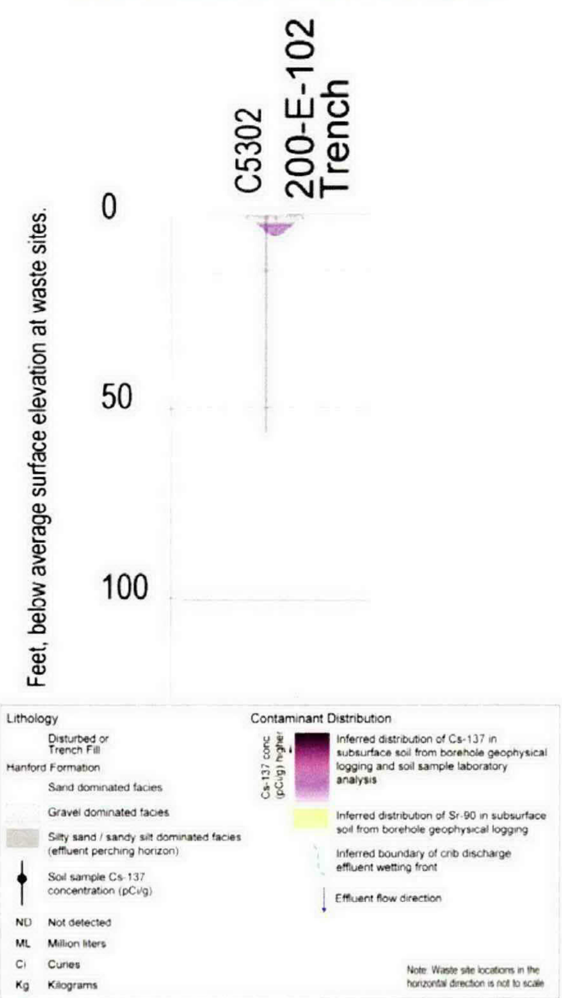
- C5302: A direct push borehole advanced to a depth of 56.4 ft bgs through the reported center of the trench. One split spoon sample collected at a depth of 54.9 to 56.4 ft bgs. Borehole also geophysically logged.

Waste Site: 200-E-102 Trench

Site Construction



Contaminant Distribution



Potential Viable Alternatives

● NO ACTION ● ICs/MNA ● REMOVE, TREAT, DISPOSE

Figure 4-17. Conceptual Site Model for the 200-E-102 Trench

UNCERTAINTY SUMMARY

The primary uncertainty at the 200-E-102 trench is that boring C5302 did not detect significant gamma activity in shallow soil. Relatively low levels of Cs-137 were detected at depths between 36 and 42 ft bgs, but are not believed to have originated from the trench. Uncertainty also remains whether the reported location of the trench is accurate, and therefore, whether the borehole was drilled in the correct location.

NATURE AND EXTENT

The extent of contamination is anticipated to lie with the trench footprint at a depth of less than 5 ft. Since no liquid waste was disposed of to the trench, significant migration of contaminants is not likely to have occurred.

Direct Exposure: Soil samples were not collected from the 0 to 15 ft bgs depth interval to assess direct exposure. However, due to the shallow depth that contaminated soil was reportedly disposed, and field gamma activity measurements of contaminated material (8 rads per hour), radionuclides are likely present at concentrations that could exceed acceptable risk levels.

Ecological Exposure: Active management controls and a lack of biological activity currently preclude exposure. However, there is potential for ecological exposure in the 1 to 4 ft bgs depth interval if these controls are discontinued.

Groundwater Protection: Due to the small volume of contaminated soil placed here, adverse groundwater quality effects are not expected.

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200-MW-1 Operable Unit

216-A-27 Crib

200 East Area

HISTORY

The 216-A-27 crib is an inactive liquid waste disposal site that received sump waste from the 293-A Building, laboratory cell drainage from the 202-A Building, and 291-A-1 Stack drainage. SIM (RPP-26744) indicates the waste stream did not contain organics and was predominantly a sodium nitrate solution with significant amounts of calcium, ammonium, carbonate and chloride.

Construction: The site is a rectangular, gravel-filled crib with a soil and gravel cover. The bottom dimensions are 200 ft x 10 ft at the top of the gravel. The maximum depth from original grade is approximately 15 feet. The sides are sloped 1.5:1 from the bottom to the surface. The bottom 5.3 feet is filled with coarse gravel, the remainder with native soil (gravelly sand). A distribution pipe 10 ft bgs discharged the effluent to the crib gravel.

Waste Volume: 23,100,000 liters (6,100,000 gallons)

Duration: 1965 to June 1970

Inventory of High Mobility Constituents:

			Inventory	
Constituent	Units	Mean	Low	High
Tritium	Ci	0.05	0.03	0.07
Tc-99	Ci	0.009	0.006	0.012
N03	kg	11,200	9,600	13,000

Low = 5th percentile
High = 95th percentile

Inventory of Low Mobility Constituents:

			Inventory	
Constituent	Units	Mean	Low	High
Cs-137	Ci	29	19	41
Pu-239/240	Ci	8.8	3.6	16
Sr-90	Ci	25	16	34
U- Metal	kg	65	22	130

Low = 5th percentile
High = 95th percentile

BASIS OF KNOWLEDGE

- Process History (Drawings and WIDS)
- SIM (RPP-26744)
- Monitor Well Geophysical Logging
- Geologic Logs

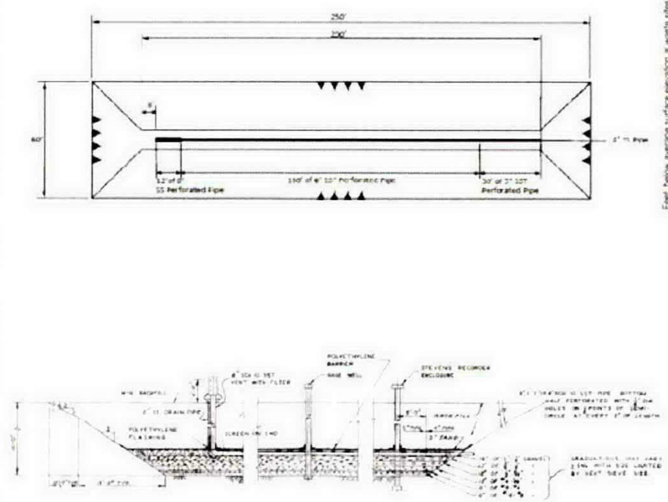
CHARACTERIZATION SUMMARY

- 299-E17-02: Monitor well constructed in 1960 to a depth of 406 ft bgs near the upstream end of the crib. The borehole was geophysically logged in 1963, 1968, 1970, 1975 and 2005, and has since been abandoned.

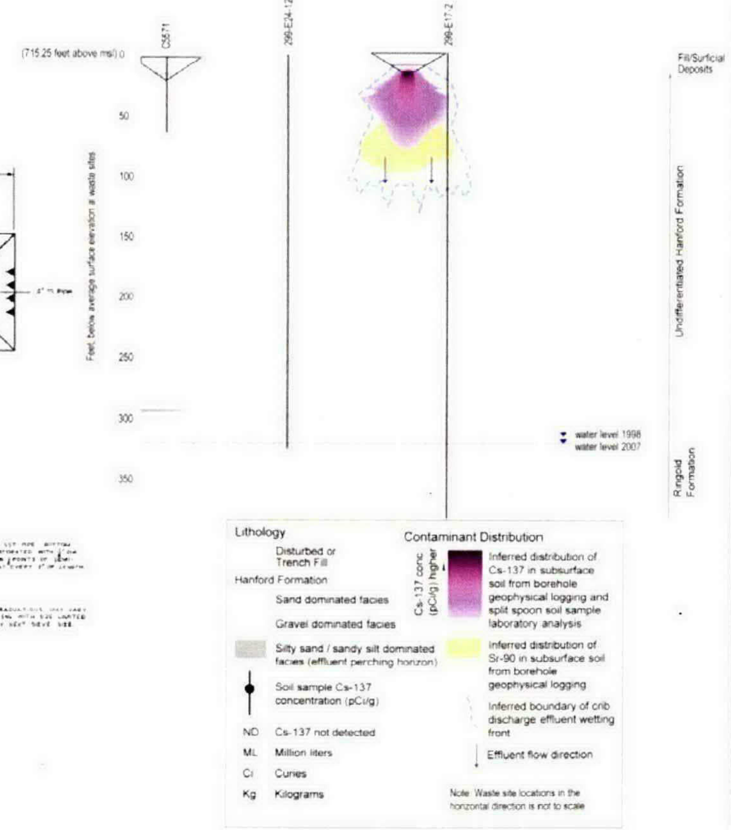
- 299-E17-03: Monitor well constructed in 1960 to a depth of 400 ft bgs near the downstream end of the crib. The borehole was geophysically logged in 1963, 1968, 1970, 1975 and 2005, and has since been abandoned.

Waste Site: 216-A-27 Crib

Site Construction



Contaminant Distribution



Potential Viable Alternatives

● NO ACTION ● ICs/MNA ● BARRIER ● REMOVE, TREAT, DISPOSE

UNCERTAINTY SUMMARY

The primary uncertainty is that no soil samples have been taken from the 0 to 15 ft bgs depth interval. Additionally, there is no borehole geophysical logging data for the subsurface zone beneath the crib. Monitor wells 299-E17-02 and 299-E-17-03 provide information along the crib's southern boundary.

NATURE AND EXTENT

Borehole geophysical logging at 299-E17-02 detected Cs-137 at concentrations between 0.2 pCi/g to 1,800 pCi/g at depths between 21 and 61 ft bgs. The peak concentration was observed at about 33 ft bgs. The 2005 geophysical logging and SIM information was used to infer a zone of Sr-90 contamination that extends below the base of the Cs-137 to an estimated depth of 86 ft bgs.

Borehole geophysical logging at 299-E17-03, located at the west (downstream) end of the crib, did not detect significant gamma activity. Based on this information, it appears the west end of the crib received very little effluent. Radionuclides detected at 299-E17-03 occurred at depths between 80 and 135 ft bgs and not above 79 ft bgs. This activity is attributed to migration from the 216-A-36A crib.

Direct Exposure: Soil samples were not collected from the 0 to 15 ft depth interval. However, based on the unit's construction, SIM information, and detailed characterization information for the 216-A-2 crib and 216-A-5 crib bounding site, contaminant concentrations within the 0 to 15 ft bgs depth interval are expected to exceed protective levels under an industrial land use scenario.

Ecological Exposure: Active management controls and a lack of biological activity currently preclude exposure. However, there is potential for ecological exposure in the 10 to 15 ft bgs depth interval if these controls are discontinued.

Groundwater Protection: RESRAD modeling performed for the 216-A-2 and 216-A-5 Cribs showed that only under unrestricted land use conditions only carbon-14 is transported to groundwater at concentrations that could exceed its MCL value. Because unrestricted land use is not expected, carbon-14 will not exceed MCL in groundwater. Therefore, adverse groundwater impacts are not expected. The 216-A-27 Crib had a lower nitrate inventory than the other 200-MW-1 OU waste sites. The uranium inventory was much less than the 216-A-4 Crib. Based on 216-A-4 modeling, uranium does not appear to have the potential to impact groundwater. Therefore, future water quality effects are expected to be less over time as evidenced by declining nitrate concentrations in groundwater in the area south of PUREX (see Appendix A).

Figure 4-18. Conceptual Site Model for the 216-A-27 Crib

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4.3.1.1 Contaminant Sources

The waste stream that had been discharged to 216-A-21 Crib was re-directed to 216-A-27 Crib when the infiltration capacity of 216-A-21 Crib was reached in 1965 (WIDS, 2008). RHO-CD-673 and the soil inventory model in RPP-26744 report that the crib received sump waste from the 293-A Building, laboratory cell drainage from the 202-A Building, and 291-A-1 Stack drainage. Based on the inventory, the contaminants discharged to the 216-A-27 Crib were the same materials discharged to the 216-A-21 Crib. With the exception of nitrate, all contaminant inventories for the 216-A-27 Crib were less than or equal to the 216-A-21 Crib.

4.3.1.2 Key Contaminants

Information from RPP-26744 indicates that the waste stream was predominantly a sodium nitrate solution containing calcium, ammonium, carbonate, and chloride. RHO-CD-673 indicates that the waste was low-salt, neutral/basic. Based on SIMs, the chemical (non-radionuclide) constituents with the largest inventories (Table 4-3) discharged to the 216-A-27 Crib included: nitrate at 11,230 kg (24,860 lb), potassium at 8,525 kg (18,800 lb), phosphate at 3,502 kg (7,720 lb) and sodium at 1,861 kg (4,103 lb). SIMs estimate that the radionuclides with the largest inventories disposed to the 216-A-27 Crib include: Pu-241 (43.1 Ci), Cs-137 (29.4 Ci), Sr-90 (24.8 Ci), Pu-239 (6.49 Ci), and Pu-240 (2.27 Ci). Uranium (65.1 kg) was also discharged to the crib.

4.3.1.3 Characterization Information

Geophysical data from two wells (299-E17-2 and 299-E17-3), each located about 7.6 m (25 ft) from the center of the crib and outside the crib boundary, were used to delineate the vertical extent of the contamination at the wells and the lateral extent of contamination from 216-A-27 Crib.

Well 299-E17-2 was logged to 118 m (387 ft) bgs in April 1963, approximately two years prior to beginning operations at the 216-A-27 Crib in June 1965. 299-E17-2 was also logged in 1970 and 1976, and again in 2005 (DOE-EM/GJ873-2005). 299-E17-3 was logged in 1976, eleven years after the 216-A-27 Crib was activated. 299-E17-3 was logged again in 2003. There are no soil sample data for the boreholes.

4.3.1.4 Nature and Extent

The 1963 log for Well 299-E17-2 shows no contamination at the level of the crib or immediately below, but shows contamination extending between approximately 94 m (308 ft) and 107 m (350 ft) bgs, the limit of the 1973 logging run. By 1976, the logs indicate no gamma radionuclide contamination is present in the groundwater. This contamination could have been due to short-lived species in the groundwater, perhaps mostly Ru-106, or contamination that has migrated beyond the borehole.

An upper zone of contamination appears in the two later logs for 299-E17-2 (1970 and 1976). The contamination between 5 and 30 m (16 and 98 ft) bgs is clearly due to crib operations, because the older 1963 log (pre-operational date) reveals no elevated gamma readings at these depths. The upper zone, extending from 7 to 17.7 m (23 to 58 ft) bgs, consists of Cs-137 with Co-60 and Eu-154. Cs-137 reaches a peak concentration of 1,834 pCi/g at 10.1 m (33 ft) bgs. Evaluation of the total gamma log indicated that elevated gamma activity observed between 18.3 and 25.9 m (60 and 85 ft) bgs does not appear to correlate with either man-made gamma or naturally occurring gamma radionuclides. This led to a determination that Sr-90 occurs within this interval. A total gamma/Shape Factor (SF2)* log was generated for this borehole. Results indicate anomalous values of SF2* between 17.1 and 26.2 m (56 and 86 ft) bgs. From these results, it is inferred that Sr-90 is present at concentrations in excess of 1,000 pCi/g to a depth of at least 26.2 m (86 ft) bgs.

The distinct lower interval of contamination, between 29 and 30.5 m (95 and 100 ft) bgs at Well 299-E17-2 also indicates a short-lived radionuclide such as Ru-106, because by the time the well is logged in 2005 this peak is almost gone. Data from the 2005 geophysical log for borehole 299-E17-2 reveal that most of the short-lived radioisotopes have decayed away, leaving primarily Cs-137. The spectral gamma log interpretation indicates that Cs-137 was detected between approximately 6.4 and 18.6 m (21 and 61 ft) bgs and at a few sporadic locations throughout the logged interval. Cesium-137 concentrations ranged between approximately 0.2 pCi/g and 1,800 pCi/g with the peak concentration measured at approximately 10.1 m (33 ft) bgs. Co-60 was detected at 7.3 m (24 ft) bgs and 7.6 m (25 ft) bgs with a peak concentration of approximately 0.3 pCi/g at 7.6 m (25 ft) bgs. Eu-154 was detected from 7 to 7.9 m (23 to 26 ft) bgs with a maximum concentration of approximately 11 pCi/g at 7.3 m (24 ft) bgs.

Based on logging of Well 299-E17-3 (ARH-ST-156, *Evaluation of Scintillation Probe Profiles from 200 Area Crib Monitoring Wells*), which is located at the west (downstream) end of the crib, contaminants were not distributed over the length of the crib. The west end of the crib received very little, if any, contaminated effluent, as evidenced by the low radiation profile immediately below the crib at Well 299-E17-3. The radionuclide constituents detected at Well 299-E17-3 occurred at depths between 24.4 to 41.2 m (80 to 135 ft) bgs, but not above 24 m (79 ft) bgs.

Well 299-E17-3 was logged again in 2003 (Stoller, GJO-2003-518-TAC). Only low levels of contaminants were found to remain at this location (for example, 0.2 pCi/g to 0.8 pCi/g Cs-137, 0.1 pCi/g to 4.9 pCi/g Co-60).

4.3.2 216-B-4 Reverse Well

Based on construction information included with the drilling log, the well is 0.2 m (0.67 ft) in diameter and 33.5 m (110 ft) deep. The well casing was perforated at depths between 25.9 and 33.5 m (85 and 110 ft) bgs.

The CSM for the 216-B-4 Reverse Well is presented in Figure 4-19. The CSM is described briefly in this section, and is followed by a discussion of specific information and data used to develop the CSM. These include information on contaminant sources, SIM waste inventory estimates, and the nature and extent of contamination. As shown in Figure 4-19, Cs-137 contamination is limited in horizontal and vertical extent to the zone immediately below the bottom of the well at 33.5 m (110 ft) bgs, and there is little horizontal migration beyond the immediate zone of the well.

The wetted front, shown as a dashed blue line on Figure 4-19, extends approximately 27.4 m (90 ft) below the bottom of the reverse well (over 30.5 m [100 ft] above the groundwater level), based on the relatively low volume of effluent discharged to the well (10,000 L [2,600 gal]) and the estimated pore volume.

4.3.2.1 Contaminant Sources

From April 1945 to August 1947, the 216-B-4 Reverse Well received stack drainage (WIDS, 2008), and from August 1947 to December 1949 it received floor drainage from the 292-B Building (WIDS and RHO-CD-673).

4.3.2.2 Key Contaminants

The waste was reported to contain less than one Ci of total beta activity (RHO-CD-673). The SIM lists the following most significant constituents in the inventory for the 216-B-4 Reverse Well: nitrate (0.12 kg), sodium (0.082 kg), Cs-137 (0.011 Ci), and U (0.0005 kg).

4.3.2.3 Characterization Information

No characterization data are available for the 216-B-4 Reverse Well.

4.3.2.4 Nature and Extent

No field data are available for the 216-B-4 Reverse Well. However, nature and extent information for this reverse well can be correlated to other reverse wells that have been characterized.

In general, the less-mobile contaminants are adsorbed to the Hanford formation sand within 3 to 6.1 m (10 to 20 ft) of their release points. The less mobile contaminants discharged to the 216-B-4 Reverse Well are expected to have distributed in a similar manner. Based on this information, the vertical extent of contamination below the 216-B-4 Reverse Well is estimated to extend 6.1 m (20 ft) below the bottom of the screen, a depth of 39.6 m (130 ft) bgs.

Characterization of reverse wells also indicates that the wastes remain within a very narrow zone around a reverse well less than 4 m (13 ft) in diameter. The wastes released to the 216-B-4 Reverse Well are assumed to have a similar distribution pattern.

4.3.3 216-C-2 Reverse Well Contaminant Distribution Model

Based on construction information included with the drilling log, the well is 0.3 m (1 ft) in diameter and 12.2 m (40 ft) deep (RHO-CD-673). An unknown length of the casing is perforated at the bottom of the well.

A CSM for the 216-C-2 Reverse Well is shown in Figure 4-20. The CSM for this waste site is based on the same reverse well information used for the 216-B-4 Reverse Well.

4.3.3.1 Contaminant Sources

The 216-C-2 Reverse Well is associated with the 291-C-1 Stack and the 291-C-1 Stack Ventilation filter (RHO-CD-673, DOE/RL-2001-65, RPP-26744, and WIDS 2008). The pipelines associated with the well are site codes 200-E-251-PL and 200-E-252-PL. The site received 291-C-1 Stack drainage and the seal water drainage from the stack ventilation filters.

4.3.3.2 Key Contaminants

The waste was reported to be "low salt, neutral/basic," and contained less than 1 Curie beta activity (RHO-CD-673). The SIM lists the following significant constituents in the inventory for the 216-C-2 Reverse Well: sodium (1.29 kg), mercury (0.027 kg), calcium (19.9 kg), nitrate (2.9 kg), sulfate (2.7 kg), NPH (0.29 kg), Sr-90 (0.08 Ci), Cs-137 (0.009 Ci), and U (0.0012 kg).

4.3.3.3 Characterization Information

No characterization data are available for the 216-C-2 Reverse Well. The extent of contamination at the 216-C-2 Reverse Well is expected to be the same as from the 216-B-4 Reverse Well.

4.3.3.4 Nature and Extent

As noted above, no field characterization data are available for the 216-C-2 Reverse Well. However, the information available from other reverse wells was used to develop the contaminant distribution model for the 216-C-2 Reverse Well.

In general, the less-mobile contaminants are adsorbed to the Hanford formation sand within 3 to 6.1 m (10 to 20 ft) of their release points. The less mobile contaminants discharged to the 216-C-2 Reverse Well are expected to have distributed in a similar manner.

Characterization of reverse wells also indicates that the wastes remain within a very narrow zone around a reverse well less than 4 m (13 ft) in diameter. The wastes released to the 216-C-2 Reverse Well are assumed to have a similar distribution pattern.

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200-MW-1 Operable Unit

216-B-4 Reverse Well

200 East Area

HISTORY

The 216-B-4 reverse well is an inactive liquid waste disposal site associated with the 291-B stack. Reverse wells typically received effluent from low-volume process streams, compared to cribs which received wastes from moderate-volume process streams (DOE/RL-98-28). While reverse wells received smaller effluent volumes, the waste streams may have been more concentrated because the reverse wells were typically designed to place waste material deeper into the soil column. (DOE/RL-96-81).

Construction: The well is an 8-inch diameter steel casing installed to a depth of 110 ft bgs (RHO-CD-673). The casing is reportedly perforated at depths between 85 and 110 ft bgs. The casing's open bottom was likely closed by collapsing it at the bottom.

Waste Volume: 10,000 liters (2,640 gallons).

Duration: April 1945 to December 1949

Inventory of High Mobility Constituents:

Constituent	Units	Inventory Mean	Inventory Low	Inventory High
Tritium	Ci	1.2 E-05	7.8E-06	1.6E-05
Tc-99	Ci	4.9E-06	3.3E-06	6.6E-06
N03	kg	0.12	0.10	0.15

Low = 5th percentile
High = 95th percentile

Inventory of Low Mobility Constituents:

Constituent	Units	Inventory Mean	Inventory Low	Inventory High
Cs-137	Ci	1.1E-02	7.2E-03	1.5E-02
Pu-239/240	Ci	6.2E-06	4.0E-06	8.4E-06
Sr-90	Ci	1.3E-03	8.7E-04	1.8E-03
U- Metal	kg	0	0	0

Low = 5th percentile
High = 95th percentile

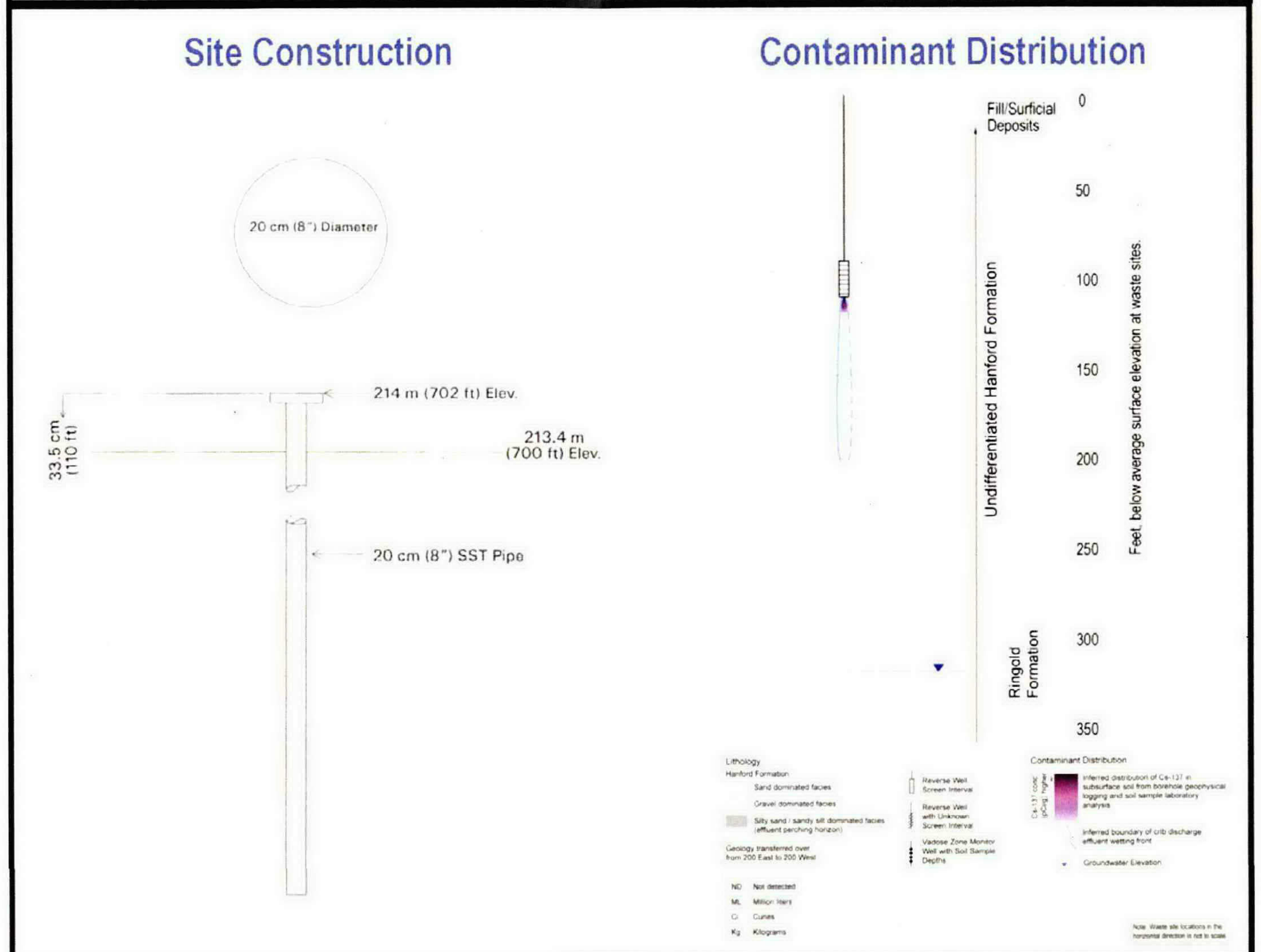
BASIS OF KNOWLEDGE

- Process history (Drawings and WIDS)
- SIM (RPP-26744)
- Geologic Logs
- Reliance on characterization performed at similar reverse well sites (216-Z-10, 216-U-4 and 216-B-6)

CHARACTERIZATION SUMMARY

No characterization was conducted at this waste site.

Waste Site: 216-B-4 Reverse Well



Potential Viable Alternatives

● NO ACTION ● ICs/MNA ● REMOVE, TREAT, DISPOSE

UNCERTAINTY SUMMARY

Although some uncertainty exists for this site due to the absence of direct investigation, data from investigations conducted at other reverse well sites allows for reasonable contaminant distribution and risk management estimates. Contaminant distribution estimates can be verified, if necessary through confirmation sampling during remedy implementation.

NATURE AND EXTENT

Reliance on characterization data from the 216-B-6 reverse well suggests the vertical extent of contamination extends approximately 20 ft below the bottom of the screen to a depth of about 130 ft.

Reliance on characterization data from the 216-Z-10 reverse well suggests contaminants remained within a very narrow cylindrical zone around the reverse well screen interval less than 13 ft in diameter. Due to the low volume of effluent discharged, the contaminants discharged from the 216-B-4 reverse well are expected to have an even smaller footprint than observed at the 216-Z-10 reverse well.

Direct Exposure: Soil samples were not collected from the 0 to 15 ft depth interval to assess direct exposure. However, based on the unit's 85-110 ft screen interval and SIM information there is no direct exposure risk at this site under an industrial land use.

Ecological Exposure: Active management controls and a lack of biological activity currently preclude exposure. Based on the unit's 85-110 ft screen interval and SIM information there is no ecological exposure at this site under industrial or unrestricted land use.

Groundwater Protection: Based on the small inventories of tritium, nitrate and uranium metal in comparison to the 216-A-2, 216-A-4 and 216-A-5 cribs where groundwater protection modeling was performed, and reliance upon characterization information from similar reverse well sites, residual contaminants at the 216-B-4 reverse well are not expected to adversely effect future groundwater quality.

Figure 4-19. Conceptual Site Model for the 216-B-4 Reverse Well

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200-MW-1 Operable Unit

216-C-2 Reverse Well

200 East Area

HISTORY

The 216-C-2 reverse well is an inactive liquid waste disposal site associated with the 291-C stack. Reverse wells typically received effluent from low-volume process streams, compared to cribs which received effluent from moderate-volume process streams (DOE/RL-98-28). While reverse wells received smaller effluent volumes, the waste streams may have been more concentrated because reverse wells were generally designed to place waste material deeper into the soil column (DOE/RL-96-81).

Construction: The well is a 12-inch diameter steel casing installed to a depth of 40 ft bgs (RHO-CD-673). The casing was reportedly perforated from 15 to 40 ft bgs. The well casing's open bottom was likely closed by collapsing the casing at the bottom.

Waste Volume: 3,150,000 liters (832,000 gallons).

Duration: 1953 to 1988

Inventory of High Mobility Constituents:

Constituent	Units	Inventory Mean	Inventory Low	Inventory High
Tritium	Ci	0	0	0
Tc-99	Ci	0	0	0
N03	kg	2.86	2.49	3.27

Low = 5th percentile
High = 95th percentile

Inventory of Low Mobility Constituents:

Constituent	Units	Inventory Mean	Inventory Low	Inventory High
Cs-137	Ci	9.4E-03	6.8E-03	1.3E-02
Pu-239/240	Ci	1.9E-04	1.2E-04	2.6E-04
Sr-90	Ci	8.0E-02	5.8E-02	1.1E-01
U- Metal	kg	0	0	0

Low = 5th percentile
High = 95th percentile

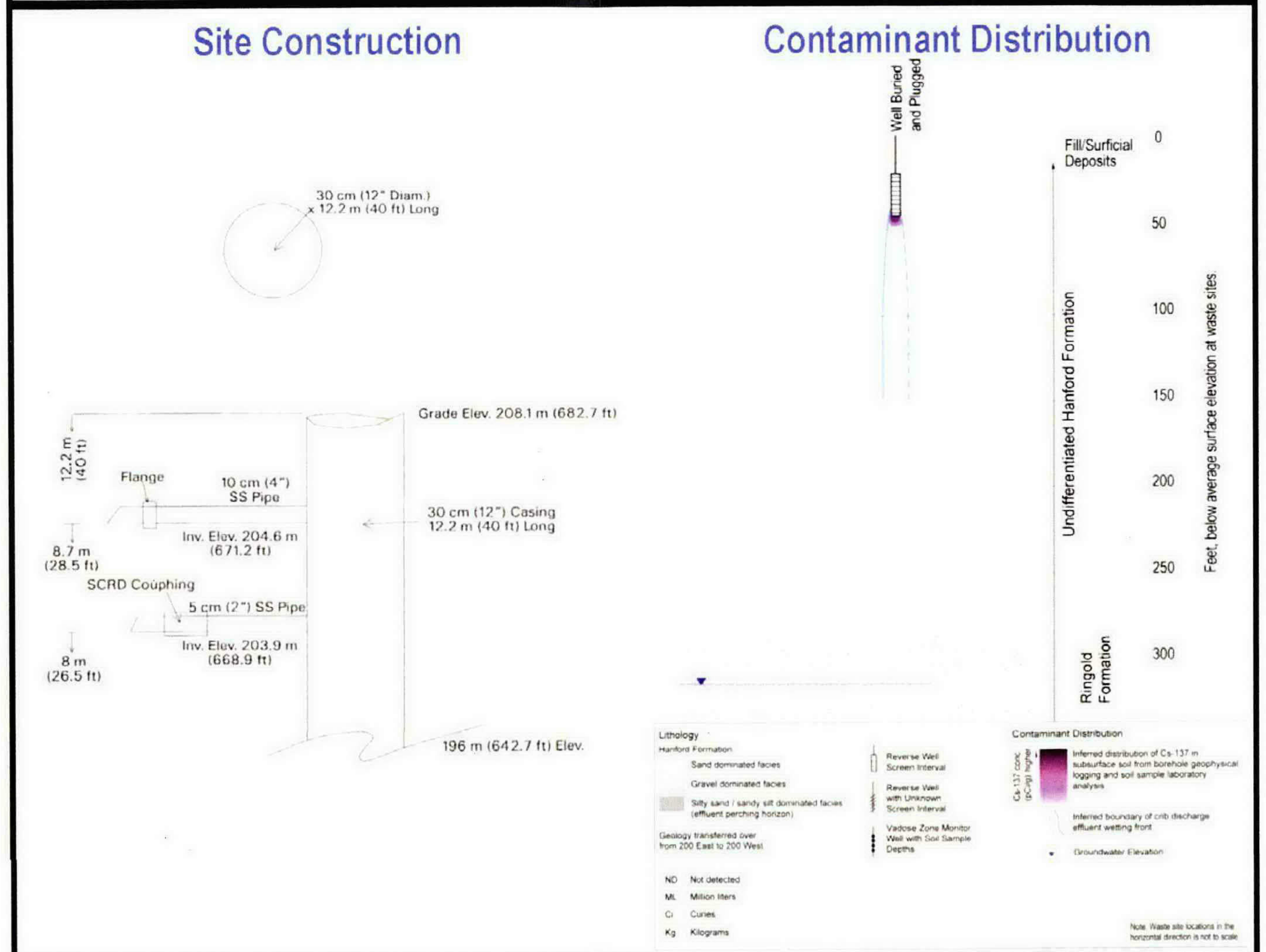
BASIS OF KNOWLEDGE

- Process History (Drawings and WIDS)
- SIM (RPP-26744)
- Geologic Logs
- Reliance on characterization performed at similar reverse well sites (216-Z-10, 216-U-4 and 216-B-6)

CHARACTERIZATION SUMMARY

No characterization was conducted as this waste site.

Waste Site: 216-C-2 Reverse Well



Potential Viable Alternatives

● NO ACTION ● ICs/MNA ● REMOVE, TREAT, DISPOSE

UNCERTAINTY SUMMARY

Although some uncertainty exists for this site due to the absence of direct investigation, data from investigations conducted at other reverse well sites allows for reasonable contaminant distribution and risk management estimates. Contaminant distribution estimates can be verified, if necessary through confirmation sampling during remedy implementation.

NATURE AND EXTENT

No direct characterization data exists for the 216-C-2 reverse well to define the vertical extent of contaminants. However, based on the effluent volume discharged to the well and the well depth, constituent migration to groundwater is unlikely.

Characterization data for the 216-B-6 reverse well indicates limited vertical migration of less-mobile constituents, such as Cs-137, below the bottom of the well. Contaminant distribution at the 216-C-2 reverse well is expected be similar.

Characterization data adjacent to the 216-U-4 reverse well indicates contaminants occur near the midpoint of the screen interval and decrease significantly within 20 vertical feet. Contaminant distribution at the 216-C-2 reverse well is expected be similar.

Characterization data for the 216-Z-10 reverse well did not detect radionuclides in soil samples collected from boreholes drilled 15 ft from the well. These results suggest that the waste remained within a very narrow zone around the less than 13 ft in diameter. The contaminants discharged to the 216-C-2 reverse well are assumed to have a similar distribution pattern.

Direct Contact Exposure: Soil samples were not collected from the 0 to 15 ft depth interval to assess direct exposure. Based on the unit's 15-40 ft screen interval and SIM information, the potential for direct exposure risk at this site under an industrial land use is expected to be low.

Ecological Exposure: Active management controls and a lack of biological activity currently preclude exposure. Based on the unit's 15 to 40 ft screen interval and SIM information there is limited ecological exposure at this site under industrial or unrestricted land use.

Groundwater Protection: Reliance on characterization data from similar reverse well sites, and SIM information, suggests residual contaminants at the 216-C-2 reverse well are unlikely to pose a future groundwater quality threat.

Figure 4-20. Conceptual Site Model for the 216-C-2 Reverse Well

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5 Conceptual Exposure Model and Contaminant Fate and Transport

This chapter describes the pathways by which contaminants present in subsurface soil at the 200-MW-1 OU waste sites may be transported to potential points of exposure, and based on the pathway analysis, a conceptual exposure model is presented to illustrate how human and ecological receptors may become exposed. This chapter also describes naturally occurring processes that can reduce contaminant concentrations between the point of release and the point of exposure. The information presented in this chapter establishes the framework for the BRA presented in Chapter 6.

5.1 Sources

Potential sources of contamination identified for the 200-MW-1 OU waste sites include:

- Vent stack/sand filter/laboratory cell drainage liquid waste discharged to the 216-A-2, 216-A-4, 216-A-21, and 216-A-27 Cribs, to the 216-B-4 and 216-C-2 Reverse Wells
- Contaminated soil buried at the 200-E-102 Trench from the UPR at the 216-A-4 Crib

The waste streams discharged to each waste site were different in composition and volume. However, these waste streams had similar waste constituents based on the constituent waste inventories. The following subsections review waste stream characteristics described previously in Section 4.2 and Section 4.3.

5.1.1 216-A-2 Crib

Based on mean value inventory estimates presented in RPP-26744, the 216-A-2 Crib received 149,200 kg (328,900 lb) of TBP and 63,920 kg (140,900 lb) of NPH. The other chemical (non-radionuclide) constituents with the largest inventories disposed to the 216-A-2 Crib are nitrate (2,370 kg [5,220 lb]) and uranium (228 kg [503 lb]). The radionuclides with the largest inventories are Sm-151 (27.2 Ci), Pu-239 (7.9 Ci), Pu-241 (6.9 Ci), Cs-137 (1.9 Ci), and Pu-240 (1.6 Ci) (see Table 4-3).

5.1.2 216-A-4 Crib

The 216-A-4 liquid effluent waste stream was categorized (RPP-26744) as a miscellaneous PUREX uranium nitrate hexahydrate and laboratory waste stream containing potassium nitrate solution with minor amounts of sodium, calcium, phosphate, and fluoride. Based on the mean value inventory estimates presented in RPP-26744 (see Table 4-3), the chemical (non-radionuclide) constituents with the largest inventories disposed to the 216-A-4 Crib are nitrate (95,370 kg [210,300 lb]), potassium (75,970 kg [167,500 lb]), uranium (5,388 kg [11,880 lb]) and phosphate (1,691 kg [3,728 lb]). The radionuclides with the largest inventories disposed to the 216-A-4 Crib are tritium (64.5 Ci), Pu-241 (7.2 Ci), Cs-137 (4.86 Ci), Sr-90 (4.14 Ci), and Pu-239 (1.08 Ci).

5.1.3 216-A-21 Crib

The 216-A-21 Crib received liquid waste that was predominately a sodium nitrate solution with significant amounts of calcium, ammonium, carbonate, and chloride. Based on the mean value inventory estimates presented in RPP-26744 (see Table 4-3), the chemical (non-radiological) constituents with the largest inventories disposed to 216-A-21 Crib are nitrate (320,000 kg [705,000 lb]), sodium (108,000 kg [238,000 lb]), ammonium (66,300 kg [146,000 lb]), calcium (28,100 kg [62,000 lb]), and iron (8,160 kg 18,000 lb]). The radionuclides with the largest inventories disposed to the 216-A-21 Crib are Cs-137 (63.7 Ci), tritium (49. 5 Ci), Pu-241 (10.1 Ci), Sr-90 (6.06 Ci), Am-241 (4.61 Ci), Pu-239 (4.61 Ci), Pu-240 (1.13 Ci), and Sm-151 (0.38 Ci).

5.1.4 216-A-27 Crib

Information from RPP-26744 indicates that the waste stream was predominantly a sodium nitrate solution containing calcium, ammonium, carbonate, and chloride. RHO-CD-673 indicates that the waste was low-salt, neutral/basic. Based on the mean value inventory estimates presented in RPP-26744, the chemical (non-radionuclide) constituents with the largest inventories disposed to the 216-A-27 Crib are nitrate (11,230 kg [24,860 lb]), potassium (8,525 kg [18,800 lb), phosphate (3,502 kg [7,720 lb]), and sodium (1,861 kg [4,103 lb]). The radionuclides with the largest inventories disposed to the 216-A-27 Crib are Pu-241 (43.1 Ci), Cs-137 (29.4 Ci), Sr-90 (24.8 Ci), Pu-239 (6.49 Ci), and Pu-240 (2.27 Ci). Uranium (65.1 kg) was also discharged to the crib. The June 1965 ISO-98 report lists U (195 kg), Pu (150 g), beta (2,753 Ci) Co-60 (8.2 Ci), Sr-90 (6.0 Ci), and Cs-137 (82.5 Ci).

5.1.5 200-E-102 Trench

The 200-E-102 Trench was a single-use excavation used to bury soils that were contaminated as a result of plugging of the 216-A-4 Crib in 1958. There is no inventory information for the material disposed of in the trench. However, the dimensions given in WIDS (2008) indicate that the trench could contain as much as 24 m^3 (1,200 ft^3) of contaminated soil.

Little information is available about the waste that was disposed in the trench. Field measurements performed at the time of the UPR at the 216-A-4 Crib detected 20 rads/hr at a distance of 25.4 cm (10 in.) on the floor of the 291-A Turbine House, while the soil (and perhaps asphalt) outside the Turbine House (or between the 291-A Stack and the 216-A-4 Crib) indicated 8 rads/hr at an unspecified distance (WIDS, 2008).

5.1.6 216-B-4 Reverse Well

From April 1945 to August 1947, the 216-B-4 Reverse Well received stack drainage (WIDS, 2008), and from August 1947 to December 1949 it received floor drainage from the 292-B Building (WIDS and RHO-CD-673). The waste was reported to contain less than one Ci of total beta activity (RHO-CD-673). Mean value inventory estimates presented in RPP-26744 list the following constituents: nitrate (0.12 kg), sodium (0.082 kg), Cs-137 (0.011 Ci), and U (0.0005 kg).

5.1.7 216-C-2 Reverse Well

The 216-C-2 Reverse Well is associated with the 291-C-1 Stack and ventilation filter (RHO-CD-673, DOE/RL-2001-65, RPP-26744, and WIDS, 2008). The pipelines associated with the well are site codes 200-E-251-PL and 200-E-252-PL. The site received 291-C-1 Stack drainage and the seal water drainage from the stack ventilation filters. The waste was reported to be "low salt, neutral/basic," and contained less than 1 Ci beta activity (RHO-CD-673). Mean value inventory estimates presented in RPP-26744 list the following constituents: sodium (1.29 kg), mercury (0.027 kg), calcium (19.9 kg), nitrate' (2.9 kg), sulfate (2.7 kg), NPH (0.29 kg), Sr-90 (0.08 Ci), Cs-137 (0.009 Ci), and U (0.0012 kg).

5.2 Release Mechanisms

Potential release mechanisms associated with discharge of liquid effluents to the 200-MW-1 OU waste sites include:

- Infiltration/percolation and leaching of contaminants from subsurface soil. This release mechanism applies to each of the waste sites.
- Wind erosion and dust generation. This release mechanism applies to the 200-E-102 Trench where contaminants occur at depths between 0.3 and 1.2 m (1 to 4 ft).

- Volatilization and vapor transport. Due to the low to non-volatile nature of the contaminants present at the 200-MW-1 OU waste sites, this release mechanism is expected to be insignificant.

Additional information on these release mechanisms and potential contaminant migration pathways is presented in Section 5.3.

5.2.1 Contaminant Transport

Currently, the primary vadose zone transport mechanism for contaminants released to subsurface soil at the 200-MW-1 OU waste sites is infiltrating/percolating water associated with rainfall, snowmelt, or leaky underground pipes. Based on contaminant source zone characteristics and contaminant transport properties (soil-water distribution coefficients and radionuclide half-life) some contaminants may be transported to groundwater which occurs at a depth of approximately 96 m (315 ft). Vadose zone transport evaluations performed using analytical and numerical modeling methods, such as RESidual RADioactive (RESRAD) computer code (ANL, 2007, *RESRAD*) and Subsurface Transport over Multiple Phases (STOMP), are presented in Section 5.2.3.

Based on the proximity of the 200 Area to surface water (15 km [8 mi] to the Columbia River), only those contaminants discharged in large enough quantities and with high mobility characteristics (nitrate and tritium) may be transported to surface water.

Based on the depth of the contamination and presence of surface stabilization material (rock or gravel) over each of the waste sites, the suspension of dust in the air is expected to be an insignificant migration pathway. Field screening results indicate emission of VOCs or ionizing radiation to outdoor air is unlikely to be a significant transport pathway from undisturbed soil.

5.2.2 Contaminant Persistence

The environmental persistence or degradation (fate) and the rate and direction of contaminant movement (transport) in the environment can be estimated based on the site conceptual model of the release, as well as on various physical and chemical properties of the vadose zone and of the contaminants. The purpose of this section is to identify and describe the physical/chemical processes that are likely to control contaminant transport and distribution in groundwater, soil, and air at the 200-MW-1 OU waste sites. The vadose zone hydrology and geochemistry of contaminant transport in the vadose zone at the Hanford Site was discussed in detail in PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*, and PNNL-17154, *Geochemical Characterization Data Package for the Vadose Zone in the Single-Shell Tank Waste Management Areas at the Hanford Site*.

As discussed in Chapter 4, the primary contaminants detected in vadose zone soil include non-radionuclides (uranium metal and nitrate), as well as several radionuclides (americium-241, carbon-14, cesium-137, strontium-90, technecium-99, tritium, and plutonium-239, -240, and -241). The physical and chemical properties of these contaminants that are likely to control contaminant transport are shown in Table 5-1 and discussed in the following subsections. These properties include radioactive half-life, mode of radioactive decay, decay products, soil-water distribution coefficient (K_d), and oxidation/valence states. Potentially significant properties of the vadose zone soil or groundwater (for example, REDOX conditions and pH) are discussed in terms of contaminant persistence and mobility. Specific information for each contaminant follows.

Table 5-1. Properties of Selected Non-Radionuclide and Radionuclide Constituents

Radionuclide/ Chemical	Soil-Water Distribution Coefficient [K_d] (cm^3/g)	Half-Life (years)	Radiation	Decay Product(s)	Half-Life of Decay Product
Chemicals					
Nitrate	0	NA	NA	NA	NA
Uranium	0.8	NA	NA	NA	NA
Radionuclides					
Americium-241	300	432.2	Alpha (some gamma)	Neptunium-237	2,100,000 years
Carbon-14	0	5,730	Beta-	Nitrogen-14	Stable
Cesium-137	2,000	30	Beta-	Barium-137m	2.6 minutes (stabilizes by emitting gamma radiation)
				Barium-137	Stable
Plutonium 239	600	24,065	Alpha	Uranium-235	700,000,000 years
Plutonium 240	600	6,537	Spontaneous Fission-Alpha	Uranium-236	2,300,000 years
Plutonium 241	600	14.4	Alpha, Beta-	Americium-241	432.2 years
Strontium-90	22	29.12	Beta-	Yttrium-90	64 hours (emits more energetic beta particle than Sr-90)
				Zirconium-90	Stable
Technetium-99	0	213,000	Beta-	Ruthenium-99	Stable
Tritium	0	12.35	Beta-	Helium-3	Stable

Notes:

Except for Am-241, the K_d values are based on the best estimate values obtained from Table 4.11 in PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*. The K_d value for Am-241 was obtained from the "no impact" category from Table A-1 in PNNL-17154, *Geochemical Characterization Data Package for the Vadose Zone in the Single-Shell Tank Waste Management Areas at the Hanford Site*.

NA = not applicable

5.2.2.1 Uranium

Physical/chemical properties of uranium are dependent on its oxidation state and associated chemical ligands as well as on the environmental conditions. Uranium generally occurs in the +4 and +6 oxidation states. Tetravalent uranium forms hydroxides, hydrated fluorides, and phosphates that are relatively stable and of low solubility. Hexavalent uranium is stable, and commonly occurs as oxides. Major compounds of uranium include oxides, fluorides, carbides, nitrates, chlorides, acetates, and others (ATSDR, 1999, *Toxicological Profile for Uranium*).

Factors that control mobility of uranium in soil and water include reduction oxidation (REDOX) potential, pH, and sorption to solids. Biological processes under anaerobic conditions can result in reduction of uranium from hexavalent (soluble) to tetravalent (insoluble) forms, decreasing its mobility. Uranium sorbs strongly (may not leach readily) to soils containing clay and iron but sorbs poorly to other geologic materials with higher silica content such as sand. Formation of soluble complexes with anions and ligands (for example, carbonate or hydroxide) or humic acid, or reduction from hexavalent to tetravalent state, can increase uranium mobility. However, even hexavalent uranium in sand-sized sediments at the Hanford Site is expected to be mobile (estimated K_d=0.8 cm^3/g, according to PNNL-14702) (see Table 5-1).

5.2.2.2 Nitrate

Nitrate is highly soluble and weakly sorbed to soil; therefore, nitrates are highly mobile in soil and groundwater environments (K_d = 0).

5.2.2.3 Americium-241

Americium-241 has a half life of 432 years. It decays by emitting an alpha particle (and some gamma emission) to produce neptunium-237, which has a half life of 2,100,000 years (see Table 5-1). The decay chain ends in bismuth-209. Americium-241 generally occurs in the +3 oxidation state, which is the most stable valence (EPA 402-R-04-002C, *Understanding Variation in Partition Coefficient, K_d, Values: Volume III: Review of Geochemistry and Available K_d Values for Americium, Arsenic, Curium, Iodine, Neptunium, Radium, and Technetium*). It sorbs to minerals, crushed rock, and soil materials, and is therefore considered moderately immobile (K_d = 300 cm^3/g); however, it can be mobile under low pH conditions. Its decay product, neptunium-237, is somewhat mobile (K_d = 10 cm^3/g).

5.2.2.4 Carbon-14

Carbon-14 has a half life of 5,730 years. It decays by emitting a beta particle to produce nitrogen-14 (see Table 5-1). Carbon-14 is present in all organic compounds. At the Hanford Site, it is also associated with the historical production of plutonium. Under typical Hanford conditions, it is assumed that carbon-14 will occur predominately as the bicarbonate ion ($H_{14}CO_3^-$) (PNNL-14702) and be mobile (K_d = 0 cm^3/g).

5.2.2.5 Cesium-137

Cesium-137 is produced when uranium and plutonium absorb neutrons and undergo fission. Cesium-137 has a half life of 30 years. It decays by emitting a beta particle to produce barium-137 (see Table 5-1). Barium-137 stabilizes itself by emitting gamma radiation. Cesium generally occurs in the +1 oxidation state and forms few stable complexes. Cesium sorbs strongly to most minerals and therefore has limited mobility in soil (EPA 402-R-99-004B, *Understanding Variation in Partition Coefficient, K_d, Values: Volume II: Review of Geochemistry and Available K_d Values for Cadmium, Cesium, Chromium, Lead, Plutonium, Radon, Strontium, Thorium, Tritium [^3H], and Uranium*). Cesium-137 has been found to be immobile (K_d = 2,000 cm^3/g) in vadose zone sediments at Hanford (see Table 5-1). Potassium is generally the only mineral that competes with sorption sites. Most cesium compounds are soluble in water. Cesium mobility can be retarded in groundwater as a result of its strong tendency to sorb to minerals.

5.2.2.6 Strontium-90

Strontium-90 is a fission product. Strontium-90 has a half life of 29.12 years. It decays by emitting a beta particle to produce yttrium-90, which decays to zirconium-90 (see Table 5-1). Strontium-90 generally occurs in the +2 oxidation state and has little tendency to form complexes. At pH values less than 9, cation exchange capacity controls partitioning (EPA 402-R-99-004B). Strontium-90 is sensitive to the presence of calcium, and it can replace calcium in carbonate soils and sediments. This chemical relationship has significance where calcium carbonate-rich zones are present, such as in the Hanford Formation and Ringold Formation soils, because these zones may effectively inhibit the downward migration of strontium-90. Strontium-90 retention in soil increases with an increasing pH value. Strontium-90 is moderately immobile (K_d = 22 cm^3/g).

5.2.2.7 Technetium-99

Technetium-99 is a fission product with a half life of 213,000 years. It decays by emitting a beta particle to produce ruthenium-99 (see Table 5-1). The mobility of technetium-99 in soil is dependent on its chemical form, which is governed by the REDOX potential of the soil (EPA 402-R-04-002C). Technetium-99 generally occurs in the +7 and +4 valence states. Technetium-99 is soluble and mobile in its +7 valence state. Technetium-99 has been found to be highly mobile (K_d = 0) in vadose zone sediments at Hanford (see Table 5-1).

5.2.2.8 Tritium

Tritium has a half life of 12.35 years. It decays by emitting a beta particle to produce helium-3 (see Table 5-1). It is mobile in soil groundwater, and migrates at the groundwater velocity (is not retarded, K_d = 0). Its mobility is not affected by aqueous speciation, precipitation, or sorption (EPA 402-R-99-004B). It readily combines with oxygen to form tritiated water.

5.2.2.9 Plutonium-239, -240, and -241

Plutonium-239, -240, and -241 isotopes have half lives of 24,065 years, 6,537 years, and 14.4 years, respectively (see Table 5-1). Plutonium decays by emitting alpha and beta particles. Plutonium-239 and-240 decay to uranium isotopes, and plutonium-241 decays to americium-241. Plutonium can occur in the +3, +4, +5, and +6 valence states, and its mobility is REDOX sensitive (EPA 402-R-99-004B). Plutonium mobility is strongly affected by the formation of strong hydroxy-carbonate mixed ligand complexes. At pH values greater than seven, formation of these complexes with plutonium results in desorption and increased mobility in the environment. Sorption to soil can vary depending on soil components. Plutonium has been found to be moderately immobile (K_d = 600) in vadose zone sediments at Hanford.

5.2.3 Contaminant Transport through Vadose Zone

Selected constituents detected in vadose soil were evaluated for their potential to be transported to and potentially affect groundwater quality beneath the 200-MW-1 OU 216-A-2 and 216-A-4 Cribs. The evaluations conducted for these two waste sites were used to assess the potential for transport to groundwater at the other 200-MW-1 OU waste sites. A summary of the vadose zone transport analysis is presented in the following subsections. Detailed information is provided in Appendix C.

5.2.3.1 216-A-2 Crib and 216-A-4 Crib Soil Screening

Potential impacts to groundwater for non-radionuclides were estimated by comparing the maximum detected soil concentration at any depth in the soil column to WAC 173-340-747, "Deriving Soil Concentrations for Ground Water Protection." Results are summarized in Appendix C.

As part of the overall BRA, non-radionuclide constituents detected in shallow zone soils and deep zone soils at the 216-A-2 and 216-A-4 Cribs were compared to their corresponding soil to groundwater protection concentrations. Soil sample results are presented in Appendix A. Soil concentrations protective of groundwater were calculated using the 40 fixed-parameter three-phase partitioning model described in WAC 173-340-747, "Model Toxics Control Act--Cleanup," "Deriving Soil Concentrations for Ground Water Protection." For the purposes of soil screening comparisons, the maximum observed concentrations of non-radionuclides detected at the 216-A-2 Crib and the 216-A-4 Crib were used.

The comparisons indicate that uranium metal concentrations in soil at the 216-A-2 (147 mg/kg) and 216-A-4 (1,970 mg/kg) Cribs, and nitrate (185 mg/kg) and cyanide (0.89 mg/kg) concentrations in soil at the 216-A-4 Crib, were greater than their respective soil to groundwater protection concentrations of 1.32 mg/kg, 40 mg/kg and 0.8 mg/kg respectively (see Table C-1).

At the 216-A-2 Crib, uranium–metal present in soil at 147 mg/kg is not expected to pose an adverse groundwater quality threat even though this concentration is greater than the soil to groundwater protection concentration of 1.32 mg/kg and the background soil concentration of 3.21 mg/kg. A groundwater sample collected from boring C5515 detected uranium-metal at a concentration of 11 μg/L compared to the MCL of 30 ug/L.

As discussed further in Section 5.2.3.2, uranium metal transport to groundwater at the 216-A-4 Crib was evaluated in greater detailed using numerical modeling methods. However, nitrate was not considered further because of the relatively low nitrate inventory (95,400 kg) discharged to the 216-A-4 Crib, and declining levels of nitrate present in groundwater south of the PUREX facility. Cyanide was not evaluated further because the maximum detected concentration of 0.89 mg/kg only slightly exceeded the soil to groundwater protection concentration of 0.80 mg/kg.

The mean value SIM inventories for uranium metal, nitrate and cyanide (see Table 4-3) indicate that the mass of uranium and cyanide discharged to the 216-A-21 and 216-A-27 Cribs, and 216-B-4 and 216-C-2 Reverse Wells, was lower than reported for the 216-A-2 and 216-A-4 Cribs; therefore, transport of these constituents to groundwater is not expected. The mean value SIM inventory for nitrate at the 216-A-21 Crib (320,300 kg) is higher than reported for the 216-A-4 Crib (95,370 kg); therefore, nitrate transport to groundwater is possible. Sampling performed at the 216-A-21 Crib was limited to depths between 6.4 and 18.3 m (21 to 60 ft) and did not include sampling of deep soil (86.9 m [285 ft]) where the maximum detected nitrate concentration at the 216-A-4 Crib was observed. Mean nitrate inventories of 0.12 kg and 2.86 kg at the two reverse wells indicates that the potential for nitrate transport to groundwater at these two sites is very low.

There is no SIMs inventory information available for the 200-E-102 Trench. However, given the characteristics of the material (contaminated soil) placed in the trench, and its association with a one-time UPR, the potential for contaminant release and transport to groundwater is expected to be low.

5.2.3.2 216-A-4 Crib Evaluation – STOMP Model Uranium Evaluation

A secondary and more detailed evaluation of uranium metal transport to groundwater at the 216-A-4 Crib was performed using a two-dimensional fate and transport model implemented with STOMP. This phase, using a more robust two-dimensional fate and transport model, was undertaken to evaluate the potential risks and impacts to groundwater beyond the initial RESRAD-based screening analysis. This phased approach to modeling is consistent with the graded approach of model evaluation and with EPA guidance on soil screening (EPA/540/F-95/041, *Soil Screening Guidance: User's Guide*). Based on the federal guidelines for the selection and use of model codes, two-dimensional modeling is an appropriate tool for the Central Plateau area of the Hanford Site as a subsequent screening and/or risk characterization tool for evaluating groundwater protection (DOE/RL-2007-34, *Regulatory Criteria for the Selection of Vadose Zone Modeling in Support of the 200-UW-1 Operable Unit*). The modeling results can be used as a basis for remedial alternative development to achieve groundwater protection at the 216-A-4 Crib.

The methodology used in this evaluation involved the calculation and estimation of uranium metal concentrations in groundwater caused by the uranium contained in the vadose zone. The uranium metal maximum contaminant level (MCL) value of 30 μg/L and model domain location with the highest modeled groundwater concentration was used as the evaluation basis. Thus, the evaluation involved estimating the residual vadose zone concentration and inventory for uranium metal at 216-A-4 Crib and comparing the modeled groundwater concentrations to the MCL value. The assumptions and key parameter values used in these evaluations are described in Appendix C.

The soil concentrations for uranium within specified vadose zone depth intervals, representing contaminated soil volumes, were used to estimate the quantity of uranium in the vadose zone. The results of modeling can be applied to the conceptual contaminant distributions and contaminant release models to provide an indication of the amount of remediation necessary to achieve protection of groundwater at 216-A-4 Crib. The recharge rates (shown in Table C4-7) represent the two most probable end states after remediation: reclamation of the shrub-steppe surface and vegetation (0.004 m/yr infiltration rate) either naturally or artificially enhanced; or a surface barrier that reduces or eliminates percolation of water through the waste site (infiltration rate is 0.0005 m/yr for 500 years and 0.001 m/yr thereafter). The protectiveness criteria can be determined by identifying the appropriate conceptual contaminant distribution, probable uranium release model, and the end state of the ground surface.

The modeling results indicate that the timeframe that uranium in the vadose zone may cause the groundwater concentration to exceed the MCL at 216-A-4 Crib is estimated to occur several thousand years into the future. With natural vegetation reestablished on the surface, uranium does not reach the water table within 1,000 years. Table C4-8 provides estimated timeframes that the groundwater concentration would exceed the MCL for uranium for the contaminant profile approximating the greatest amount and deepest extent of uranium contamination. The earliest breakthrough of uranium in groundwater above the MCL does not occur until after approximately 6,800 years in Year 8814 (Table C4-8).

5.2.3.3 RESRAD Radionuclide Evaluation

RESRAD modeling was used to determine whether the radionuclides beneath the 200-MW-1 OU waste sites will be transported to groundwater within 1,000 years. If any of the radionuclides reach groundwater during the period of simulation, the resulting concentrations in groundwater were compared to their corresponding MCL values.

The RESRAD modeling was performed using information obtained for the 216-A-2 Crib and the 216-A-5 Crib site. The 216-A-5 Crib is close in proximity, and types of contaminants are similar to the other 200-MW-1 waste sites. RESRAD modeling for the 216-A-4, 216-A-21, and 216-A-27 Cribs, the 200-E-102 Trench, and the 216-B-4 and 216-C-2 Reverse Wells was not performed because the site characterization data available for these waste sites is not adequate to allow for meaningful simulations. The RESRAD modeling results for the 216-A-2 and 216-A-5 Cribs are expected to provide information that encompasses the range of conditions present at the other 200-MW-1 OU waste sites to allow for a reasonable assessment of radionuclide transport potential. Modeling methods, assumptions, and results for the 216-A-2 Crib and the 216-A-5 Crib are presented in Appendix C.

RESRAD incorporates a simplified model of contaminant transport from the contaminated zone through the vadose zone to the aquifer. It is assumed that the radionuclide constituents are evenly distributed within a homogeneous contaminated zone that has a specified thickness and specified physical properties.

RESRAD employs a one-dimensional simplified representation of advective flow in the vadose zone. The major processes affecting radionuclide transport, such as advection, sorption, and radioactive decay and ingrowths, are included. This simplified one-dimensional model leads to conservative (biased high) estimates of radionuclide concentrations in groundwater because it does not account for other processes that can further reduce concentrations such as longitudinal and transverse dispersion, mineral precipitation/dissolution, and other site-specific hydrogeologic influences.

To simulate the concentration in groundwater, RESRAD assumes that a groundwater well is installed at the down-gradient boundary of the waste site. The well is pumped during the entire 1,000-year period of interest. This implementation of RESRAD results in leaching of radionuclides from the contaminated zone and travel with the infiltrating water downward through the unsaturated zone. The radionuclides that reach groundwater during the period of interest travel down-gradient in the groundwater in the horizontal direction. The radionuclides that reach the groundwater are then captured at the well. Time-dependent contaminant concentrations at the well are calculated and compared to their respective federal MCL values.

The RESRAD transport simulations were conducted using two land use scenarios: restricted, and unrestricted. A set of input parameters was developed for each land use assumption. These parameters, the rationale for their selection, and references to the sources on which the input values were defined are provided in Table C-2. For the restricted land use (that is, industrial) simulation, it is assumed there is infiltration through the soil column from precipitation. For the unrestricted land use simulation there is infiltration through the soil column from precipitation and irrigation.

216-A-2 Crib. The exposure point concentrations (or contaminant source term concentrations) used for the analysis were the maximum concentrations detected in soil between ground surface and the water table at borehole C5515 at the 216-A-2 Crib. Site-specific data for the 216-A-4 Crib were not used because the deep borehole (C5301) at this location was drilled outside the crib's boundary. The maximum observed radionuclide concentrations were detected in samples collected from the 8 to 12 m (27 to 40 ft) depth interval except tritium, which was encountered at its highest concentration within the 76 to 96 m (250.5 ft to 315 ft) depth interval. For the purposes of the RESRAD evaluation, the 8 to 12 m (27 to 40 ft) depth interval is referred to as the shallow contaminated zone and the 76 to 96 m (250.5 ft to 315 ft) depth interval as the deep contaminated zone. The radionuclide source term concentrations and distribution coefficients (K_d values) used for the shallow and deep contaminated zones are provided in Table C-3 and Table C-4.

For the restricted land use RESRAD simulation, none of the identified radionuclides present in shallow zone soil reached groundwater during the 1,000-year simulation period. Because it does not sorb to soil (distribution coefficient K_d=0 cm^3/g), Tc-99 had the shortest time of travel through the vadose zone, reaching groundwater in 3,114 years. The maximum predicted Tc-99 concentration in groundwater at the point of entry is 12 pCi/L, which occurs in 3,524 years. This concentration is less than its MCL value of 900 pCi/L. The remaining radionuclides evaluated with the RESRAD simulation have a high affinity for soil, as indicated by their non-zero distribution coefficients, and reach groundwater at times greater than 31,000 years.

For the restricted land use (no irrigation) RESRAD simulation, tritium present in deep zone soil at a concentration of 2,860 pCi/L reaches the water table within the first year of the 1,000-year simulation period. The simulation predicts a peak concentration of 298 pCi/L 19 years in the future. The maximum predicted concentration of 298 pCi/L is approximately ten times lower than the source concentration of 2,860 pCi/g, and well below the MCL value of 20,000 pCi/L.

For the unrestricted land use (irrigation and precipitation) RESRAD simulation, Tc-99 is the only radionuclide present in shallow zone soil that reaches the water table during the 1,000-year simulation period. The maximum predicted Tc-99 concentration of 4.0 pCi/L occurs 781 years in the future and is below its MCL of 900 pCi/L. Tc-99 did not reach the water table in the restricted land use scenario because the infiltration rate of 0.004 m/yr is five times smaller than the 0.02 m/yr infiltration rate used for the unrestricted land use simulation.

For the unrestricted land use RESRAD simulation, tritium present in deep zone soil reaches groundwater within the 1,000-year simulation period. The simulation predicts a peak concentration 15 years in the future of 1,300 pCi/L. This concentration is approximately 50 percent less than the source concentration of 2,860 pCi/g, and below the 20,000 pCi/L MCL.

216-A-5 Crib. The 216-A-5 waste site received far more liquid waste than any of the cribs in the 200-MW-1 OU: 1.6 billion liters (420 million gallons), or approximately 150 pore volumes. In addition, the liquid effluent discharged to the 216-A-5 Crib was acidic in nature. As discussed above, mobility of some contaminants, including strontium-90 and americium-241, can increase under low pH conditions. The input parameters, the rationale for their selection, and references to the sources on which the input values were defined are provided in Table C-30. Consistent with the simulation for the 216-A-2 Crib, it was assumed there is infiltration through the soil column from precipitation and irrigation (unrestricted land use) and precipitation (restricted land use).

Exposure point concentrations (contaminant source term) used for this analysis were the maximum concentrations detected in soil between ground surface and the water table at borehole C6552, which was advanced through the center of the 216-A-5 Crib. Three contaminated zones were defined based on the contaminant distribution pattern in the borehole C6552 sample data: an upper contaminated zone from 10.5 to 24.3 m (34.5 to 79.8 ft) bgs, a middle contaminated zone from 17.6 to 39.7 m (57.9 to 130.1 ft) bgs, and a lower contaminated zone from 30.6 to 100.4 m (100.4 to 329.47 ft) bgs. The radionuclide source term concentrations used for the shallow and deep contaminated zones are provided in Table C-31.

For the upper contaminated zone, the acidic fluids are assumed to have affected K_d values. The K_d values used to represent the upper contaminated zone in RESRAD are the best estimate values for the "very acidic waste category, high-impact zone" provided in PNNL-14702 (Table 4.11). The upper contaminated zone K_d values are listed in Table C-32. For all other RESRAD modeling layers (contaminated zones 2 and 3, all unsaturated zone layers, and the saturated zone), the acidic fluids are assumed to have been neutralized by the natural soil. The K_d values used to represent the other modeling layers in RESRAD are the best estimate values for the "very acidic waste category, intermediate impact zone" provided in PNNL-14702 (Table 4.11). The K_d values for the other modeling layers are listed in Table C-33. Comparison of K_d values indicates values are lower under acidic conditions (indicating less partitioning to the soil phase) for several contaminants. For example, the K_d value for Cs-137 is 1,000 cm^3/g under acidic conditions and 2,000 cm^3/g under neutral conditions; the K_d value for plutonium is 0.4 cm^3/g under acidic conditions and 600 cm^3/g under neutral conditions.

Among the radionuclides detected in the upper contaminated zone, only carbon-14 reaches the groundwater table during the 1,000-year period. Carbon-14 has the shortest time of travel through the vadose zone because it does not sorb ($K_d = 0$ cm^3/g), reaching the groundwater in 560 years. The maximum carbon-14 concentration in groundwater is 2,240 pCi/L at 638 years in the future. The peak carbon-14 concentration slightly exceeds the MCL of 2,000 pCi/L but occurs as a sharp spike that diminishes to less than 2,000 pCi/L within 50 years of the peak concentration. At 1,000 years in the future, the carbon-14 concentration in groundwater has fallen to less than 100 pCi/L.

Strontium-90 is the only radionuclide present in the middle contaminated zone. Strontium-90 is moderately immobile in the environment (K_d – 22 cm^3/g) and travels slowly through the unsaturated zone. Analysis results indicate that strontium-90 will not reach groundwater during the 1,000-year period. The RESRAD calculated time of travel to the groundwater table is 134,000 years.

Tritium is the only radionuclide present in the deep contaminated zone. Tritium is non-sorbing ($K_d = 0$ cm^3/g) and reaches the groundwater during the first year of the simulation. The maximum groundwater concentration is 14,422 pCi/L at 18 years in the future. The peak tritium concentration is below the MCL of 20,000 pCi/L and quickly diminishes by radioactive decay.

These results reflect conditions under an unrestricted land use assumption in which the site receives irrigation water (irrigation rate=0.76 m/yr) in addition to water that infiltrates through precipitation. For a restricted land use assumption in which there is no irrigation at the site (irrigation rate=0 m/yr), transport is significantly reduced compared to the conditions which occur under an unrestricted land use case. Carbon-14 reaches the groundwater table from the upper contaminated zone in 2,575 years (versus 560 years) with the maximum groundwater concentration of 1,868 pCi/L arriving 2,984 years (versus 638 years) in the future. Tritium still reaches the groundwater table from the lower contaminated zone in the first year of the simulation but the maximum groundwater concentration is 3,157 pCi/L at 18 years in the future, which is significantly less than the 20,000 pCi/L MCL value.

Extrapolation of RESRAD Model Results to Other 200-MW-1 OU Waste Sites. The RESRAD modeling performed for the 216-A-2 and 216-A-5 Cribs, under both restricted and unrestricted land use assumptions, showed that only carbon-14 under unrestricted land use conditions is transported to groundwater at concentrations that could exceed its MCL. Because the SIM mean inventory for carbon-14, tritium and strontium-90 at the other 200-MW-1 OU waste sites (see Table 4-3) lies with the range encompassed by the 216-A-2 and 216-A-5 Cribs, transport of these constituents to groundwater at concentrations resulting in an exceedance of MCLs at a water supply well located at the edge of the waste unit is not expected.

5.2.3.4 216-A-5 Crib Evaluation – STOMP Model Carbon-14 Evaluation

Similar to the uranium evaluation at the 216-A-4 Crib (Section 5.2.3.2), a secondary and more detailed evaluation of carbon-14 transport to groundwater at the 216-A-5 Crib was performed using the STOMP two-dimensional fate and transport model. The modeling results can be used as a basis for remedial alternative development to achieve groundwater protection at the 216-A-5 Crib.

The methodology used in this evaluation involved the calculation and estimation of carbon-14 concentrations in groundwater caused by the carbon-14 contained in the vadose zone. The carbon-14 MCL value of 2,000 pCi/L and the model domain location with the highest modeled groundwater concentration were used as the evaluation basis. Thus, the evaluation involved estimating the residual vadose zone concentration and inventory for carbon-14 at the 216-A-5 Crib, and comparing the modeled groundwater concentrations to the MCL value. The assumptions and key parameter values used in these evaluations are described in Appendix C.

The soil concentrations for carbon-14 within specified vadose zone depth intervals, representing contaminated soil volumes, were used to estimate the quantity of carbon-14 in the vadose zone. The results of modeling can be applied to the conceptual contaminant distributions and contaminant release models to provide an indication of the amount of remediation necessary to achieve protection of groundwater at the 216-A-5 Crib. The recharge rates (shown in Table C4-7) represent the two most probable end states after remediation: reclamation of the shrub-steppe surface and vegetation (0.004 m/yr infiltration rate) either naturally or artificially enhanced, or a surface barrier that reduces or eliminates percolation of water through the waste site (infiltration rate is 0.0005 m/yr for 500 years and 0.001 m/yr thereafter). The protectiveness criteria can be determined by identifying the appropriate conceptual contaminant distribution and the end state of the ground surface.

The modeling results indicate that the carbon-14 in the vadose zone will not cause the groundwater concentration to exceed the MCL at the 216-A-5 Crib. With natural vegetation reestablished on the surface, maximum carbon-14 concentration in groundwater does not exceed 1,000 pCi/L, which is one-half of the MCL. Table C4-8 provides the maximum estimated groundwater concentrations for carbon-14 associated with various future surface conditions. No breakthrough of carbon-14 in groundwater above the MCL occurs in any of these scenarios (Table C4-8).

5.3 Pathways

An exposure pathway can be described as the physical course that a contaminant takes from the point of release to the receptor. Contaminant intake or exposure route is the means by which a contaminant enters a receptor. For an exposure pathway to be complete, all of the following components must be present:

- A contaminant source
- A mechanism of contaminant release and transport
- An exposure point (that is, a location where people or wildlife can come into contact with the contaminants)
- An exposure route
- A receptor or exposed population

In the absence of any one of these components, an exposure pathway is considered incomplete and, by definition, no risk or hazard exists. The conceptual exposure model for the 200-MW-1 OU waste sites to be evaluated in the BRA in Chapter 6 is presented in Figure 5-1.

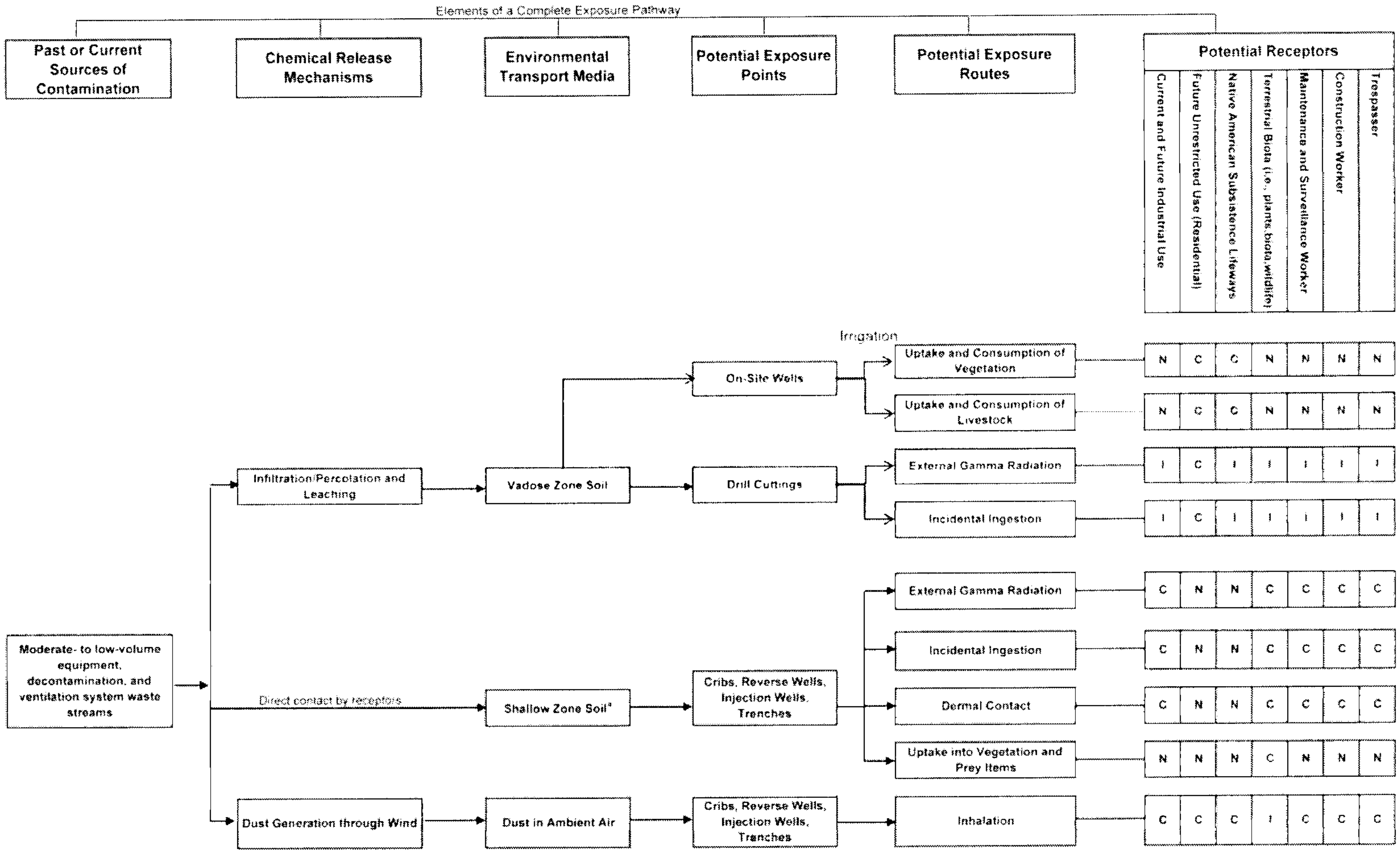
5.3.1 Contaminant Sources

The 200-MW-1 OU representative waste sites consist of four cribs, two injection/reverse wells, and one trench that received moderate-to low-volume equipment, decontamination, and ventilation system waste streams. Although there are seven waste sites included in the 200-MW-1 OU, only the 216-A-2 Crib and the 216-A-4 Crib will be included in the quantitative BRA. In accordance with the approved sampling and analysis plans, data necessary for risk assessment calculations at the 216-A-21 and 216-A-27 Cribs, the 200-E-102 Trench, and the 216-B-4 and 216-C-2 Reverse Wells, was not collected during the remedial and supplemental investigations.

5.3.2 Release Mechanisms and Environmental Transport Media

The following presents the primary releases that transport contaminants from their sources, via environmental media, to potential receptors in the vicinity of the cribs:

- Direct contact and external radiation with soil containing contaminants (receptor contact with shallow zone soil replaces release and transport).
- Infiltration, percolation, and leaching of contaminants from waste site soil to groundwater.
- Generation of dust emanating from shallow zone soil to ambient air from wind or during maintenance or construction activities at the site.



a Shallow zone soil is defined as zero to 15 feet below ground surface. This depth could be extended beyond 15' bgs when suggested by site-specific data

C = Potentially complete pathway
N = Incomplete pathway
I = This is a potentially complete pathway, however exposure is considered insignificant

Figure 5-1. Conceptual Exposure Model for the 200-MW-1 Operable Unit

5.3.3 Potentially Complete Human Exposure Pathways and Receptors

The exposure pathways for potential current and future human receptors at the 200-MW-1 OU have been formulated based on the site conceptual model, in accordance with EPA/540/1-89/002, *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A): Interim Final*, OSWER 9285.7-02B. Because the waste sites are located within the industrial (exclusive) land use area (DOE/EIS-0222-F), the most likely human receptor is an industrial worker. However, a variety of receptors are evaluated in the risk assessment to indicate what potential exposures would be if future land use were unrestricted. On the basis of current understanding of land use, the most plausible exposure pathways considered for characterizing human health risks are presented in Figure 5-1. A brief description of each exposure scenario considered for industrial (exclusive) land use and unauthorized land use is described below.

5.3.3.1 Exposure Scenarios

Industrial Worker Scenario. Under reasonably anticipated future site conditions, industrial workers could potentially be exposed to shallow zone soil from the waste site. The future industrial worker exposure scenario assumes that the workplace is the key source of contaminant exposure and that the receptor could potentially be exposed to shallow zone soil. Potential routes of exposure to soil include direct external exposure, incidental soil ingestion, dermal contact with soil, and inhalation of ambient vapors or dust generated from wind or maintenance activities. This exposure scenario assumes that drinking water is obtained from a source other than the groundwater beneath the site and that food products are not grown on the site.

Maintenance and Surveillance Worker (Authorized User) Scenario. Under reasonably anticipated future site conditions, maintenance and surveillance workers (authorized users) could potentially be exposed to the top three feet of surface soil within the inner area of the Central Plateau. The future maintenance and surveillance worker exposure scenario assumes that exposure to surface soil occurs while performing waste site surveillance activities such as walk downs and visual inspections and during preventative maintenance and building surveillance activities. Potential routes of exposure to surface soil include direct external exposure, incidental soil ingestion, dermal contact with soil, and inhalation of ambient vapors or dust generated from wind or maintenance and surveillance activities. This exposure scenario assumes that drinking water is obtained from a source other than the groundwater beneath the site.

Trespasser (Unauthorized User) Scenario. Under reasonably anticipated future site conditions, an older youth and adult who trespass within the inner area of the Central Plateau could potentially be exposed to the top three feet of surface soil. The future trespasser (unauthorized user) exposure scenario assumes that exposure to surface soil occurs when trespasser infrequently enter the inner area of the Central Plateau to conduct unauthorized off-road activities such as dirt bike riding, mountain bike riding, or hiking. Potential routes of exposure to surface soil include direct external exposure, incidental soil ingestion, dermal contact with soil, and inhalation of ambient vapors or dust generated from wind or off-road activities. This exposure scenario assumes that drinking water is obtained from a source other than the groundwater beneath the site.

Construction Worker (Authorized User) Scenario. Under reasonably anticipated future site conditions, construction workers (authorized users) could potentially be exposed to the top 15 feet of soil within the inner area of the Central Plateau. The future construction worker exposure scenario assumes that exposure to shallow zone soil occurs while performing short-term work activities such as trenching or excavation. Potential routes of exposure to soil include direct external exposure, incidental soil ingestion, dermal contact with soil, and inhalation of ambient vapors or dust generated from wind, trenching, or excavation activities. This exposure scenario assumes that drinking water is obtained from a source other than the groundwater beneath the site.

Rural Residential Scenario. To provide a consistent basis for determining whether remedial action is necessary at waste sites, DOE has begun including a rural residential exposure scenario in BRAs for these sites. The rural residential scenario represents the true baseline risk to evaluate the "no action alternative" in which DOE could walk away from the site, essentially leaving it available for completely unrestricted use. Inclusion of a rural residential scenario in a BRA is consistent with EPA and DOE guidance provided in EH-231-014/1292, *Use of Institutional Controls in a CERCLA Baseline Risk Assessment*, and is intended to provide a conservative yet defensible estimate of the relative maximum exposure, or "true" baseline risk, associated with a waste site in the absence of any remedial action or control (institutional or otherwise).

In estimating a baseline RME, the only pre-existing controls or actions that can be considered are those actions that have already been taken to reduce or eliminate contaminants as opposed to controlling or precluding exposure (EH-231-014/1292). No credit is taken for actions that simply control access to a site or limit exposure to existing contamination in developing the rural residential scenario. Therefore, although the existing institutional controls (ICs) at the 216-A-2 Crib limit current and future exposures, they do not reduce or eliminate contaminants from the site and are not considered in the exposure assessment for this analysis.

The rural residential scenario is evaluated based on exposure to a hypothetical rural resident assuming unrestricted use. This scenario does not represent one of the future land uses envisioned for the Central Plateau and generally is not the basis for developing final remediation goals. Use of this scenario is only intended to define the true baseline to evaluate the "no action alternative" within the FS. The results of this analysis can be used as a basis for taking remedial action and can be used in evaluation of remedial alternatives to identify areas where ICs or other remedial actions may need to be implemented.

Under future site conditions, the hypothetical rural resident resides on the waste site, consumes crops raised in a backyard garden, and consumes meat (that is, beef and poultry) and milk from penned livestock. Based on the land uses identified in DOE/EIS-0222-F, it is unlikely that the 200-MW-1 OU waste sites will be used for residential purposes. A fundamental assumption associated with having a residence on the Central Plateau is the presence of a nearby well that is used for drinking water and irrigation purposes. For purposes of this scenario, it is assumed that such a well has been drilled to groundwater within the footprint of the 216-A-2 Crib and that the drill cuttings from the well have been disposed of by spreading them over the surface of a nearby land parcel. Well drilling is conservatively assumed to occur with the waste site in its current configuration, prior to any migration of radioactive contamination away from the site. However, this supplemental RI and risk assessment focuses on contamination present in the soils within the waste site and does not address existing groundwater contamination beneath the OU. As a result, groundwater and soil exposure pathways relevant to the hypothetical rural resident cannot be summarily combined. It should be noted that for radiological contaminants, the contribution of soil contamination to drinking water and water used for irrigation purposes is evaluated. Exposure pathways associated with existing groundwater contamination beneath the 200-MW-1 OU is not considered in the risk evaluation and will be addressed in the 200-PO-1 Groundwater OU.

The hypothetical rural resident is assumed to establish a residence on the land parcel immediately after the well is drilled and to receive exposure to radioactive contamination in the drill cuttings by direct contact with the soil and through the food chain. The direct contact pathway includes exposure through external radiation, incidental soil ingestion, and inhalation of dust particulates. The food chain pathway includes exposure from ingestion of fruits and vegetables grown in a backyard garden and consumption of meat and milk from livestock raised in the contaminated area. Uptake of contamination into crops and livestock is solely from contamination present in soil, and includes use of groundwater contaminated by migration of contaminants in the soil beneath the waste site. The contribution of radioactive contamination in the redistributed drill cuttings to drinking water and water used for irrigation purposes is also included in the evaluation. Radioactive soil contamination represents a potential future source of exposure via the groundwater pathway through leaching and transport of the soil contamination to groundwater by infiltrating moisture.

5.3.3.2 Tribal Use Scenarios

Several local and regional Tribes have ancestral ties to the Hanford Reach of the Columbia River and surrounding lands. DOE has requested that each Tribe provide an exposure scenario that reflects their traditional activities. At this time, the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) (Harris and Harper, 1997, "A Native American Exposure Scenario") and the Yakama Nation (Ridolfi, 2007, *Yakama Nation Exposure Scenario for Hanford Site Risk Assessment*) have provided scenarios. A quantitative risk evaluation is included for both Tribal use scenarios, and the results are presented in Appendix D and Appendix E.

The CTUIR and Yakama Nation exposure scenarios each include an evaluation of external gamma radiation, incidental soil ingestion, and inhalation of dust particulates for the direct-contact pathway. These scenarios also include exposure from food chain pathways, including consumption of fruits and vegetables grown in a backyard garden and consumption of beef and poultry that graze on and are penned on a pasture. Milk consumption is included in the Yakama Nation exposure scenario but is not included in the food consumption pathway for the CTUIR scenario. Exposure from the food chain pathways is solely from contamination present in soil, and includes use of groundwater contaminated by migration of contaminants in the soil beneath the waste site. As described earlier, existing groundwater contamination beneath the 200-MW-1 OU is not considered in this risk evaluation and will be addressed in the 200-PO-1 Groundwater OU.

Additionally, the CTUIR and Yakama Nation exposure scenario includes potential exposure from consumption of wild game hunted on the Central Plateau. However, exposure from consumption of wild game is not included in this evaluation because the size of these cribs could not support foraging wild game. The area of the 216-A-2 and 216-A-4 Cribs sites are each approximately 88 m^2 (947 ft^2). The CTUIR and Yakama Nation scenarios also include assumptions to estimate potential exposure from the consumption of fish and sweat lodge use. For purposes of this risk assessment, both exposure pathways are considered incomplete and were not evaluated. The fish consumption exposure pathway is being included by the 100 Areas and 300 Area River Corridor BRA. The sweat lodge exposure pathway is not included because only contamination associated with the source area is addressed in this risk assessment.

5.3.4 Potentially Complete Ecological Exposure Pathways and Receptors

The conceptual model for ecological exposures is presented in Chapter 6.

5.4 Uncertainties

The site characterization data collected as part of the remedial and supplemental investigations performed at the 200-MW-1 OU waste sites provided important information on the nature and vertical distribution of contaminants discharged to the 216-A-2 and 216-A-4 Cribs. The remaining 200-MW-1 OU crib sites were characterized through process knowledge and correlation of site characterization data from the 216-A-5 Crib, providing reasonable estimates on the probable nature and distribution of contaminants in the subsurface at the remaining sites, and allowing for risk management decisions. Process knowledge was utilized to characterize the reverse wells and the trench.

The primary uncertainty remaining from the 200-MW-1 OU RI relates to defining the actual distribution of contaminants in subsurface soil at each of the waste sites. The information obtained from the RI can be used to plan for more detailed characterizations, as needed, to support remedy implementation. Therefore, additional sampling to confirm the preliminary conceptual site models presented in Chapter Four will be an important element for all of the remedial alternatives to be developed in the FS. Based on existing information, the conceptual site model confirmation for these investigations should focus on:

- 216-A-2 Crib: The nature and vertical distribution of contaminants has been defined based on information obtained from boring C5515. Because the effluent volume discharged to this unit is low, the lateral distribution of contaminants is likely confined within the crib's footprint. No further investigatory information is needed.
- 216-A-4 Crib: The lateral distribution of contaminants is based on the information obtained from boring C5301. However, the vertical extent beneath the crib footprint has not been defined below a depth of approximately 7 m (23 ft). One additional boring advanced to the water table would provide confirmation of uranium-metal distribution per the STOMP model simulations.
- 216-A-21 Crib: The information obtained from the single boring advanced through the crib footprint provides some information on the nature, lateral and vertical distribution of contaminants. One additional boring is recommended. The boring would be placed within the crib footprint at the downstream end of the distribution pipe and advanced to the water table. Samples should be tested for general chemistry parameters, selected metals, and radionuclides.
- 216-A-27 Crib: The information obtained from geophysical logging of the two monitor wells located along the south boundary of the crib footprint provides some information on the nature, lateral and vertical distribution of contaminants. One additional boring is recommended. The boring would be placed within the crib footprint at the downstream end of the distribution pipe and advanced to the water table. Samples should be tested for general chemistry parameters, selected metals, and radionuclides.
- 200-E-102 Trench: The single boring advanced through the reported trench footprint did not encounter significant shallow zone contamination. Two to three additional direct push boreholes advanced to depths of up to 3 m (10 ft) is recommended to verify the presence or absence of contaminated soil placed in the trench and to confirm its lateral extent. Samples should be tested for radionuclides.
- 216-B-4 and 216-C-2 Reverse Wells: No sampling was performed at these waste sites during the RI. Sampling conducted at other reverse well sites has confirmed that there is very little lateral migration associated with these types of waste units. Therefore, one boring at each reverse well, advanced in close proximity to the original well casing is recommended. Each boring would be advanced to the water table. Samples should be tested for radionuclides to confirm the limited depth of contamination.

These sampling scenarios will be utilized during remedial activities to validate the understanding of the contaminant distribution at each waste site during remedial activities. If the sampling data do not validate the information discussed in this FS, then additional assessment may be conducted to determine the impact of the data on the risk assessment and remedial selection process.

The conceptual exposure model has outlined the exposure pathways and receptors that will be evaluated in Chapter 6. The future industrial use (industrial worker) and future unrestricted use (rural resident) exposure scenarios will be evaluated as the basis for action at the waste sites. The remaining exposure scenarios (construction worker, maintenance worker, and trespasser [unauthorized user]) will be utilized to develop PRGs for the waste sites during remedial activities.

6 Baseline Risk Assessment

This chapter provides a description of the methods, results, and uncertainties associated with the human health and ecological BRA conducted for the seven waste sites comprising the 200-MW-1 OU. The human health and ecological BRA is an estimate of the risk to hypothetical receptors exposed to site-related constituents, assuming no further remedial actions are performed. The purpose of the BRA is to estimate the possible risk to human health and ecological resources from exposure to the hazardous and radiological constituents detected in and beneath the 200-MW-1 waste sites. Accordingly, the BRA process used information developed during site investigations to:

- Determine the COPCs for the 200-MW-1 OU waste sites.
- Assess the potential for human exposure at the individual waste sites (using quantitative and qualitative information for the waste sites, as appropriate).
- Assess the potential for ecological exposure at the individual waste sites (using quantitative and qualitative information for the waste sites, as appropriate).
- Assess the potential for threats to groundwater at the individual waste sites (using quantitative and qualitative information for the waste sites, as appropriate).
- Based on the data and information available, quantify potential exposures for both an assumed unrestricted baseline (i.e., unrestricted rural residential) land-use scenario, and also for a reasonably anticipated Hanford Central Plateau specific future industrial land-use scenario.
- Provide a summary of the risk-related rationale for the development of remedial alternatives for the seven 200-MW-1 waste sites, considering both the assumed unrestricted baseline and the reasonably anticipated future land-use scenarios.

The results of the BRA will help determine the need for remedial action, identify specific environmental media and areas for which cleanup is appropriate, present a "baseline" of potential human health and ecological risks for the no-action alternative in the feasibility study, and provide criteria for determining appropriate cleanup levels. A summary of the methods used and the detailed calculations of the risk assessment are presented in Appendix D.

This chapter is organized into four major subsections: Section 6.1 and Section 6.2 address the human health risk assessment component and associated results, respectively, while Section 6.3 and Section 6.4 provide the ecological risk assessment component and associated results, respectively. Within Section 6.1, the following major human health subtopics are included:

- An overview of the risk assessment framework, methods, conceptual exposure model development, points of compliance, and data sources/data usability
- A presentation of the human health risks under an assumed baseline (unrestricted–rural residential) land-use scenario; human health risks under the reasonably anticipated future industrial land-use scenario; and human health risks for additional scenarios (the tribal land use scenarios) of interest to Hanford stakeholders.

Within the baseline human health evaluation in Section 6.2, both the baseline direct contact human health pathways are considered along with an evaluation of future waste site threats to underlying groundwater. For the baseline direct contact human health analysis, two unrestricted rural residential exposure scenarios are presented:

1. A shallow scenario, representing direct contact exposure to contamination within a 0-15 feet exposure depth.

2. A Hanford-specific deep scenario, representing direct contact exposure to contamination from deeper horizons beneath the Central Plateau in the form of drill cuttings (extending from 15 feet to groundwater depth) brought to the surface during a hypothetical future domestic well drilling scenario. This scenario further assumes the drill cuttings are then hypothetically mixed with surface soils at the location of the hypothetical rural resident and used in a gardening scenario.

Finally, in Section 6.4, a summary of the quantitative and qualitative risk assessment results are provided, including a tabulation of the risk-related rationale for remediation and subsequent development of remedial alternatives for each of the seven waste sites comprising 200-MW-1 OU.

Figure 6-1 summarizes the overall risk management and remedial action evaluation decisions supported by the human health and ecological BRA.

6.1 Human Health Risk Assessment

The human health risk assessment was performed in accordance with available EPA guidance for conducting risk assessments under CERCLA. It is also consistent with Tri-Party Agreement requirements and approaches for risk assessment developed by the Tri-Party Agencies.

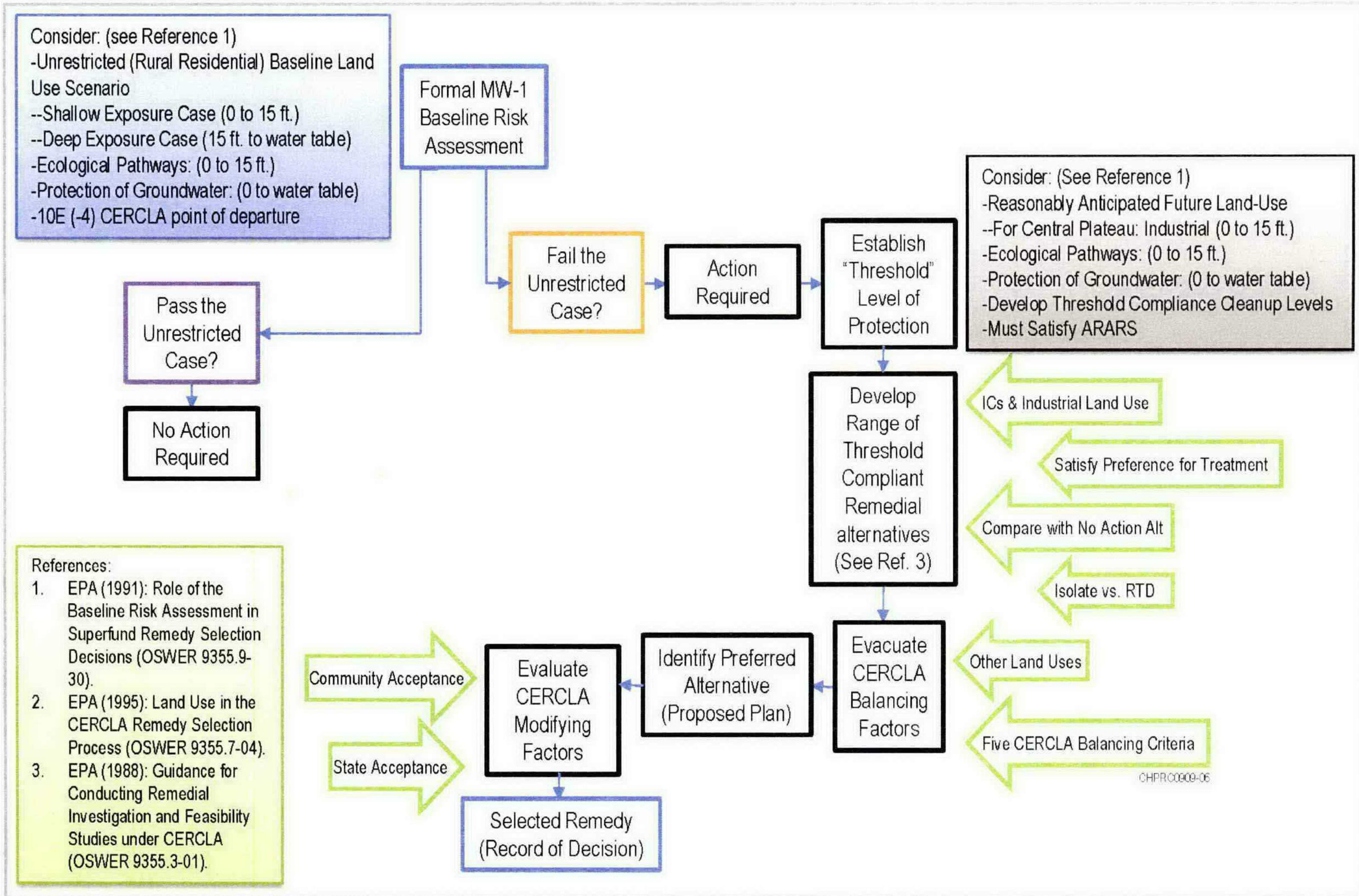
6.1.1 Assessment Framework, Data Sources, and Data Usability

The RI/FS process is an analytical process designed to support risk management decision making for CERCLA sites, and the assessment of health and environmental risks plays an essential role in the RI/FS (EPA/540/G-89/004).

A BRA is performed as one of the objectives of the RI Report (DOE/RL-2001-65). Uncertainties associated with the assessment of risk to HHE, as well as the evaluation of remedial options

> "...can be numerous, ranging from potential unknowns regarding site hydrogeology and the actual extent of contamination, to the performance of treatment and engineering controls being considered as part of the remedial strategy. While these uncertainties foster a natural desire to want to know more, this desire competes with the CERCLA program's mandate to perform cleanups within designated schedules. The objective of the RI/FS process is not the unobtainable goal of removing *all* uncertainty, but rather to gather information sufficient to support an informed risk management decision regarding which remedy appears to be most appropriate for a given site."

Therefore, as part of the assessment of health and environmental risk, the level of uncertainty associated with a number of factors considered during the assessment is also identified and discussed (EPA/540/G-89/004).



EPA (1995): Refer to Laws, 1995.

EPA (1988): Refer to EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*.

Figure 6-1. Central Plateau Risk Information and Decisions Supported by the MW-1 Human Health and Ecological Baseline Risk Assessment

The 200-MW-1 OU consists of the seven inactive waste sites shown in Table 6-1.

Table 6-1. 200-MW-1 Source Operable Unit Waste Sites

Waste Site	Site Type	Site Status	Location
216-A-2	Crib	Inactive	200 East Area
216-A-4	Crib	Inactive	200 East Area
216-A-21	Crib	Inactive	200 East Area
216-A-27	Crib	Inactive	200 East Area
216-B-4	Injection/Reverse well	Inactive	200 East Area
216-C-2	Injection/Reverse well	Inactive	200 East Area
216-E-102	Trench	Inactive	200 East Area

Based on the timing and sequencing of primary and supplemental characterization activities for the 200-MW-1 OU, quantitative data for use in the BRA are available for only two sites: the 216-A-2 and 216-A-4 Cribs. Characterization data acquired from RI activities for the 216-A-5 Crib were used to help develop conceptual site models for several 200-MW-1 OU cribs and to be informed of decisions regarding groundwater impacts. The remaining five sites have some data available, but these data are not adequate for risk assessment purposes and are treated qualitatively based on process knowledge, site history, and inferential knowledge derived from similar bounding sites in other OUs. The qualitative assessments for the five sites are provided at the end of Chapter 6, where the summary of the baseline results is provided.

Note that while the qualitative assessments for the five sites that do not have data available are technically not part of the BRA (since quantitative data are required to perform a formal CERCLA BRA), professional judgments are still necessary to decide on the need for action for these sites. Therefore, for the five sites that are treated qualitatively conservative assumptions are made as appropriate that will be refined with additional characterization activities planned to be conducted during remedial design and implementation. The need for further characterization during remedial design and implementation is a fundamental tenet of DOE's commitment to properly clean up the nearly 1,200 or more waste sites distributed across the Central Plateau.

EPA/540/1-89/002 defines a BRA as

> "…an analysis of the potential adverse health effects (current or future) caused by hazardous substance releases from a site in the absence of any actions to control or mitigate these releases (i.e., under an assumption of no action)." The BRA characterizes current site conditions and contamination in the absence of any remedial action that might reduce potential risks in the present or future."

The following are the purposes of the BRA:

- Provide an analysis of baseline risks and help determine the need for action at sites.[4]

[4] Baseline risks are risks that might exist if no remediation or institutional controls were applied at a site.

- Provide a basis for determining levels of constituents that can remain onsite and still be adequately protective of public health.
- Provide a basis for comparing potential health impacts of various remedial alternatives.
- Provide a consistent process for evaluating and documenting public health threats at sites.

The BRA process provides a framework for developing the risk information necessary to assist decision making at remedial sites (EPA/540/1-89/002). The BRA presents relevant and available site data, methodologies followed, identified risks, and associated uncertainties in a clear, logical, easy-to-understand, and transparent manner.

In general, the BRA completed for this RI follows EPA risk assessment guidance (EPA/540/1-89/002; EPA/540/R-97/006) and Ecology guidance (WAC 173-340). The approach includes the following:

- Adherence to CERCLA guidance and the WAC for a human health risk assessment, a screening level ecological risk assessment (SLERA), and an analysis of the groundwater exposure pathway.
- Use of maximum concentrations in all exposure scenario calculations.
- Selection of reasonable maximum exposure assumptions for the reasonable maximum industrial and unrestricted land use exposure scenarios to provide a conservative estimate of health risk.

In addition to human health and ecological risk assessments, potential threats to groundwater under the 200-MW-1 OU were evaluated as part of the assessment (presented in Section 6. 2.4). This assessment is referred to as the "protection of groundwater pathway" and was used to understand potential impacts to groundwater from migration of radionuclide and chemical constituents in contaminated soil through the vadose zone to the aquifer. The findings of the contaminant transport analysis are summarized in Section 5.2.3 and Appendix C.

6.1.2 RI Sampling Strategy and Data Usability

The sampling strategy for the 216-A-4 Crib and the 200-E-102 Trench is described in the DOE/RL-2006-47, and the sampling strategy for the 216-A-2 and 216-A-21 Cribs is described in DOE/RL-2006-77. The RI activities at these cribs and trench were designed to provide site-specific soil data to refine the CSM, support an assessment of risk, and evaluate a range of remedial alternatives for cleanup at these waste sites. Data collected specifically for use in the BRA were limited to the 216-A-2 and 216-A-4 Cribs. Additional data were collected for the other waste sites but are not considered adequate for risk assessment purposes. The types of information and data collected at each of the waste sites are described below.

6.1.2.1 216-A-4 Crib

In July 2004, RI activities were initiated at the 216-A-4 Crib. However, high radiological contamination levels encountered while drilling borehole C4560 resulted in termination of the drilling at a depth of 7.6 m (25 ft). Three split-spoon samples were collected from borehole C4560 from depth intervals ranging between 0.15 and 6.4 m (0.5 and 21 ft) bgs. Commercial laboratory data are available for general chemistry, metals, VOCs, SVOCs, PCBs, total petroleum hydrocarbons, and radiological constituents. Additionally, one opportunistic grab sample was collected from borehole C4560 at approximately 6.7 to 7 m (22 to 23 ft) bgs and was analyzed for radiological constituents. The radiological levels encountered at borehole C4560 were unexpectedly high. With the exception of the opportunistic grab sample, the commercial data from this borehole was used in the BRA. The quality requirements for the opportunistic sample could not be met because the sample mass was inadequate.

To help understand the contamination at the crib, an 18-m (60-ft) direct push hole (C4671) was drilled next to borehole C4560 and geophysically logged for gamma emitting radioisotopes. Logging results indicated a very high zone of Cs-137 near the bottom of the crib, with the potential for americium (Appendix B). In 2007, a new borehole (C5301) was drilled approximately 3 m (10 ft) southwest of the corner of the 216-A-4 Crib, advanced to groundwater, and completed as a monitoring well (299-E-24-23). Six split-spoon samples were collected from the vadose zone at various depth intervals and analyzed.

Commercial laboratory data (split-spoon samples) are available for general chemistry, metals, VOCs, SVOCs, PCBs, total petroleum hydrocarbons, and radiological constituents. Additionally, grab samples were collected for analysis by the ESL. Borehole C5301 analytical data from the commercial laboratory and the ESL grab sample analysis were used to develop a CSM; however, the ESL results are not included in the BRA. The grab samples analyzed by ESL were not collected specifically for characterization or risk assessment purposes. The quality assurance/quality control (QA/QC) performance criteria required for these analyses are not as stringent as those required for risk assessment purposes.

6.1.2.2 200-E-102 Trench

Remedial investigation activities were initiated at the 200-E-102 Trench in 2006. Direct push borehole C5302 was installed through the 200-E-102 Trench and advanced to a depth of 17.2 m (56.4 ft). This borehole was geophysically logged for gamma emitting radioisotopes and one sample was collected at the depth interval of 16.7 to 17.2 m (54.9 to 56.4 ft) bgs. No commercial laboratory data are available for this borehole, but one grab sample from the bottom of the borehole was analyzed by the ESL. These data were used to supplement the CSM but are not used in the BRA.

6.1.2.3 216-A-2 Crib

RI activities were initiated at the 216-A-2 Crib in 2007. A biased (focused) sampling approach was used at the 216-A-2 Crib to increase the chance of encountering the highest levels of contamination in the local soil column. Borehole C5515 was drilled to groundwater and 12 split-spoon samples were collected from the vadose zone at various depth intervals and analyzed for general chemistry, metals, VOCs, SVOCs, PCBs, total petroleum hydrocarbons, and radiological constituents. Grab samples also were collected and analyzed by the ESL. Select grab samples sent to the ESL were analyzed for a limited list of metals, anions, and radiological isotopes. Analytical data from the commercial laboratory and the ESL were used to support the development of the CSM. However, only commercial laboratory data from borehole C5515 were used in the BRA.

6.1.2.4 216-A-21 Crib

RI activities were initiated at the 216-A-21 Crib in 2007. One direct push borehole was installed through the 216-A-21 Crib (C5571) and advanced to a depth of 18.3 m (60.0 ft). This borehole was geophysically logged for gamma emitting radioisotopes and grab samples were collected from five discrete depth intervals. Commercial laboratory data are available for VOCs only from all depth intervals; mercury analysis also was conducted at 11.9 to 12.3 m (39 to 40.5 ft) and 17.7 to 18.2 m (58.2 to 59.9 ft) bgs. Soil samples from those depths also were collected and analyzed by the ESL for select metals, anions, and radiological isotopes. These data were used to supplement the CSM but are not used in the BRA. The grab samples analyzed by ESL were not collected specifically for characterization or risk assessment purposes. The QA/QC performance criteria required for these analyses are not as stringent as those required for risk assessment purposes.

6.1.2.5 216-A-5 Crib

The 216-A-5 Crib is not part of the 200-MW-1 OU. However, data acquired from RI activities at this waste site were used to help develop CSMs for several 200-MW-1 OU cribs with limited site characterization data. RI activities were initiated at the 216-A-5 Crib in 2008. Two boreholes were drilled through the crib to include a shallow borehole for preliminary geophysical data acquisition and a deep borehole for characterization purposes.

Borehole C6551, located roughly 3.0 m (10 ft) northwest of the center of the crib, was advanced to a total depth of 18.7 m (61.5 ft) bgs. It was installed to collect preliminary data for the planned adjacent characterization borehole. This borehole was geophysically logged for gamma and neutron emitting radioisotopes. A planned sample was collected from the base of the borehole and analyzed for general chemistry, metals, anions, and radiological constituents. These data were used to supplement the contaminant distribution model but are not used in the BRA.

Borehole C6552, located roughly 3.0 m (10 ft) northeast of the center of the crib, was advanced to a total depth of 100.4 m (329.5 ft) bgs. This borehole was geophysically logged for gamma and neutron emitting radioisotopes. Borehole C5515 was drilled to groundwater and 14 split-spoon samples were collected from the vadose zone at various depth intervals and analyzed for general chemistry, metals, VOCs, SVOCs, PCBs, total petroleum hydrocarbons, and radiological constituents. Grab samples also were collected and analyzed by the ESL. Select grab samples sent to the ESL were analyzed for a limited list of metals, anions, and radiological isotopes. Analytical data from the commercial laboratory and the ESL were used to support the development of the CSMs for the 216-A-4, 216-A-21 and 216-A-27 Cribs, but were not used in the BRA because the 216-A-5 Crib is not part of the 200-MW-1 OU.

6.1.2.6 Data Usability

The data used for the BRA were collected in accordance with SAPs (DOE/RL-2006-47 and DOE/RL-2006-77), based on the DQOs established for this OU in BHI-01592. In accordance with the QA/QC procedures specified in these SAPs, at least five percent of all data were validated, and a DQA was performed. The DQA is summarized in Appendix A. No sample results were rejected based on this DQA.

In addition to outlining characterization strategy and sampling protocols, the Work Plan (DOE/RL-2001-65) and the SAPs (DOE/RL-2006-47 and DOE/RL-2006-77) provides a preliminary list of COPCs for the 200-MW-1 OU, which includes all contaminants potentially discharged to the waste sites. Additional data for a number of contaminants not on the COC list in the Work Plan were provided in the data set used for the BRA. The raw data used for the BRA are provided in Appendix A.

6.1.3 Framework for the Baseline Risk Assessment

This BRA was conducted to determine whether a potential for risk to HHE exists under current and reasonably anticipated future site-use conditions at the 200-MW-1 OU waste sites. The BRA provides a determination on whether remedial action is warranted at a given waste site. In addition, DOE has agreed to include tribal-use exposure scenarios in the BRA to support risk communication and provide early public participation. The framework for the baseline risk assessment is described in the following subsections.

The scope of the risk assessment follows EPA guidance and the WAC and conducts quantitative assessments for three waste sites (the 216-A-4 Crib, the 216-A-5 Crib, and the 216-A-2 Crib) in the 200-MW-1 OU. The exposure area (or exposure unit) evaluated in the BRA is the soil within or beneath the engineered crib structure at each of the two sites. The remaining five sites are evaluated qualitatively.

As identified by DOE, groundwater use by humans is precluded for the foreseeable future, and is not observed in the shallow soil zone where ecological receptors may contact groundwater. As a result, the use of groundwater by human or ecological receptors is not evaluated as a potential exposure pathway for the 200-MW-1 waste sites. Readers should be aware that remediation of contaminated groundwater beneath the 200-MW-1 OU is the subject of the parallel RI/FS activities underway for the 200-PO-1 Groundwater OU. An evaluation of groundwater exposure pathways and groundwater under assumed baseline scenario conditions (unrestricted rural resident) will be evaluated as part of the 200-PO-1 OU activities.

The main objectives of the risk assessments presented in this RI are as follows:

- Logically present the methodology used and describe the various steps of each assessment.
- Identify chemical and radionuclide COCs, based on their potential for presenting unacceptable health and environmental risks.
- Clearly present the inherent uncertainties associated with the available data; assumptions and parameters used for exposure, toxicity, and contaminant fate and transport; and the resulting risk outcome, for use in the analysis of remedial alternatives.

The following provides the framework of the BRA used to support remedial action decision making. During the RI, the BRA helps determine the need for remedial action at sites. During the FS, the BRA is used to provide a basis for determining levels of constituents that can remain onsite and still be adequately protective of public health (preliminary remediation goals). The BRA can also be used to provide a basis for comparing potential health impacts of various remedial alternatives.

To support the RI decision making process for the 200-MW-1 OU, several points of compliance are considered. Several different land use assumptions and exposure scenarios are applied to each point of compliance to determine whether remedial action should be further evaluated or required. The exposure scenarios and points of compliance used for RI decision making are provided in Table 6-2.

Table 6-2. Summary of Points of Compliance and Exposure Scenarios Used for the Baseline Risk Assessment in the Remedial Investigation

	216-A-2 Crib		**216-A-4 Crib**	
Point of Compliance[1]	0 to 4.6 m (0 to 15 ft) bgs	Full Vadose Zone Soil Column	0 to 4.6 m (0 to 15 ft) bgs	Full Vadose Zone Soil Column
Land Use(s)	Unrestricted Use (Shallow Scenario) and Industrial Land Use	Unrestricted Use – Deep Scenario[2] (0 ft to groundwater)	Unrestricted Use (Shallow Scenario) and Industrial Land Use	Unrestricted Use – Deep Scenario[2] (0 ft to groundwater)
Exposure Scenario	Rural Residential Industrial Worker CTUIR Yakama Nation	Rural Residential Soil Impact on Groundwater – Full soil column (see Section 5.2)	Rural Residential Industrial Worker CTUIR Yakama Nation	Rural Residential Soil Impact on Groundwater – Full Soil Column (see Section 5.2)

[1] Reflects maximum contaminant concentrations within the boundary of each crib and current site configuration.

[2] Assumes rural resident is exposed to drill cuttings.

The current and reasonably anticipated land use for the waste site areas within the 200-MW-1 OU has been designated by DOE as industrial (exclusive). As described in Chapter 4 of this RI Report, the CSMs for the 216-A-2 Crib and the 216-A-4 Crib show that the mass of contamination is located at the base of the crib, which occurs at depths greater than 4.6 m (15 ft). Land use is of interest to the BRA because remedial actions at CERCLA sites should be based on an estimate of the reasonable maximum exposure expected to occur under both current and future land-use conditions, along with an examination of risks for an unrestricted (rural residential) scenario.

6.1.3.1 Conceptual Exposure Model

The conceptual exposure model provides a current understanding of the sources of contamination, physical and ecological setting, current and future land use, and identifies potentially complete human and ecological exposure pathways for the 200-MW-1 OU. Information generated during the development of the RI/FS has been incorporated into this conceptual exposure model to identify potential exposure scenarios.

The DOE worked for several years with cooperating agencies and stakeholders to define land use goals for the Hanford Site and to develop future land-use plans (Drummond, 1992). Cooperating agencies and stakeholders included the National Park Service, Tribal Nations, the States of Washington and Oregon, local county and city governments, economic and business development interests, environmental groups, and agricultural interests. These activities initially were reported by Drummond, 1992 and culminated in the DOE/EIS-0222-F and 64 FR 61615, which were issued in 1999.

Based on DOE/EIS-0222-F and 64 FR 61615, industrial (exclusive) land use is defined as "preserving DOE control of the continuing remediation activities and use of the existing compatible infrastructure required to support activities such as dangerous waste, radioactive waste, and mixed waste treatment, storage, and disposal facilities" (DOE/EIS-0222-F). All waste sites assigned to the 200-MW-1 OU, including the 216-A-2 and 216-A-4 Cribs are located within the core zone. Identification of industrial land use is consistent with the Tri-Parties' response (Klein et al., 2002) to HAB 132. That document indicates that this area of the Hanford Site will have an industrial scenario for the foreseeable future, and authorized access will be controlled and approved by DOE. As a result, an industrial land-use is evaluated as the reasonably anticipated future land use for the 200-MW-1 OU waste sites in the BRA.

In addition to evaluating industrial land use as the future anticipated land use, several unrestricted land-use scenarios (that is, residential and Tribal use) are evaluated in the risk assessment. RL has agreed to include a quantitative analysis of the two available tribal use exposure scenarios in the RI/FS documents.

The inclusion of the Tribal use exposure scenarios supports, in part, the evaluation of the CERCLA modifying criteria of community acceptance. The final remedial action decision will be made based on the evaluation of all nine CERCLA criteria to support remedy selection. Inclusion of the Tribal use exposure scenarios establishes the potential risks to these receptors if the land use designation for this OU were to change from industrial (exclusive) or if a loss of institutional controls were to occur in the future. However, inclusion of the Tribal use scenarios will not be used to define preliminary remediation goals and the resulting cleanup levels.

Under current site-use conditions, no complete human or ecological exposure pathways to groundwater are assumed at these waste sites. Local groundwater is not a current source of drinking water at the 200-MW-1 OU waste sites. Direct exposure to groundwater by terrestrial receptors is considered an incomplete exposure pathway, because no groundwater connection to the surface is available. In addition, the aquifer is too deep (approximately 80 m [262 ft]) for plant roots to bring groundwater contaminants from the aquifer to the surface of the sites. Remediation of contaminated groundwater beneath the Central Plateau is the subject of the RI/FS activities under way for the 200-BP-5, 200-PO-1, 200-UP-1, and 200-ZP-1 Groundwater OUs and is not included in the scope of this BRA.

6.1.3.2 Points of Compliance for the Baseline Risk Assessment

WAC 173-340-740(6), "Unrestricted Land Use Soil Cleanup Standards," "Point of Compliance," and WAC 173-340-745(7), "Point of Compliance," establish a point of compliance for soil-cleanup levels based on potential human exposure to soils via direct contact. This point of compliance is established for soils from the ground surface to 4.6 m (15 ft) bgs. This is intended to represent a reasonable estimate of the depth of soil that could be excavated and distributed at the soil surface, resulting in the potential for human and ecological receptors to contact soil contaminants. In compliance with WAC 173-340-740(6) and WAC 173-340-745(7), the BRA assumes for all scenarios that human and ecological receptors have the potential to contact shallow zone soils from the ground surface to a depth of 4.6 m (15 ft) bgs.

Point of Compliance Considerations for the 216-A-2 Crib

At the 216-A-2 Crib, borehole C5515 was drilled within the crib boundary to a total depth of 99 m (325 ft). Ten soil samples representing 0.76 m (2.5 ft) depth intervals were collected at depths ranging from 4.0 to 97.4 m (13 to 319.5 ft) bgs. Of these ten soil samples, one soil sample was collected from the top 4.6 m (15 ft), which will be used for establishing compliance based on potential human or ecological exposure to soils via direct contact. The remaining soil samples were collected from depths below 4.6 m (15 ft) bgs. All soil samples collected from borehole C5515 were used to rural residential scenario and evaluate impacts to groundwater.

Point of Compliance Considerations for the 216-A-4 Crib

At the 216-A-4 Crib, only soil samples collected from borehole C4560 were used to establish compliance based on potential human exposure to soils via direct contact in the 0 to 4.6 m (0 to 15 ft) bgs point of compliance (Table 6-2). To evaluate impacts of soil on groundwater, it was assumed that results obtained from the 216-A-2 Crib would better represent the vertical distribution of contaminants within the boundary of the 216-A-4 Crib and thus was used in the risk assessment. A replacement borehole C5301 was drilled 2.5 m (8.2 ft) outside the 216-A-4 Crib boundary. These data provide information on lateral distribution of contaminants but do not reflect maximum concentrations within the crib boundary (that is, directly beneath the crib footprint). However, because of the extended depth to groundwater and the close location of borehole C5301, the deep sample results should be compared with the 216-A-2 Crib results.

Point of Compliance Considerations for the 216-A-5 Crib

At the 216-A-5 Crib, borehole C6552 was drilled within the crib boundary to a total depth of 100.43 m (329 ft). Thirty soil samples representing 0.76 m (2.5 ft) depth intervals were collected at depths ranging from 3.8 to 100.43 m (12.5 to 329 ft) bgs. Of these 30 soil samples, one soil sample was collected from the top 4.6 m (15 ft). The remaining soil samples were collected from depths below 4.6 m (15 ft) bgs. All soil samples collected from borehole C6552 were used to evaluate impacts to groundwater.

6.1.3.3 Computation of Exposure Point Concentrations

EPA recommends using an average concentration to represent a "reasonable estimate of the concentration likely to be contacted over time" (EPA/540/1-89/002). EPA also recommends using the 95 percent upper confidence limit (UCL) on the mean for this variable (EPA, 1992, *Supplemental Guidance to RAGS: Calculating the Concentration Term*, OSWER Publication 9285.7-081). However, minimum sample size requirements are not available for calculating a 95 percent UCL concentration because of the small number of samples collected from each of the waste site locations. Therefore, the maximum detected concentration was used as the exposure point concentration (EPC) for each waste site.

6.1.3.4 Selection of Contaminants of Potential Concern

COPCs are chemicals or radionuclides present in the environment at levels that may place exposed humans at risk for experiencing adverse health effects and may partially or wholly originate from site-related sources. COPCs are chemicals or radionuclides present at levels that may result in an adverse health effect for ecological receptors. To identify COPCs at the 200-MW-1 OU, a step-wise selection process described by EPA/540/1-89/002, EPA/540/R-97/006, and WAC 173-340 was used.

6.1.4 Data Summary

The data collected for the RI (and other surveys) and used for this risk assessment were extracted from the HEIS database. This section provides a broad summary of the analytical data. A PNNL letter report provides a detailed summary and presents the minimum and maximum detected and undetected concentrations for all analytes, as well as the detection frequency, by waste site. Each soil sample was analyzed for inorganic chemicals (including metals and anions), organic chemicals (VOCs, SVOCs, PCBs, and TBP), and radionuclides.

6.1.5 Data Evaluation

The data evaluation steps used in identifying COPCs at the 200-MW-1 OU include the following:

- Identification of detected constituents
- Elimination of essential nutrients
- Comparison of shallow zone and deep zone soils to Hanford Site background levels
- Availability of toxicity values for the human health evaluation

COPCs were identified separately for shallow zone soils for the human and ecological receptors, and COPCs were identified for the combined shallow- and deep zone soils for the groundwater protection pathway.

For purposes of the BRA, the sample data were partitioned into groups based on the depth the sample was collected and the point of compliance (Table 6-2).

Shallow zone soil samples collected from the 216-A-2 Crib were defined as depths ranging from 0 to 4.6 m (0 to 15 ft) bgs for the purpose of evaluating the ecological and human health direct contact exposure pathways.

Deep zone soil samples collected from 216-A-2 Crib were defined as those samples collected from the soil surface to the groundwater table for the purpose of evaluating impact to groundwater in Section 5.2 of this report.

Shallow zone soil samples collected from the 216-A-4 Crib were defined as depths ranging from zero to 4.6 m (0 to 15 ft) bgs for the purpose of evaluating the human health direct contact exposure pathways.

Deep zone soil samples collected from 216-A-5 Crib were defined as those samples collected from the soil surface to the groundwater table for the purpose of evaluating impact to groundwater in Section 5.2 of this report.

6.1.6 Identification of Detected Constituents

As described previously, the HEIS database was queried and the data were grouped to identify the maximum detected concentration per analyte for each waste site, by shallow and deep zone soils. All non-radiological and radiological constituents detected in one or more samples were included in the human health and ecological risk assessments and the groundwater impacts analysis. Maximum detected results were selected for use in all cases. Sample data with estimated concentrations (that is, those qualified with a "J," indicating that the result is an estimate) were evaluated at their reported concentrations. The data for some analytes were qualified to indicate analytes detected in associated laboratory blanks (that is, those qualified with a "B"). These data were evaluated at their reported concentrations.

All constituents that were detected at least once in any of the shallow or deep zone soil samples were retained and carried forward into the next step of the analysis. Constituents not detected in any of the soil samples (that is, zero percent frequency of detection) were not carried forward into the BRA. The PNNL letter report shows all analytes, including those with 0 percent frequency of detection.

6.1.7 Identification of Essential Nutrients

Essential nutrients are those constituents considered essential for human nutrition. Recommended daily allowances are developed for essential nutrients to estimate safe and adequate daily dietary intakes (NAS, 1989, *Recommended Dietary Allowances*).

Examples of essential nutrients for human health are described in EPA/540/1-89/002 and include iron, magnesium, calcium, potassium, and sodium. To ensure that site concentrations of essential nutrients are not significantly elevated above background levels, these analytes were compared to their background concentrations. However, essential nutrients generally are not evaluated in a risk assessment (EPA/540/1-89/002). All essential nutrients were eliminated as human health COPCs, because they were not greater than background concentrations.

6.1.8 Comparison to Hanford Site Background Values

Detected constituents were compared to the Hanford Site background values described in Chapter Four. Constituents with concentrations above background concentrations were retained for further evaluation.

6.1.9 Availability of Toxicity Values

If a toxicity value was not available from EPA's Integrated Risk Information System (IRIS) database or the Provisional Peer-Reviewed Toxicity Values database, then the chemical was further evaluated to determine if a structurally similar chemical could be used as a surrogate toxicity factor.

Toxicity values were not available from any source for bismuth, sulfate, phosphate, 2,4-dimethylheptane, and 2,6-dimethylheptane.

Bismuth has a long history of use as a pharmaceutical in Europe and North America. A well known, clinically used form of bismuth is bismuth subsalicylate, or Pepto-Bismol®. Most bismuth compounds are insoluble and poorly absorbed from the gastrointestinal tract with less than one percent of an oral dose being absorbed. Bismuth compounds are also poorly absorbed when applied to the skin, even when the skin is abraded or burned. Acute renal toxicity is possible with oral administration of bismuth, particularly in children. Chronic toxicity with a broad spectrum of symptoms and manifestations is also possible at clinical doses (Klaassen, 2001, *Casarett and Doull's Toxicology: The Basic Science of Poisons*). Even though bismuth may be toxic at doses related to clinical treatment, effects from exposure to environmental concentrations are unlikely to be seen because of the very low absorption potential of bismuth. The amount of bismuth subsalicylate in a single dose of Pepto-Bismol® is 524 mg (7.8 mg/kg bw/d) for a 70 kg adult.

Sulfate and phosphate are anions generally recognized to be nontoxic to humans.

® Pepto-Bismol is a registered trademark of Proctor and Gamble Corporation, Cincinatti, Ohio.

The Agency for Toxic Substances and Disease Registry developed a list of substances that were not considered for the 2007 priority list of substances (ATSDR, 2007). This list includes substances of petroleum origin regulated by legislation other than CERCLA and therefore are excluded from becoming potential toxicological profile candidates under CERCLA. Included in this list of substances is dimethyl heptane and 1,2,4-trimethylbenzene: 2,4-and 2,6-dimethylheptane are isomers of n-heptane, which is a straight chain alkane. Toxicological values are not available for n-heptane. These constituents do not have toxicological values that are not expected to be significant contributors to total site risk; therefore, surrogate toxicological values were not used in the BRA. Total petroleum hydrocarbons were analyzed in all soil samples collected from the 200-MW-1 OU but were never detected.

6.1.10 Results of the COPC Selection Process

The following two subsections present the results of the COPC selection process for the BRA and the risk evaluation used to support the balancing and modifying criteria evaluation. The COPC selection process outlined in the previous four sections is the same for both risk assessment activities. The results of COPC identification process is presented separately for each risk assessment activity because the points of compliance used for the BRA are different from the points of calculation used to support the balancing and modifying criteria evaluation.

6.1.11 COPCs Identified for the Baseline Risk Assessment

COPCs identified for the shallow zone represent soil depths ranging from 0 to 4.6 m (0 to 15 ft) bgs. The purpose of this process is to identify site-related constituents that should be carried into the direct contact exposure analysis. Results for the COPCs selection process are shown in Table 6-3 through Table 6-5. The results of the COPC selection process for constituents detected in shallow zone soil 0 to 4.6 m (0 to 15 ft bgs) from the 216-A-2 and 216-A-4 Cribs are provided in Table 6-3 and Table 6-5, respectively. The results of the COPC selection process for constituents detected in deep zone soil (zero to the groundwater table) from the 216-A-2 Crib is provided in Table 6-4.

216-A-2 Crib (0 to 4.6 m [0 to 15 ft] bgs). One soil sample was collected and analyzed from the 4.0 to 4.7 m (13 to 15.5 ft) bgs depth interval. Of all the constituents analyzed, six metals (arsenic, barium, chromium, copper, lead, and uranium), two general chemistry parameters (nitrate and sulfate), and three of the uranium isotopes were detected. All metals, general chemistry parameters, and the three uranium isotopes were detected at concentrations below their respective lognormal 90^{th} percentile Hanford Site background concentrations (Table 6-3). Therefore, no COPCs are carried forward into the BRA to evaluate the direct contact exposure pathway.

These results are consistent with the contaminant distribution model for the 216-A-2 Crib, which indicates that the mass of contamination at this crib is at the point of discharge (at or below 8.2 m [27 ft] bgs).

Table 6-3. 216-A-2 Crib (C5515) Comparison of Maximum Soil Concentrations from 0 to 4.6 m (0 to 15 ft) bgs to Hanford Site Background

Constituent Name	Maximum Detected Concentration	Depth of Maximum Detected	Lognormal 90th Percentile Background Concentration	Does Maximum Detected Exceed Background?
Metals Analyses (mg/kg)				
Arsenic	3.32	13-15.5	6.47	No
Barium	50	13-15.5	132	No

Table 6-3. 216-A-2 Crib (C5515) Comparison of Maximum Soil Concentrations from 0 to 4.6 m (0 to 15 ft) bgs to Hanford Site Background

Constituent Name	Maximum Detected Concentration	Depth of Maximum Detected	Lognormal 90th Percentile Background Concentration	Does Maximum Detected Exceed Background?
Chromium (III)	6.02	13-15.5	18.5	No
Copper	7.91	13-15.5	22	No
Lead	3.41	13-15.5	10.2	No
Uranium (total)	0.364	13-15.5	3.21	No
General Inorganic Chemistry (mg/kg)				
Nitrate as N	0.6	13-15.5	11.75 (Nitrate as N) or 52 (Nitrate)	No
Sulfate	12.7	13-15.5	237	No
Radiological Constituents (pCi/g)				
Uranium-233/234	0.15	13-15.5	1.1	No
Uranium-235	0.016	13-15.5	1.109	No
Uranium-238	0.13	13-15.5	1.06	No

216-A-2 Crib (0 to groundwater table). Thirteen soil samples were collected and analyzed from the soil column of the 216-A-2 Crib. Soil samples were collected from depth intervals that ranged from 4.0 m to the groundwater table (4.0 to119 m [13 to 391 ft]). Of all the constituents analyzed, eleven metals, five general chemistry parameters, five VOCs, five SVOCs, Aroclor-1254, and 18 radiological isotopes were detected.

Maximum concentrations of arsenic, barium, cadmium, mercury, silver, uranium, nitrate, and sulfate were below their respective lognormal 90th percentile Hanford Site background value and are not carried further in the risk evaluation process. Similarly, K-40, Ra-226, Ra-228, Th-228, and Th-232 were below their respective lognormal 90th percentile Hanford Site background value and are not carried further into the risk evaluation process.

Toxicity values are not available from any source for 2,4-dimethylheptane or 2,6-dimethylheptane. However, exposure to environmental levels of 2,4- and 2,6-dimethylheptane are unlikely to result in a potential risk. Therefore, these two constituents are not carried forward into the risk evaluation process.

Constituents with maximum concentrations greater than their respective lognormal 90th percentile Hanford Site background value or those without background values are carried forward to determine if their concentrations have the potential to impact groundwater beneath the 200-MW-1 OU. Maximum concentrations of chromium, copper, lead, Cs-137, Co-60, Eu-154, Pu-238, Pu-239/240, Sr-90, U-233/234, U-235, and U-238 are above their respective lognormal 90th percentile Hanford Site background values. As shown in Table 4-2, background values are not available for any of the VOCs, SVOCs, Aroclor-1254, hexavalent chromium, selenium, Am-241, Ni-63, tritium, and U-236.

Table 6-4. 216-A-2 Crib Comparison of Maximum Soil Concentrations from 0 to Groundwater Table to Hanford Site Background

Constituent Name	Maximum Detected Concentration from 0 to Groundwater Table	Depth of Maximum Detected from 0 to Groundwater Table	Lognormal 90th Percentile Background Concentration	Does Maximum Detected from 0 to Groundwater Table Exceed Background?
Metals Analyses (mg/kg)				
Arsenic	6.4	285-287	6.5	No
Barium	117	285-287	132	No
Cadmium	0.35	285-287	0.81	No
Total Chromium	24	285-287	19	Yes
Chromium (VI)	0.25	132.5-135	Not Available	No Background
Copper	23	285-287	22	Yes
Lead	10.3	285-287	10	Yes
Mercury	0.15	32-34.5	0.33	No
Selenium	0.79	285-287	Not Available	No Background
Silver	0.63	29-31.5	0.73	No
Uranium (total)	147	29-31.5	3.2	Yes
General Inorganic Chemistry (mg/kg)				
Cyanide	0.23	29-31.5	Not Available	No Background
Nitrate as N	13	285-287	11.75 (Nitrate as N) or 52 (Nitrate)	Yes
Nitrite as N	0.78	29-31.5	Not Available	No Background
Phosphate	313	29-31.5	0.79	Yes
Sulfate	35	285-287	237	No
Volatile Organic Compounds (mg/kg)				
1,2,4-Trimethylbenzene	5.50E-04	32-34.5	Not Available	No Background
Acetone	0.0082	32-34.5	Not Available	No Background
Methylene Chloride	0.0037	32-34.5	Not Available	No Background
Styrene	0.0090	32-34.5	Not Available	No Background
Toluene	5.70E-04	32-34.5	Not Available	No Background
Semi-volatile Organic Compounds (mg/kg)				
2,4-Dimethylheptane	0.24	32-34.5	Not Available	No Background
2,6-Dimethylheptane	0.15	32-34.5	Not Available	No Background
Bis (2-ethylhexyl) phthalate	0.047	32-34.5	Not Available	No Background
Di-n-butylphthalate	0.038	32-34.5	Not Available	No Background
Tributyl Phosphate	0.12	29-31.5	Not Available	No Background

Table 6-4. 216-A-2 Crib Comparison of Maximum Soil Concentrations from 0 to Groundwater Table to Hanford Site Background

Constituent Name	Maximum Detected Concentration from 0 to Groundwater Table	Depth of Maximum Detected from 0 to Groundwater Table	Lognormal 90th Percentile Background Concentration	Does Maximum Detected from 0 to Groundwater Table Exceed Background?
Miscellaneous Organic Analyses (mg/kg)				
Aroclor-1254	0.052	29-31.5	Not Available	No Background
Radiological Constituents (pCi/g)				
Americium-241	94,000	27-27.5	Not Available	No Background
Cesium-137	31,000	27-27.5	1.1	Yes
Cobalt-60	0.38	29-31.5	0.0084	Yes
Europium-154	1.3	32-34.5	0.0034	Yes
Nickel-63	11	32-34.5	Not Available	No Background
Plutonium-238	120	32-34.5	0.0038	Yes
Plutonium-239/240	426,000	27-27.5	0.025	Yes
Potassium-40	14	29-31.5	17	No
Radium-226	0.40	32-34.5	0.82	No
Radium-228	0.83	32-34.5	1.3	No
Thorium-228	0.71	32-34.5	1.3	No
Thorium-232	0.83	32-34.5	1.3	No
Strontium-90	125,000	27-27.5	0.18	Yes
Tritium	2,860	285-287	Not Available	No Background
Uranium-233/234	50	27-27.5	1.1	Yes
Uranium-235	4.3	29-31.5	1.1	Yes
Uranium-236	1.0	27-27.5	Not Available	No Background
Uranium-238	57	32-34.5	1.1	Yes

216-A-4 Crib (0 to 4.6m [0 to 15 ft]) bgs. Two soil samples were collected and analyzed from 0 to 4.6 m (0 to 15 ft) bgs; these samples were collected from the 0.15 to 0.9 m (0.5 to 3.0 ft) bgs depth interval and the 3.8 to 4.6 m (12.5 to 15 ft) depth interval. Of all the constituents analyzed, four metals (cadmium, chromium, copper, and lead), two general chemistry parameters (nitrate and nitrate/nitrite as N), and seven radiological isotopes were detected. All metals, general chemistry parameters, and four of the radiological isotopes (Cs-137 and the three uranium isotopes) were detected at concentrations below their respective lognormal 90th percentile Hanford Site background concentrations. Plutonium-239/240 and Sr-90 were slightly greater than their respective lognormal 90^{th} percentile background concentrations and Am-241 does not have a background value. Therefore, Am-241, Pu-239/240, and Sr-90 are carried forward into the BRA to evaluate the direct contact exposure pathway (Table 6-5).

Table 6-5. 216-A-4 Crib Comparison of Maximum Soil Concentrations from 0 to 4.6 m (0 to 15 ft) bgs to Hanford Site Background

Constituent Name	Maximum Detected Concentration	Depth of Maximum Detected	Lognormal 90th Percentile Background Concentration	Does Maximum Detected Exceed Background
Metals Analyses (mg/kg)				
Cadmium	0.20	0.5–3.0	0.81	No
Chromium (III)	4.5	0.5–3.0	19	No
Copper	0.73	0.5–3.0	22	No
Lead	9.2	0.5–3.0	10	No
General Inorganic Chemistry (mg/kg)				
Nitrate as N	1.0	0.5–3.0	11.75 (Nitrate as N) or 52 (Nitrate)	No
Nitrate/nitrite as N	0.84	0.5–3.0	12	No
Radiological Constituents (pCi/g)				
Americium-241	0.088	12.5-15	Not Available	No Background
Cesium-137	0.61	0.5-3	1.1	No
Plutonium-239/240	0.45	12.5-15	0.025	Yes
Strontium-90	0.37	12.5-15	0.18	Yes
Uranium-233/234	0.14	12.5-15	1.1	No
Uranium-235	0.022	12.5-15	1.1	No
Uranium-238	0.16	0.5-3	1.1	No

216-A-5 Crib (0 to groundwater table). Thirteen soil samples were collected and analyzed from the soil column of the 216-A-5 Crib. Soil samples were collected from depth intervals that ranged from 3.8 m to the groundwater table (3.8 to 100.43 m [12.5 to 329 ft]). The results from the 216-A-5 Crib are used to evaluate the impacts of radiological constituents in soil on groundwater.

A total of 21 radioisotopes were detected in the soil boring from the 216-A-5 Crib. Maximum concentrations of K-40, Ra-226, Ra-228, Th-228, Th-230, and Th-232 were below their respective lognormal 90th percentile Hanford Site background value and are not carried further into the risk evaluation process.

Constituents with maximum concentrations greater than their respective lognormal 90th percentile Hanford Site background value or those without background values are carried forward to determine if their concentrations have the potential to impact groundwater beneath the 200-MW-1 OU. Maximum concentrations of Am-241, Cs-137, Eu-154, Eu-155, Pu-238, Pu-239, Pu-239/240, Sr-90, U-233/234, U-235, and U-238 are above their respective lognormal 90th percentile Hanford Site background values. Background values are not available for Am-241, C-14, I-129, Np-237, and tritium (Table 6-6).

Table 6-6. 216-A-5 Crib Comparison of Maximum Soil Concentrations from 0 to Groundwater Table to Hanford Site Background

Constituent Name	Maximum Detected Concentration from 0 to Groundwater Table	Depth of Maximum Detected from 0 to Groundwater Table (ft)	Lognormal 90th Percentile Background Concentration	Does Maximum Detected from 0 to Groundwater Table Exceed Background?
Radiological Constituents (pCi/g)				
Americium-241	422	10.6-11.4	Not Available	No Background
Carbon-14	36	18.2–18.9	Not Available	No Background
Cesium-137	2,860	10.6-11.4	1.1	Yes
Europium-154	0.34	17.7–18.3	0.033	Yes
Europium-155	0.13	17.7–18.3	0.054	Yes
Iodine-129	11	10.6-11.4	Not Available	No Background
Neptunium-237	0.39	10.6-11.4	Not Available	No Background
Plutonium-238	14	10.6-11.4	0.0038	Yes
Plutonium-239/240	8,870	10.5-10.7	0.025	Yes
Potassium-40	18	18.2–18.7	17	No
Radium-226	0.56	18.2–18.7	0.82	No
Radium-228	0.96	19.7–20.4	1.3	No
Thorium-228	1.1	15.1–15.9	1.3	No
Thorium-230	0.98	NA–30.6	1.1	
Thorium-232	1.0	3.8–4.6	1.3	No
Strontium-90	69	19.7–20.4	0.18	Yes
Tritium	1,560	86.7–87.4	Not Available	No Background
Uranium-233/234	4.2	11.4–12.2	1.1	Yes
Uranium-235	0.34	11.4–12.2	0.11	Yes
Uranium-238	4.4	11.4–12.2	1.1	Yes

Notes: The presence of potassium-40 is within the range of background concentrations expected at the Hanford Site.

6.2 Risk Characterization Results

This section includes the human health risks under the Assumed Baseline Land-Use Scenario (Unrestricted Rural Residential). The results for both the shallow (0 to 15 ft) and deep (0 ft to groundwater depth) scenarios representing the unrestricted rural residential land use condition are presented. In addition to the overview discussion in Section 6.2.1, risk characterization results for the hypothetical rural residential scenario–deep exposure pathway are discussed in Section 6.2.3; risk characterization results for the hypothetical rural residential scenario–shallow exposure pathway are in

Section 6.2.4; and risk characterization results for the protection of underlying groundwater are described in Section 6.2.5.

6.2.1 Overview of the Baseline Scenario Human Health Risk Assessment

The baseline human health risk assessment evaluates potential adverse health effects in the absence of any remedial action. In the first phase of the risk assessment, COPCs were identified. Potential risks are evaluated for non-radionuclides and radionuclides following EPA/540/1-89/002. The results of the human health risk evaluation are presented, and the associated uncertainty discussion is presented in Section 6.2.6.

To evaluate baseline conditions for the direct contact exposure pathway, unrestricted land use criteria under a rural residential exposure scenario for the ground surface to 4.6 m (0 to 15 ft) bgs and ground surface to the groundwater table points of compliance were evaluated for three cribs. The purpose of this evaluation is to determine whether current soil concentrations can meet the unrestricted land use criteria and the EPA target risk threshold of 10^{-4} for a no action alternative. Additionally, an industrial worker exposure scenario for the 0 to 4.6 m (0 to 15 ft) bgs point of compliance was evaluated for two cribs. The purpose of this evaluation is to determine whether current soil concentrations can meet the EPA target risk threshold of 10^{-4} for the reasonably anticipated future land use condition.

Before the non-radionuclide and radionuclide risk assessment discussions below, it should be noted that the EPCs used for both non-radionuclides and radionuclides at these waste sites are the maximum detected concentrations. A 95 percent UCL on an average concentration generally is the recommended approach to estimate an EPC for the reasonable maximum exposure expected to occur at a site (EPA, 2002, *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites*, OSWER 9285.6-10; EPA/540/1-89/002). In addition, EPA guidance recommends the use of the reasonable maximum exposure scenario as the basis for alternative evaluation in the FS (Clay, 1991, "Role of Baseline Risk Assessment in CERCLA Remedy Selection Decisions"). Because of the limited number of boreholes and the limited number of samples that could be collected from each borehole, the use of a maximum concentration is more appropriate for this OU. The few independent sample locations create some uncertainty related to the representativeness of the data to estimate exposure.

The human health risk assessment uses analytical data and information from the 216-A-2 and 216-A-4 Cribs. At the 216-A-2 Crib, borehole C5515 was placed through the center of the waste site where the highest levels of contamination were expected to be encountered. The results from this borehole are used to estimate exposure from the direct contact exposure pathways and to determine if soil concentrations remaining in the soil profile will impact groundwater.

As discussed previously, the 216-A-4 Crib borehole (C4560) could only be completed to 6.4 m (21 ft) bgs and limited data are available. The analytical data from this borehole are used, in part, to develop the contaminant distribution model. An 18.3 m (60 ft) bgs direct push borehole (C4671) was placed next to the 216-A-4 Crib borehole and geophysically logged to understand where the mass of contamination is located. This direct push also provided qualitative information that confirms that the maximum contaminant concentrations of gamma emitting radioisotopes are located within the boundary of the crib. Another borehole was installed next to the 216-A-4 Crib (C5301) and completed to groundwater for understanding the lateral extent of contamination resulting from disposal practices at this crib. To estimate groundwater impacts, the incomplete borehole from 216-A-4 Crib (C4560) was used. Because disposal practices were similar between the 216-A-4 Crib and 216-A-2 Crib, the 216-A-2 Crib results from the unrestricted land use scenario and the impact of soil on groundwater are used as points of comparison from this crib. Collectively, the information obtained from the 216-A-4 Crib is used in the RI to provide an understanding of the CSM.

EPA uses the general 10^{-4} to 10^{-6} risk range within which the Agency strives to manage risks as part of a CERCLA cleanup. Once a decision has been made to take an action (utilizing the 10^{-4} upper end of the risk range as the general criterion below which action is generally not warranted), the Agency has expressed a preference for cleanups achieving the more protective end of the range (i.e., the point of departure, 10^{-6}), although waste management strategies achieving reductions in site risks anywhere within the risk range may be deemed acceptable by the EPA risk manager. Furthermore, the upper boundary of the risk range is not a discrete line at 1×10^{-4}, although EPA generally uses 1×10^{-4} in making risk management decisions (EPA, 1991).

Luftig and Weinstock, 1997, "Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination," OSWER Directive 9200.4-18, specifies that cleanup levels for radioactive contamination at CERCLA sites should be established as they would for any chemical that poses an unacceptable risk and the risks should be characterized in standard Agency risk language consistent with CERCLA guidance. EPA/540/R-99/006, *Radiation Risk Assessment At CERCLA Sites: Q&A*, OSWER Directive 9200.4-31P, further indicates that references to 15 mrem/yr in Luftig and Weinstock, 1997 are intended as guidance for the evaluation of potential ARARs and to be considered, and should be used as a to be considered for establishing 15 mrem/yr cleanup levels at CERCLA sites.

6.2.1.1 Non-Radionuclides

To determine whether concentrations of non-radiological COPCs are present at concentrations that warrant remedial action, maximum soil concentrations are compared to the "Regional Screening Levels for Chemical Contaminants at Superfund Sites." This website was developed with DOE's Oak Ridge National Laboratory under an Interagency Agreement as an update of the EPA Region 3 risk-based concentration table, the Region 6 human health median specific screening level (MSSL) table, and the Region 9 PRG table. Because EPA Region 10 does not calculate their own screening levels, Region 10 mandates the use of regional screening levels for EPA projects in Region 10. This process provides a streamlined approach that combines the components of the exposure assessment (the type and magnitude of exposure) and the chemical-specific toxicity information to characterize risk. The outcome of this process provides a simplified means of characterizing total health risks by using standard exposure assumptions. It also provides a cumulative estimate of exposure over all pathways and all contaminants. Therefore, the use of the regional screening levels is considered the risk assessment phase for non-radionuclides as it is consistent with the BRA methodology described in EPA/540/1-89/002.

6.2.1.2 Exposure Assessment Methodology

The residential and industrial soil screening levels were obtained from the Mid-Atlantic Risk Assessment Web site (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm). These screening levels include common human health exposure pathways, including incidental ingestion of soil, dermal contact with soil, and inhalation of dust particulates or vapors and correspond to a fixed level of risk at 1×10^{-6} or a hazard quotient (HQ) of one. With any given EPC, the screening level can be used to calculate the corresponding ELCR or a HQ. The screening levels do not include the food chain pathways as identified for the hypothetical future rural residential exposure scenario. The uncertainties associated with this approach are discussed in the uncertainty section.

EPA toxicity values, known as non-carcinogenic reference doses and carcinogenic slope factors were obtained from IRIS database, Provisional Peer-Reviewed Toxicity Values, Health Effects Assessment Summary Tables (HEAST), EPA's National Center for Environmental Assessment (NCEA), and others. The priority among sources of toxicological constants used to develop the Region 6 screening table is as follows: (1) IRIS database, (2) Provisional Peer-Reviewed Toxicity Values and (3) a determination between NCEA, HEAST, and other documents including those from Cal EPA. The IRIS, Provisional Peer-Reviewed Toxicity Values, and NCEA values were updated as of May 2009. The HEAST values were not reviewed since HEAST has not been updated since the last screening value table.

6.2.1.3 Equations and Exposure Assumptions for Residential Soil Screening Levels

The following equations were used to calculate the residential soil screening levels for carcinogens and non-carcinogens.

Carcinogens. The following equation is used to calculate the residential soil screening levels for carcinogenic chemicals:

Ingestion

$$SL_{res-sol-ca-ing}(mg/kg) = \frac{TR \times AT_r \times \left(\frac{365\,days}{year} \times LT(70\,years)\right)}{CSF_o\left(\frac{mg}{kg-day}\right)^{-1} \times EF_r\left(\frac{350\,days}{year}\right) \times IFS_{adj}\left(\frac{114\,mg-year}{kg-day}\right) \times \left(\frac{10^{-6}\,kg}{mg}\right)}$$

where:

$$IFS_{adj}\left(\frac{114\,mg-year}{kg-day}\right) = \left(\frac{ED_c(6\,years) \times IRS_c\left(\frac{200\,mg}{day}\right)}{BW_c(15\,kg)}\right) + \left(\frac{ED_r - ED_c(24\,years) \times IRS_a\left(\frac{100\,mg}{day}\right)}{BW_a(70\,kg)}\right)$$

Dermal

$$SL_{res-sol-ca-der}(mg/kg) = \frac{TR \times AT_r \times \left(\frac{365\,days}{year} \times LT(70\,years)\right)}{\left(\frac{CSF_o\left(\frac{mg}{kg-day}\right)^{-1}}{GIABS}\right) \times EF_r\left(\frac{350\,days}{year}\right) \times DFS_{adj}\left(\frac{361\,mg-year}{kg-day}\right) \times ABS_d\left(\frac{10^{-6}\,kg}{mg}\right)}$$

where:

$$DFS_{adj}\left(\frac{361\,mg-year}{kg-day}\right) = \left(\frac{ED_c(6\,years) \times SA_c\left(\frac{2800\,cm^2}{day}\right) \times AF_c\left(\frac{0.2\,mg}{cm^2}\right)}{BW_c(15\,kg)}\right) + \left(\frac{ED_r - ED_c(24\,years) \times SA_a\left(\frac{5700\,cm^2}{day}\right) \times AF_a\left(\frac{0.07\,mg}{cm^2}\right)}{BW_a(70\,kg)}\right)$$

Inhalation

$$SL_{res-sol-ca-inh}(mg/kg)=\frac{TR\times AT_c\times\left(\frac{365\,days}{year}\times LT\,(70\,years)\right)}{IUR\left(\frac{\mu g}{m^3}\right)^{-1}\times\left(\frac{1000\,\mu g}{mg}\right)\times EF_r\left(\frac{350\,days}{year}\right)\times\left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)}+\frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right)\times ED_r\,(30\,years)\times ET_{rs}\left(\frac{24\,hours}{day}\right)\times\left(\frac{1\,day}{24\,hours}\right)}$$

Total

$$SL_{res-sol-ca-tot}(mg/kg)=\frac{1}{\frac{1}{SL_{res-sol-ca-ing}}+\frac{1}{SL_{res-sol-ca-der}}+\frac{1}{SL_{res-sol-ca-inh}}}$$

Conversely, this equation can be rearranged to solve for the ELCR when the individual chemical concentration in soil is known.

Non-carcinogens. The following equation is used to calculate the residential soil screening levels for non-carcinogenic chemicals:

Ingestion

$$SL_{res-sol-nc-ing}(mg/kg)=\frac{THQ\times AT_r\left(\frac{365\,days}{year}\times ED_r\,(6\,years)\right)\times BW_c\,(15\,kg)}{EF_r\left(\frac{350\,days}{year}\right)\times ED_r\,(6\,years)\times\frac{1}{RfD_o\left(\frac{mg}{kg-day}\right)}\times IRS_c\left(\frac{200\,mg}{day}\right)\times\frac{10^{-6}\,kg}{1\,mg}}$$

Dermal

$$SL_{res-sol-nc-der}(mg/kg)=\frac{THQ\times AT_r\left(\frac{365\,days}{year}\times ED_r\,(6\,years)\right)\times BW_c\,(15\,kg)}{EF_r\left(\frac{350\,days}{year}\right)\times ED_r\,(6\,years)\times\frac{1}{\left(RfD_o\left(\frac{mg}{kg-day}\right)\times GIABS\right)}\times SA_c\left(\frac{2800\,cm^2}{day}\right)\times AF_c\left(\frac{0.2\,mg}{cm^2}\right)\times ABS_d\times\frac{10^{-6}\,kg}{1\,mg}}$$

Inhalation

$$SL_{res-sol-nc-inh}(mg/kg)=\frac{THQ\times AT_r\left(\frac{365\,days}{year}\times ED_r\,(6\,years)\right)}{EF_r\left(\frac{350\,days}{year}\right)\times ED_r\,(6\,years)\times ET_{rs}\left(\frac{24\,hours}{day}\right)\times\left(\frac{1\,day}{24\,hours}\right)\times\frac{1}{RfC\left(\frac{mg}{m^3}\right)}\times\left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)}+\frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right)}$$

Total

$$SL_{res-sol-nc-tot}(mg/kg)=\frac{1}{\frac{1}{SL_{res-sol-nc-ing}}+\frac{1}{SL_{res-sol-nc-der}}+\frac{1}{SL_{res-sol-nc-der}}}$$

Similarly, this equation can be rearranged to solve for the HQ when an individual chemical concentration in soil is known.

6.2.1.4 Equations and Exposure Assumptions for Indoor Industrial Worker Soil Screening Levels

The following equations were used to calculate the industrial soil screening levels for carcinogens and non-carcinogens.

Carcinogens. The following equation is used to calculate the indoor industrial worker soil screening levels for carcinogenic chemicals:

Ingestion

$$SL_{iw-sol-ca-ing}(mg/kg)=\frac{TR\times AT_{iw}\left(365\frac{days}{year}\times LT(70\,years)\right)\times BW_{iw}(70\,kg)}{EF_{iw}\left(250\frac{days}{year}\right)\times ED_{iw}(25\,years)\times CSF_{o}\left(\frac{mg}{kg-day}\right)^{-1}\times IR_{iw}\left(50\frac{mg}{day}\right)\times\left(\frac{10^{-6}\,kg}{1\,mg}\right)}$$

Inhalation

$$SL_{iw-sol-ca-inh}(mg/kg)=\frac{TR\times AT_{iw}\left(\frac{365days}{year}\times LT(70\,years)\right)}{EF_{iw}\left(250\frac{days}{year}\right)\times ED_{iw}(25\,years)\times ET_{iw}\left(\frac{8\,hours}{day}\right)\times\left(\frac{1\,day}{24\,hours}\right)\times IUR\left(\frac{\mu g}{m^{3}}\right)^{-1}\times\left(\frac{1000\,\mu g}{mg}\right)\times\left(\frac{1}{VF_{s}\left(\frac{m^{3}}{kg}\right)}+\frac{1}{PEF_{w}\left(\frac{m^{3}}{kg}\right)}\right)}$$

Total

$$SL_{iw-ca-tot}(mg/kg)=\frac{1}{\frac{1}{SL_{iw-ca-ing}}+\frac{1}{SL_{iw-ca-inh}}}$$

Non-carcinogens. The following equation is used to calculate the indoor industrial worker soil MSSLs for non-carcinogenic chemicals:

Ingestion

$$SL_{iw-nc-ing}(mg/kg)=\frac{THQ\times AT_{iw}\left(365\frac{days}{year}\times ED_{iw}(25\,years)\right)\times BW_{iw}(70\,kg)}{EF_{iw}\left(250\frac{days}{year}\right)\times ED_{iw}(25\,years)\times\frac{1}{RfD_{o}\left(\frac{mg}{kg-day}\right)}\times IR_{iw}\left(50\frac{mg}{day}\right)\times\left(\frac{10^{-6}\,kg}{1\,mg}\right)}$$

Inhalation

$$SL_{iw-nc-inh}(mg/kg)=\frac{THQ\times AT_{iw}\left(\frac{365days}{year}\times ED_{iw}(25\,years)\right)}{EF_{iw}\left(250\frac{days}{year}\right)\times ED_{iw}(25\,years)\times ET_{iw}\left(\frac{8\,hours}{day}\right)\times\left(\frac{1\,day}{24\,hours}\right)\times\left(\frac{1}{RfC\left(\frac{mg}{m^{3}}\right)}\right)\times\left(\frac{1}{VF_{s}\left(\frac{m^{3}}{kg}\right)}+\frac{1}{PEF_{w}\left(\frac{m^{3}}{kg}\right)}\right)}$$

Total

$$SL_{iw-nc-tot}(mg/kg)=\frac{1}{\frac{1}{SL_{iw-nc-ing}}+\frac{1}{SL_{iw-nc-inh}}}$$

Similarly, this equation can be rearranged to solve for the HQ when an individual chemical concentration in soil is known.

6.2.1.5 Cancer Risk Estimation Method

The potential for cancer effects is evaluated by estimating the ELCR. This risk is the incremental increase in the probability of developing cancer during one's lifetime in addition to the background probability of developing cancer (that is, if no exposure to site chemicals occurs). For example, a 2×10^{-6} ELCR means that, for every one million people exposed to the carcinogen throughout their lifetimes, the average incidence of cancer may increase by two cases of cancer. In the United States, the background probability of developing cancer for men is a little less than one in two, and for women a little more than one in three (ACS, 2003, *Cancer Facts & Figures 2003*). As previously mentioned, cancer slope factors developed by the EPA represent upper bound estimates, so any cancer risks generated in this assessment should be regarded as an upper bound on the potential cancer risks rather than accurate representations of true cancer risk. The true cancer risk is likely to be less than that predicted (EPA/540/1-89/002).

Although synergistic or antagonistic interactions might occur between cancer causing chemicals and other chemicals, information is generally lacking in the toxicological literature to predict quantitatively the effects of these potential interactions. Therefore, cancer risks are treated as additive within an exposure route in this assessment. This is consistent with the EPA guidelines on chemical mixtures (EPA, 2001, *Health Effects Assessment Summary Tables*, "April 16, 2001 Update: Radionuclide Toxicity," "Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors." To estimate the cancer risks from exposure to multiple carcinogens from all exposure routes considered, the following equation is used:

$$Risk_T = \sum_i^N \frac{C_{soil}}{SSL_{carcinogen}} \times TR$$

where:

$Risk_T$	=	Total excess lifetime cancer risk for all chemicals
C_{soil}	=	Chemical concentration in soil (mg/kg)
$SSL_{carcinogen}$	=	Soil screening value based on carcinogenic effect (mg/kg)
TR	=	Target excess lifetime cancer risk (10^{-6})

6.2.1.6 Non-Cancer Risk Estimation Method

For non-cancer effects, the likelihood that a receptor will develop an adverse effect is estimated by comparing the predicted level of exposure for a particular chemical with the highest level of exposure that is considered protective (its reference dose). The ratio of the chronic daily intake divided by reference dose is termed the HQ.

When the HQ for a chemical exceeds one (exposure exceeds reference doses), there is a concern for potential non-cancer health effects. To assess the potential for non-cancer effects posed by exposure to multiple chemicals, a hazard index (HI) approach was used according to EPA guidance (EPA/540/1-89/002). This approach assumes that the non-cancer hazard associated with exposure to more than one chemical is additive; therefore, synergistic or antagonistic interactions between chemicals are not accounted for. The HI may exceed one even if all the individual HQs are less than one. In this case, the chemicals may be segregated by similar mechanisms of toxicity and toxicological effects. Separate HIs may then be derived based on mechanism and effect. To estimate the HI from all exposure routes considered, the following equation is used:

$$HI_T = \sum_i^N \frac{C_{soil}}{SSLC_{noncarcinogen}}$$

where:

HI_T	=	Total hazard index for all chemicals
C_{soil}	=	Chemical concentration in soil (mg/kg)

$SSLC_{noncarcinogen}$ = Soil screening value based on non-carcinogenic effect (mg/kg)

Should they become necessary, comparisons of maximum soil concentrations to WAC cleanup levels have been provided in Appendix F. The methodology for this comparison is consistent with previously described EPA methodology.

6.2.1.7 Results of the Non-Radionuclide Baseline Risk Assessment

The BRA for non-radiological COPCs was performed using the points of compliance and exposure scenarios described in Chapter 5 and listed in Table 6-2. ELCR estimates and HQs were calculated for COPCs using the following methodology:

- **216-A-2 Crib (0 to 4.6 m [0 to 15 ft] bgs).** Non-radiological COPCs were not identified in the 0 to 4.6 m (0 to 15 ft) bgs interval. Because non-radiological COPCs were not identified, there is no associated ELCR or HI.
- **216-A-4 Crib (0 to 4.6 m [0 to 15 ft] bgs.** Non-radiological COPCs were not identified in the 0 to 4.6 m (0 to 15 ft) bgs interval. Because non-radiological COPCs were not identified, there is no associated ELCR or HI.

6.2.1.8 Summary of Non-Radionuclide Contaminants of Concern

For purposes of the BRA, non-radiological COCs were not identified in shallow zone soil (0 to 4.6 m [0 to 15 ft] bgs) from the 216-A-2 Crib or the 216-A-4 Crib. Because no COPCs were identified, comparison of the EPCs to unrestricted rural resident (and industrial worker) screening level concentrations was not performed.

6.2.1.9 Radionuclide Risk Assessment

Radionuclide risk assessment closely follows the EPA approach of identifying COPCs, completing exposure and toxicity assessments, and integrating that information into risk characterization and discussing uncertainty, as outlined in EPA/540/1-89/002. Human health risk assessment for radionuclides is consistent with the conceptual exposure model described in Section 5.3.3 and shown in Figure 5-1.

Risk assessment for radionuclides was accomplished using the RESRAD code, Version 6.4. EPA evaluated the suitability of over two dozen multimedia pathway models and computer codes for analysis of radionuclide cleanup sites. Three models met the majority of the evaluation criteria; ANL, 1994, *RESRAD*, Version 5.19, was identified as one of the three models (EPA 402-R-96-011 A, *Radiation Site Cleanup Regulations: Technical Support Document for the Development of Radionuclide Cleanup Levels for Soil: Review Draft*). EPA evaluated the codes for their ability to model the transport of a contaminant via an exposure pathway, including defining the following:

- The nature, extent, and location of the contaminant source or sources
- The actual or potential mechanisms of release, migration, and fate in the environment
- A medium or media through which the contaminant is transported or in which the contaminant remains
- The points of possible receptor contact with the contaminated medium
- An exposure route (for example, ingestion)

These criteria are consistent with the important elements of the analyses to be performed to support this RI.

RESRAD, Version 6.4 was used to estimate the annual dose rate and the ELCR. The analysis proceeds in two steps. First, the results of soil characterization in shallow zone soils are used to construct a simplified model of radionuclide distributions in the soil at each site. The soil model specifies the concentration of various radionuclides in the shallow zone soils at the 200-MW-1 OU waste sites. In this simplified approach, the soil contamination is assumed to be present in layers below the ground surface, each layer having a uniform concentration of the contaminants. The RESRAD model uses soil chemistry parameters, exposure assumptions, toxicological data, and radiological decay information, to calculate annual dose rates and total ELCR. Second, the soil model is input to the RESRAD software to calculate annual dose rates and the potential human health risks from the contamination. The integration of these two steps is considered risk characterization and is discussed below.

The annual radiation doses and ELCR are calculated for various time periods. For comparative purposes, radiation dose and risk estimates are discussed relative to the following exposure times.

- Zero year represents current waste site conditions
- 50 years is the estimated time that DOE will have an on-site presence
- 150 years is the estimated time that ICs are assumed to be effective
- 500 years is the estimated time that passive ICs are assumed to be effective
- 1,000 years is the estimated time frame that peak radiation dose and risk estimates should fall within

The exposure time includes the year in which the target radiation dose limit of 15 mrem/yr is achieved.

Radionuclide COPCs, assumptions, input parameters, and model results for potential human health risks based on RESRAD modeling are discussed below. Appendices C and D contain the details of the RESRAD analyses for the 216-A-2 and 216-A-4 Cribs, respectively.

6.2.1.10 Radionuclide Contaminants of Potential Concern

Radiological COPCs were selected in accordance with the COPC selection process and were identified for the BRA.

6.2.1.11 Radionuclide Exposure Assumptions

Similar to the non-radiological risk assessment, exposure assumptions estimate the type and magnitude of exposure to the COPCs present at the site. The exposure assumptions that are used for each exposure scenario input into the RESRAD code are provided in the summary tables contained in Appendix D. Each summary table lists the required RESRAD input parameter, lists the values that are input into the code, and provides the rationale and citation for each of the input parameters. A detailed description of how each exposure scenario was evaluated by the RESRAD code is also provided in Appendix D.

For radionuclides, the integration of toxicological information, radioactive decay information, and exposure factors to calculate annual dose rates and total lifetime excess cancer risk using the RESRAD code is considered risk characterization.

6.2.1.12 RESRAD Results

The radiological risk assessment was completed using an approach similar to that for the non-radiological constituents. A BRA was completed using the direct contact point of compliance (i.e., 0 to 4.6 m [0 to 15 ft] bgs) to determine the potential for exposure and risk. The following subsections present the results of the BRA. Details of the RESRAD analysis for the 216-A-2 Crib and the 216-A-4 Crib are presented in Appendix D.

216-A-2 Crib (0 to 4.6 m [0 to 15 ft] bgs). Radiological COPCs were not identified in the 0 to 4.6 m (0 to 15 ft) bgs interval. Therefore, dose and risk were not estimated for the unrestricted rural residential (or industrial) scenarios at this waste site.

216-A-2 Crib (0 to groundwater table). The COPC selection process for radiological constituents identified Am-241, Cs-137, Co-60, Eu-154, Ni-63, Pu-238, Pu-239/240, Sr-90, Tc-99, U-33/234, U-235, U-236, and U-238 as COPCs to be evaluated in the direct contact exposure analysis.

6.2.2 Rural Residential Scenario – Deep Exposure Pathway

This analysis addresses the potential for exposure via the deep exposure scenario in which drill cuttings are brought to the surface and mixed with surface soils within the hypothetical rural residential exposure setting. The cuttings and commingled surface soils are assumed to be utilized for gardening at the location of the rural resident.

Analysis results indicate that contributions from four radionuclides (Cs-137, Sr-90, Am-241, and Pu-239) account for nearly 100 percent of the total ELCR over the entire 1,000-year simulation period. Contributions from the other radionuclides included in the analysis do not exceed 0.01 percent of the total ELCR. Analysis results indicate that over the 1,000-year simulation period there are no exposure contributions from water dependent pathways (that is, use of groundwater for drinking water, crop irrigation, and livestock water). The RESRAD calculations indicate that leaching would not cause radionuclides in the redistributed drill cuttings to reach the water table during the 1,000-year simulation period. The maximum ELCR occurs at the beginning of the simulation period (that is, analysis time zero) at a value slightly greater than 1×10^{-2}. The ELCR remains above EPA's target risk threshold of 1×10^{-4} through the end of the simulation period, and the ELCR is projected to remain above the risk threshold until approximately 5,740 years from the present. The primary contributors to the ELCR at time zero are Cs-137 from external radiation exposure (77 percent) and Sr-90 from plant consumption (12 percent). The total ELCR falls sharply for the first 150 years in response to radioactive decay of Cs-137 and Sr-90 and thereafter falls more gradually as the long lived isotopes Am-241 and Pu-239 become the primary ELCR contributors. After 500 years, Cs-137 and Sr-90 have decayed completely and the primary contributors to total ELCR are Pu-239 from inhalation (42 percent) and soil ingestion (16 percent) and Am-241 from external radiation exposure (29 percent). At the end of the 1,000-year simulation period, the primary contributors to total ELCR continue to be Pu-239 from inhalation (51 percent) and soil ingestion (20 percent) and Am-241 from external radiation exposure (16 percent).

216-A-4 Crib (0 to 4.6 m [0 to 15 ft]) bgs). The outcome of the COPC selection process for contaminants present in the 0 to 4.6 m (0 to 15 ft) bgs depth interval at the 216-A-4 Crib indicates that concentrations of Sr-90, Pu-239/240, and Am-241 were detected at relatively low levels and are identified as COPCs.

6.2.3 Rural Residential Scenario – Shallow Exposure Pathway

The rural residential exposure scenario is evaluated to determine the exposure conditions if the land within the industrial exclusive zone of the Central Plateau were released for unrestricted land use. This exposure pathway is evaluated when waste site contamination resides between 0 and 4.6 m (15 ft) bgs. Based on the current site configuration, waste site contamination does not reside between 0 and 4.6 m (15 ft) bgs; therefore, no dose and no risk currently exist. Although there are currently low concentrations of COPCs measured in the 0 to 4.6 m (0 to 15 ft) bgs, interval exposure through the direct contact and food chain pathways is minimal. The rural residential scenario for the deep exposure pathway represents potential exposure conditions to waste site contamination that resides below 4.6 m (15 ft) bgs (see Section 6.2.2).

6.2.4 Protection of Groundwater beneath the 200-MW-1 Operable Unit Waste Sites

The 216-A-2, 216-A-4, and 216-A-5 Cribs and the other five sites were evaluated via information searches and computer modeling as appropriate to examine whether the sites posed unacceptable baseline risks to the underlying groundwater.

The results of the modeling evaluations and the consideration of the qualitative information histories for the sites are presented in Section 5.2.3, where contaminant transport issues are discussed. The results indicate that of the seven 200-MW-1 OU sites and the 216-A-5 Crib, none of the sites threaten groundwater over the long term. This finding is summarized in Table 6-7 at the end of this chapter, where the managerial implications of the quantitative risk assessment and the accompanying qualitative evaluations are summarized into the rationale for remedial alternative development.

6.2.5 Human Health Risks for the Industrial Scenario

The industrial worker exposure scenario for the BRA reflects the current and reasonably anticipated future land use within the industrial exclusive zone of the Central Plateau. The direct contact exposure routes evaluated for the industrial worker are external gamma radiation, incidental soil ingestion, and inhalation of dust particulates. Based on the current site configuration, waste site contamination does not reside between 0 and 4.6 m (15 ft) bgs; therefore, no dose and no risk currently exist. Although there are currently low concentrations of COPCs measured in the 0 to 4.6 m (0 to 15 ft) bgs, interval exposure through the direct contact is minimal. The rural residential scenario for the deep exposure pathway represents potential exposure conditions to waste site contamination that resides below 4.6 m (15 ft) bgs (see Section 6.2.2).

6.2.5.1 Additional Exposure Scenarios of Interest to Hanford Stakeholders (Tribal Scenarios)

CTUIR Scenario. Based on the current site configuration of the 216-A-2 and 216-A-4 Cribs, there is currently no dose and no risk because the direct contact exposure pathway is incomplete (that is, the receptor cannot come into direct contact with contamination). Exposure through the food chain pathway cannot occur because the depth of contamination is greater than the rooting depth of typical homegrown fruit, produce, and livestock fodder.

Yakama Nation Scenario. Based on the current site configuration of the 216-A-2 and 216-A-4 Cribs, there is currently no dose and no risk because the direct contact exposure pathway is incomplete (that is, the receptor cannot come into direct contact with contamination). Exposure through the food chain pathway cannot occur because the depth of contamination is greater than the rooting depth of typical homegrown fruit, produce, and livestock fodder.

6.2.6 Human Health Risk Assessment Summary and Uncertainty Analysis

The purpose of this risk assessment is to identify potential risk and hazards from exposure to contaminants in soil within the boundaries of the 216-A-2 Crib and the 216-A-4 Crib. Estimating and evaluating health risk from exposure to environmental containments is a complex process with inherent uncertainties. Uncertainty reflects limitations in knowledge, and simplifying assumptions must be made to quantify health risks.

In this assessment, uncertainties are generally associated with the use of maximum concentrations for estimating exposure, limitations in available data from each crib, and the development and use of exposure assumptions to estimate risk.

Uncertainties associated with using maximum concentrations to estimate exposure and risk include the following:

- Maximum concentrations were used because there are limited characterization data available from each crib. One borehole was completed through the center of the 216-A-2 Crib and one borehole was completed 2.5 m outside the boundary of the 216-A-4 Crib. Use of maximum concentrations most likely over-states health risks because the toxicity factors for estimating both cancer and non-cancer risks are based on long-term average exposures. EPA recommends using an average concentration to represent a "reasonable estimate of the concentration likely to be contacted over time" (EPA/540/1-89/002). Using the maximum detected concentration estimates peak health risks rather than average exposure and risk as recommended by EPA.

Uncertainties associated with the limitations in available data include the following:

- Samples analyzed by the ESL were not used in the risk assessment. These samples were collected and analyzed from the 216-A-2 Crib specifically for performing geochemical modeling and to confirm the spatial distribution of contamination. These sampling results were not collected for the intent and purpose of estimating risk; the associated QA/QC sample sets (for example, field splits, duplicates) were not obtained. It should be noted, that additional RESRAD analyses were conducted to include this analytical data and showed no difference in estimated risk or dose.

- This risk assessment addressed potential exposures and health risk from contaminants currently present in the soil and does not include existing or potential future contamination in the groundwater beneath the 200-MW-1 OU. This assumption potentially under-states the health risks for the rural residential, CTUIR, and the Yakama Nation exposure scenarios. It should be noted that health risks from potential exposure to groundwater beneath the 200-MW-1 OU will be evaluated in the 200-PO-1 Groundwater OU. Cumulative risks across soil and groundwater will be evaluated as balancing factors in evaluating remedial alternatives from the groundwater OU.

The following uncertainty is associated with limitations in available exposure assumptions:

- Ingestion of contaminants that could potentially bioaccumulate in wild game was not included as an exposure pathway in the Yakama Nation and the CTUIR exposure scenarios. The size of the waste sites (approximately 176 m^2 combined) is considered too small to support a sufficient number and variety of foraging wild game for consumption. While consumption of game animals is a potentially complete exposure pathway, it is not reasonable to assume that those animals could accumulate contaminants solely from the 216-A-2 Crib and the 216-A-4 Cribs. Therefore, this pathway was not considered to contribute significantly to total exposure.

6.3 Ecological Risk Assessment

An SLERA was performed for the 216-A-2 and 216-A-4 Cribs following EPA 540-R-97-006. The waste sites were considered with regard to exposure potential to terrestrial wildlife.

The first two steps of the SLERA focus the assessment on determining whether the potential for exposure and adverse health effects warrants further investigation. The most critical aspect of the SLERA is problem formulation. This is the systematic planning incorporated into the beginning of the risk assessment process that identifies the major factors to be considered and is linked to the regulatory and policy contexts of the assessment. As established in the ecological DQOs and SAPs for the Central Plateau, ERAGS is the regulatory context for assessing ecological risks at the Hanford Site. The DQOs are WMP-20570, *Central Plateau Terrestrial Ecological Risk Assessment Data Quality Objectives Summary Report – Phase I*; WMP-25493, *Central Plateau Terrestrial Ecological Risk Assessment Data Quality Objectives Summary Report – Phase II*; and WMP-29253, *Central Plateau Terrestrial Ecological Risk Assessment Data Quality Objectives Summary Report – Phase III*. The sampling and analysis plans are DOE/RL-2004-42, *Central Plateau Terrestrial Ecological Sampling and Analysis Plan – Phase I*; DOE/RL-2005-30, *Central Plateau Terrestrial Ecological Sampling and Analysis Plan – Phase II*; and DOE/RL-2006-27, *Central Plateau Terrestrial Ecological Sampling and Analysis Plan – Phase III*.

Problem formulation involves reviewing relevant site records as a first step to assess existing data about site conditions pertinent to ecological exposure. This information was considered before the site visit was undertaken (Step 1). A possible outcome of the site visit is a determination that present or future ecological impacts are negligible because complete exposure pathways do not exist. This is an important determination, and the guidance emphasizes that all sites should be evaluated by qualified personnel to determine whether this conclusion is appropriate. In accordance with this guidance, the contaminant distribution models and analytical data were used to assess whether complete exposure pathways exist for the 216-A-4 and 216-A-2 Cribs.

Evaluating potential ecological exposure pathways is one of the primary objectives of the screening level characterization of a waste site. For an exposure pathway to be complete, a contaminant must be able to travel from the source to ecological receptors and to be taken up by the receptors via one or more exposure routes. If an exposure pathway is not complete for a specific contaminant, the exposure pathway does not need to be evaluated further.

Exposure potential was one of the key considerations in the framework of the Central Plateau Ecological Risk Assessment study design and was considered in selecting areas for sampling and analysis. This process started with a master list of sites including all Central Plateau waste sites listed in the Tri-Party Agreement, Appendix C, as amended September 1, 2003. A query of the WIDS database was used for waste site selection. Given the focus of the Central Plateau Ecological Risk Assessment to support remediation decisions, considerable effort went into evaluating the soil depth where cleanup is required. WAC 173-340-7490(4)(b), "Terrestrial Ecological Evaluation Procedures," "Point of Compliance," "Standard Point of Compliance," defines the soil cleanup depth (the standard point of compliance) as extending from the ground surface to 4.6 m (15 ft) bgs.

Information is available for the deeper rooted plant species and deeper burrowing mammal and ant species occurring on the Hanford Site (PNL-2774, *Characterization of the Hanford 300 Area Burial Grounds: Task IV–Biological Transport*, and RHO-SA-211, *Intrusion of Radioactive Waste Burial Sites by the Great Basin Pocket Mouse [*Perognathus parvus*]*). None of the maximum depths reported for plant or animal species were greater than 3 m (10 ft), well above the 4.6 m (15 ft) interval defined for applicability of shallow zone screening thresholds (WAC 173-340-7490[4][b]), which indicates that the pathway from deep soil to ecological receptors is incomplete. The Hanford Site-specific data indicate that the shallow zone soil (<4.6 m [15 ft] bgs) is the primary contaminated medium of concern for ecological receptors. Waste sites were considered inaccessible to ecological receptors if the contamination was deeper than 4.6 m (15 ft) bgs or if the potential contaminant pathways to ecological receptors have been broken by man-made structural features.

In considering the subsurface extent of plant roots or animal burrows, it is important to realize that burrow and root density are not continuous from the soil surface to the maximum reported depths; biotic activity decreases with depth. In recognition of this, the WAC allows for a conditional point of compliance to be set at the terminus of the biologically active zone (WAC-173-340-7490[4][a], "Conditional Point of Compliance") for sites having institutional controls in place, such as those sites in the 200-MW-1 OU. The depths to which insects, animals (burrows), and plants (roots) are likely to occur define the biologically active zone. The working hypothesis is that biological activity is limited largely to the top 3 m (10 ft).

As shown with the CSM presented in Chapter 4, the contaminated intervals occur at depths below 4.6 m (15 ft) at both the 216-A-2 and 216-A-4 Cribs. Based on these considerations, the direct contact exposure pathway for ecological receptors is incomplete at these two waste sites. Therefore, these waste sites are eliminated from further evaluation in the SLERA.

6.4 Summary of the Risk Assessment Results

This section describes the quantitative and qualitative results from both the human health and ecological risk assessment process. Table 6-7 provides a summary of this information.

6.4.1 Quantitative Human Health Results for the 216-A-2, 216-A-4, and 216-A-5 Cribs (Two Sites)

The 216-A-2, 216-A-4, and 216-A-5 Cribs are the sites used to evaluate the seven 200-MW-1 sites for which quantitative data are available to support a quantitative BRA. The remaining five 200-MW-1 sites were evaluated qualitatively (Section 6.4.4) using professional judgment, process history, and similar conditions for waste sites within other OUs.

For purposes of the BRA, non-radionuclide and radionuclide COCs were not identified in the shallow zone soil (0 to 4.6 m [0 to 15 ft] bgs) at the 216-A-2 Crib or the 216-A-4 Crib. Therefore, based on the current site configuration, there is currently no dose and no risk when evaluating the restricted access (industrial receptor) scenario because of the depth of cover that is currently present over these two waste sites. Similarly, there is currently no dose and no risk for the shallow exposure pathway for the unrestricted (rural residential receptor) access scenario, since COCs were not identified in the shallow zone soil. There is also no dose and no risk for the tribal scenarios, since these scenarios also examine the potential for unacceptable exposure within the shallow soil zone (15 ft. or less).

For the purposes of evaluating the potential for exposure due to loss of ICs, the hypothetical unrestricted (rural residential) deep exposure pathway scenario was evaluated at the 216-A-2 Crib. In this scenario, contaminated drill cuttings obtained from depths greater than 15 feet are assumed to be commingled with surface soils resulting in an exposure pathway to the unrestricted (rural residential) receptor. The total maximum ELCR for the unrestricted (rural residential) deep exposure pathway is approximately 1.2×10^{-2} at time zero and is greater than the threshold ELCR value of 10^{-4}. The primary contributors to risk for this hypothetical scenario include Cs-137, Sr-90, Am-241, and Pu-239. The ELCR remains above EPA's target risk threshold of 1×10^{-4} through the end of the 1,000-year simulation period, and the ELCR is projected to remain above the 10^{-4} ELCR threshold until approximately 5,740 years from the present.

6.4.2 Protection of Groundwater Results

Based on the lines of evidence discussed in Section 5.2, none of the Cribs are believed to represent a potential threat to groundwater over the long term. This conclusion is based on contaminant source inventory reviews and conservative professional judgments that will require further quantitative substantiation during remedial design and implementation. As discussed throughout this RI/FS report, confirmatory sampling will be designed and conducted as part of the implementation phase.

6.4.3 Ecological Protection Results for the 216-A-2 and 216-A-4 Cribs (Two Sites)

Based on the results of the SLERA presented in Section 6.3, the contaminated intervals occur at depths below 4.6 m (15 ft) at both the 216-A-2 and 216-A-4 Cribs. Based on these considerations, the direct contact exposure pathway for ecological receptors is incomplete at these two waste sites. As a result, there are no ecological risks identified for the two cribs.

6.4.4 Qualitative Evaluation Results for the Remaining 200-MW-1 OU Sites

Although not part of the formal BRA (since quantitative data are not available), professional judgment was used to identify a qualitative human health, ecological pathway, and protection of groundwater rationale for the remaining five sites constituting the 200-MW-1 OU. These sites were evaluated based on known process history, process knowledge, site inventory records, and extension of similar conditions for similarly configured waste sites within other OUs.

The risk results from the rural residential scenario for the 216-A-2 and 216-A-4 Cribs were used to determine whether remedial alternatives would be evaluated in the FS. The results from the rural residential scenario (deep exposure pathway) indicate that risks exceed the EPA's target risk threshold of 10^{-4}. The trespasser (unauthorized user) and the maintenance and surveillance worker (authorized user) exposure scenarios are included for the purposes of evaluating the threshold evaluation criteria in the FS. These scenarios represent the most likely human receptors that will use the Hanford Site after remedial activities have been completed on the Central Plateau. The results of the qualitative evaluation of the five sites to the potentially complete exposure pathways and receptors are summarized in Table 6-7 below, along with the quantitative BRA results for the 216-A-2 and 216-A-4 Cribs.

In Table 6-7, the known or estimated conditions at the seven sites have been summarized by displaying the quantitative findings (or qualitative judgments) for each site against the direct contact exposure pathway (two human health exposure scenarios of interest to the remedial alternatives analysis – the trespasser [unauthorized user] scenario, the maintenance and surveillance worker [authorized user] scenario), the ecological protection pathway, and the groundwater protection pathway.

As can be seen from the table, only the 216-A-4 Crib is believed to represent a potential baseline groundwater protection threat. All the sites represent various combinations of potential risk as displayed in the table. These results provide managerial insight and serve as the basis for supporting Tri-Party Agency decisions concerning the need for individual waste site remediation. The use of these quantitative results and qualitative judgments in supporting the development, screening, and evaluation of remedial alternatives will be presented in the remaining chapters of this RI/FS.

As discussed throughout this document, additional characterization activities are planned as appropriate as part of the remedial design/remedial action phase to verify the conservative and qualitative conclusions and professional judgments summarized in this section.

Table 6-7. Rationale for Remedial Alternatives Development for 200-MW-1 Waste Sites

Future Land Use/ Exposure Scenario	Depth	Waste Site						
		Cribs				Trench	Reverse Wells	
		216-A-2	216-A-4	216-A-21	216-A-27	200-E-102	216-B-4	216-C-2
Trespasser Scenario	0 – 3 ft	NR	HH[b]	HH[b]	HH[b]	HH[b]	NR	NR
Groundwater Protection Pathway	0 – groundwater	NR	NR	NR	NR	NR	NR	NR
Ecological Pathway	0 – 10 ft	NR	ECO[b]	ECO[b]	ECO[b]	ECO[b]	NR	NR
Maintenance and Surveillance Worker Scenario	0 – 3 ft	NR	HH[b]	HH[b]	HH[b]	HH[b]	NR	NR

Notes:

The 216-A-2 and 216-A-4 sites are the only two sites that have quantitative information available to support the formal baseline risk assessment; the remaining five sites were assessed qualitatively based on professional judgment, process knowledge, site history, and the extrapolation/analysis of conditions at other similar sites within other operable units. The information supporting the qualitative evaluations is summarized in Chapters 4 and 5 of this RI/FS.

NR = No Risk; quantitative or qualitative results indicate no contamination present above PRG within the designated exposure horizon.

ECO = Ecological Risk, contamination present above PRG within the 0-10 ft exposure horizon (maximum).

ECO[b]= The potential for ecological risk from direct contact with soil is pending confirmatory sampling.

HH = Human Health Risk via direct contact; contamination present above respective PRG within the 0-15 ft exposure horizon.

HH[b] = The potential for human health risk from direct contact with soil is pending confirmatory sampling.

GW = Groundwater Protection Risk; contamination present above groundwater protection criteria within the vadose zone column.

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7 Identification and Screening of Technologies

This chapter presents the basis for developing RAOs to address the specific threat these sites pose to HHE, based on the exposure scenarios presented in Chapter 6. These RAOs are then used to develop specific preliminary remediation goals (PRGs) used as a measure of achieving RAOs. General response actions and specific remedial technologies are then identified and screened.

7.1 Remedial Action Objectives

RAOs are general descriptions of what a remedial action is expected to accomplish. They are developed using information on current and reasonably anticipated future land uses, groundwater beneficial uses, the BRA findings, and ARARs. The following subsections present background information used in the development of RAOs for the 200-MW-1 OU. The RAOs address site-specific receptors, exposure pathways, and contaminants in accordance with 40 CFR 300.430(e)(2)(i), "Feasibility Study," and CERCLA RI/FS Guidance (EPA/540/G-89/004).

As discussed in Section 6.3 of the BRA, there are no unacceptable public health risks associated with the 216-A-2, 216-A-21, and 216-A-27 Cribs or 216-B-4 and 216-C-2 Reverse Wells because of the depth of contamination; in other words, the exposure pathway is incomplete under the current and future anticipated land use. Fate and transport modeling showed no adverse impact to groundwater associated with the leaching of uranium metal-contaminated soil at the 216-A-4 Crib; however, there is some uncertainty associated with this determination because uranium metal has been detected at concentrations above the 30 μg/L MCL in groundwater samples collected in the vicinity of the 216-A-4 Crib.

7.1.1 Contaminants of Concern

The BRA did not identify non-radiological or radiological contaminants of concern (COCs) in the shallow zone soil (0 to 4.6 m [0 to 15 ft] bgs) from the 216-A-2 Crib or the 216-A-4 Crib. However, because of uncertainties in the representativeness of characterization data at the 216-A-4 Crib, 216-A-21, and 216-A-27 Cribs (Chapter 4), the potential exists for shallow contamination that exceeds acceptable risk levels. Likewise, based on historical information related to the 200-E-102 Trench, shallow contamination is also believed to exist at this waste site.

7.1.2 Applicable or Relevant and Appropriate Requirements

As part of the process for establishing RAOs and PRGs for a Superfund site, and defining response actions, ARARs are reviewed to identify promulgated federal and state standards that will (or may) affect the development and selection of remedial actions. The ARARs identification process presented in this section is based on CERCLA guidance (EPA/540/G-89/006, *CERCLA Compliance with Other Laws Manual: Interim Final*), and RI/FS guidance (EPA/540/G-89/004).

7.1.2.1 Definition and Determination of ARARs

Remedial actions under CERCLA, as amended under 42 USC 9601 to 6975, must attain levels of cleanup for hazardous substances released into the environment, and control further release, to ensure overall protection of HHE. The *Superfund Amendments and Reauthorization Act of 1986* specifies that a selected remedial action must achieve a level of control that at least attains requirements that are legally applicable to the hazardous substances of concern, or relevant and appropriate under the circumstances of the release or threatened release.

The identification of ARARs is a two-step process: 1) it must be determined if the law or regulation is applicable, and 2) if not applicable, it must be determined if the law or regulation is both relevant and appropriate. The terms "applicable" and "relevant and appropriate" are defined in 40 CFR 300.5, "Definitions," as follows:

- "Applicable" means those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility citing laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable.

- "Relevant and appropriate" requirements means those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, although not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well-suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate.

In evaluating the relevance and appropriateness of a requirement, the following eight comparison factors in 40 CFR 300.400(g)(2), "General," "Identification of Applicable or Relevant and Appropriate Requirements," are considered.

1. The purpose of the requirement and the purpose of the CERCLA action.
2. The medium regulated or affected by the requirement and the medium contaminated or affected at the CERCLA site.
3. The substances regulated by the requirement and the substances found at the CERCLA site.
4. The actions or activities regulated by the requirement and the remedial action contemplated at the CERCLA site.
5. Any variances, waivers, or exemptions of the requirement and their availability for the circumstances at the CERCLA site.
6. The type of place regulated and the type of place affected by the release or CERCLA action.
7. The type and size of structure or facility regulated and the type and size of structure or facility affected by the release or contemplated by the CERCLA action.
8. Any consideration of use or potential use of affected resources in the requirement and the use or potential use of the affected resource at the CERCLA site.

> "To be considered" (TBC) information represents another category of non-promulgated advisories or guidance documents issued by federal or state governments that are not legally binding and do not have the status of potential ARARs. In some circumstances, TBC information will be evaluated along with ARARs in determining the remedial action necessary to protect HHE. TBC information complements ARARs in determining protectiveness at a site or implementation of certain actions. For example, because soil cleanup standards do not exist for all contaminants, the health advisories, which would be TBC information, may be helpful in defining appropriate remedial action goals."

ARARs are divided into three categories: contaminant-specific, action-specific, and location-specific, as follows:

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

A distinction and clarification related to ARARs involves onsite and offsite actions. Onsite actions are defined to be "the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action" (400 CFR 300). Onsite actions must comply with ARARs, but need to comply only with the substantive parts of those requirements. Offsite actions must comply with both the substantive and administrative requirements. For onsite activities, a requirement under federal and state environmental laws may be either applicable or relevant and appropriate, but not both.

In summary, a requirement is applicable if the specific terms or jurisdictional prerequisites of the law or regulations directly address the circumstances at a site. If not applicable, a requirement may nevertheless be relevant and appropriate if: 1) circumstances at the site are, based on best professional judgment, sufficiently similar to the problems or situations regulated by the requirement, and 2) the requirement's use is well suited to the site. Only the substantive requirements (for example, use of control/containment equipment and compliance with numerical standards) associated with ARARs apply to CERCLA onsite activities. The ARARs associated with administrative requirements, such as permitting, are not applicable to CERCLA onsite activities (CERCLA, Section 121[e] [1]). In general, this CERCLA permitting exemption will be extended to all remedial and corrective action activities conducted at the 200-MW-1 OU. Potential federal and state ARARs are presented in Appendix E.

7.1.2.2 Chemical-Specific ARARs Identified for the 200-MW-1 OU Feasibility Study

The chemical specific ARARs that may affect remediation of the 200-MW-1 OU waste sites are the elements of the WAC regulations that implement WAC 173- 340. Within this branch of the WAC, there are detailed regulations associated with developing standards for remedial actions involving soil cleanup (WAC 173-340-745 and WAC 173-340-747). These standards are in the form of risk-based concentrations that help establish soil cleanup standards for nonradioactive and radioactive contaminants.

Elsewhere with federal and state air regulations, emission standards exist that are likely to be important in identifying limits and control requirements for any remedial action that has the potential to produce hazardous air pollutants and radionuclides. The RCRA Land Disposal Restrictions under 40 CFR 268, "Land Disposal Restrictions," also contain important standards applicable to management and disposal of hazardous wastes and debris generated during remedial actions that will be land disposed.

7.1.2.3 Location-Specific ARARs Identified for the 200-MW-1 OU Feasibility Study

Potential location-specific ARARs that have been identified for the 200 MW-01 OU include those that protect cultural, historic, and Native American sites and artifacts, and those that protect critical habitats of federally endangered and threatened species although these resources are not expected to be encountered during 200-MW-01 OU remediation.

7.1.2.4 Action-Specific ARARs Identified for the 200-MW-1 OU Feasibility Study

Action-specific ARARs that could be pertinent to possible remediation activities relate to the state solid and dangerous waste regulations (for management of characterization and remediation wastes and performance standards for waste left in place) and *Atomic Energy Act of 1954* regulations (for performance standards for radioactive waste sites).

In regards to waste management activities during remediation, a variety of waste streams may be generated under the proposed remedial action alternatives. It is anticipated that most of the waste will be designated as radioactive LLW. There is the potential for encountering chemically hazardous (dangerous) waste or mixed dangerous and radioactive (mixed) waste, PCB contaminated waste, and asbestos and asbestos containing material (ACM) from buried pipelines and structures during remediation activities. Based on existing site information, the potential for encountering PCB contaminated soil at concentrations above regulatory thresholds, mixed waste, and ACM is expected to be low.

The identification and TSD of hazardous wastes and debris, and the hazardous component of mixed waste, are governed by RCRA. The State of Washington, which implements RCRA requirements under WAC 173-303, "Dangerous Waste Regulations," has been authorized to implement most elements of the RCRA program. The WAC 173-303 standards for generation and storage would apply to the management of any dangerous or mixed waste generated, and its subsequent storage prior to final disposition, during this remedial action. Treatment standards for dangerous or mixed waste and hazardous debris subject to RCRA Land Disposal Restrictions as set forth by the EPA in 40 CFR 268, and which are incorporated by reference into WAC 173-303-140, "Land Disposal Restrictions," will also apply.

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

Removal and disposal of asbestos and ACM are regulated under the *Clean Air Act of 1990*, 40 CFR Part 61, "National Emission Standards for Hazardous Air Pollutants," Subpart M, "National Emission Standard for Asbestos." This regulation provides for special precautions to prevent environmental releases or exposure to personnel of airborne emissions of asbestos fibers during remedial actions. 40 CFR 61.52, "Emission Standard," identifies packaging requirements. Asbestos and ACM would be removed, packaged as appropriate, and disposed in the ERDF.

All remedial action alternatives will be performed in compliance with the waste management ARARs. Waste streams will be evaluated, designated, and managed in compliance with the ARARs. Before disposal, waste will be managed in a protective manner to prevent releases to the environment or unnecessary exposure to personnel.

Some remedial action alternatives have the potential to generate airborne emissions of radioactive and hazardous air pollutants. The federal *Clean Air Act of 1990* and RCW 70.94, "Public Health and Safety," "Washington Clean Air Act," require regulation of air pollutants. Under federal implementing regulations, 40 CFR 61, Subpart H, requires that airborne radionuclide emissions from the facility shall be controlled so as not to exceed amounts that would cause an exposure to any member of the public of greater than 10 mrem per year effective dose equivalent.

The same regulation addresses point sources (i.e., stacks or vents) emitting airborne radioactive emissions, requiring monitoring of such sources with a major potential for airborne radioactive emissions, and requiring periodic confirmatory measurement sufficient to verify low emissions from such sources with a minor potential for emissions. Under portions of the state implementing regulations, the federal regulations are paralleled by adoption. In addition, WAC 246-247-040(3) and (4), "Department of Health," "Radiation Protection—Air Emissions," "General Standards," require the use of applicable control technologies to address radioactive airborne emissions from new and existing units. In order to address the substantive aspect of these requirements, best or reasonably achieved control technology will be addressed by ensuring that applicable emission control technologies (those successfully operated in similar applications) will be used when economically and technologically feasible (i.e., based on cost/benefit). If it is determined that there are substantive aspects of the requirement for monitoring of fugitive or non-point sources emitting radioactive airborne emissions (WAC 246-247-075[8], "Monitoring, Testing and Assurance"), then these will be addressed by sampling the effluent streams and/or ambient air as appropriate using reasonable and effective methods.

7.1.3 Remedial Action Objectives

RAOs provide a general description of what a Superfund cleanup is designed to accomplish. Under 40 CFR 300, RAOs are developed to guide the development of a remedial alternative(s), and once an alternative is selected, to monitor its progress. The RAOs for the 200-MW-1 OU incorporate site-specific information on the exposure pathway(s), media, and COCs to be addressed by remedial action, and the allowable concentration of contaminants that can remain in environmental media when the remedial action is completed.

The RAOs proposed for the 200-MW-1 OU are:

- RAO 1 – Protect human receptors from direct-contact exposure to radionuclides and non-radionuclides present within 4.6 m (15 ft) of the ground surface at concentrations corresponding to an ELCR greater than 1 in 10,000 (1×10^{-4}) or non-cancer hazard index greater than 1.0.
- RAO 2 – Protect ecological receptors from direct-contact exposure to radionuclides and non-radionuclides present within 3 m (10 ft) of the ground surface, based on a dose rate limit of 0.1 rad/day for terrestrial organisms and 1.0 rad/day for terrestrial plants.
- RAO 3 – Reduce the migration of radionuclides and non-radionuclides through the soil column so that no further degradation of groundwater quality occurs.

7.1.3.1 RAO 1 – Protect Human Receptors

The first RAO proposed for the 200-MW-1 OU provides for protection of human receptors. The WAC defines the soil cleanup depth (the standard point of compliance) as extending from the ground surface to 4.6 m (15 ft) bgs (WAC 173-340-740) for industrial land use. This represents the depth of soils that could potentially be available for human exposure to soils via direct-contact exposure when access restrictions are in place.

An RAO to protect current and future human receptors is listed in Table 7-1. It is presumed that a site worker could be exposed to contaminated material. Protection of current and future construction workers, maintenance workers, and trespassers (as unauthorized users) will be achieved by preventing exposure to, or reducing the concentration of, non-radionuclide and radionuclide contaminants present in the upper 4.6 m (15 ft) soil exposure horizon at concentrations corresponding to an ELCR of 1×10^{-4} for individual constituents.

Table 7-1. Remedial Action Objective Metrics

RAO	General Description	Metric	Point of Compliance
RAO No. 1	Protect human receptors	Trespasser PRGs	0 to 1 m (0 to 3 ft) bgs
		Maintenance Worker PRGs	0 to 1 m (0 to 3 ft) bgs
		Construction Worker PRGs	0 to 4.6 m (0 to 15 ft) bgs
RAO No. 2	Protect ecological receptors	Terrestrial Organisms-0.1 rad/day	0 to 2.4 m (0 to 10 ft) bgs
		Terrestrial Plant-1.0 rad/day	
RAO No. 3	Reduce migration of uranium metal to groundwater	MCL	0 to groundwater table

bgs = below ground surface

MCL = maximum contaminant level

7.1.3.2 RAO 2 – Protect Ecological Receptors

An RAO to protect terrestrial ecological receptors is needed because it is presumed that exposure to contaminated soil present at two waste sites could occur if existing management controls were discontinued or become ineffective. This RAO will be achieved by continuing existing management controls, which prevent ecological receptors from becoming established at the 200-MW-1 OU waste sites, or by preventing ecological receptor contact with soil or wastes that contain radionuclides at concentrations corresponding to a dose rate of 0.1 rad/day for terrestrial organisms and 1.0 rad/day for terrestrial plants (DOE-STD-1153-2002, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*).

The WAC defines the soil cleanup depth (the standard point of compliance) as extending from the ground surface to 4.6 m (15 ft) bgs (WAC 173-340-7490[4][b]). However, WAC-173-340-7492(4)(a) allows for a conditional point of compliance to be used. This FS proposes a conditional point of compliance of 3 m (10 ft).

7.1.3.3 RAO 3 – Protect Groundwater

An RAO to protect groundwater is proposed due to uncertainties associated with representativeness of waste site investigation data. Therefore, there may be a potential for leaching of radionuclide and non-radionuclide contamination from contaminated soil to have an adverse affect on groundwater quality.

Groundwater protection will be achieved by reducing the amount of precipitation that percolates through the vadose zone, or reducing the amount of contaminants present in vadose zone soil, such that concentrations present in the soil, or remaining once remedial action is complete, do not result in an adverse impact to groundwater that could exceed MCLs and non-zero MCL goals under the *Safe Drinking Water Act of 1974*. MCLs for non-radionuclides and radionuclides will be attained at a designated point of compliance defined by EPA and Ecology in the ROD.

7.1.4 Preliminary Remediation Goals

Remediation goals are numeric representations of RAOs that define the allowable concentration of contaminants in environmental media necessary to protect HHE under specified exposure conditions. Remediation goals, in combination with points of compliance, typically define the area and volume of environmental media that must be addressed by a remedial action. PRGs are developed in the FS and presented to the public for comment in the Proposed Plan, and the final remediation goals are established in the ROD. This section summarizes the process used to develop soil PRGs for 200-MW-1 OU.

7.1.4.1 Development Approach

PRGs are developed based on current and reasonably anticipated future land and groundwater use expectations, the exposure pathways and COCs identified in the BRA, and ARARs. Groundwater and surface water PRGs are generally established from ARARs that are protective of the designated beneficial use. Where remediation goals are not defined by ARARs, as is typically the case with soil, human health PRGs for radionuclides (the defined exposure conditions) are set at concentrations that correspond to an ELCR 1×10^{-4}. Depending on site-specific considerations, soil PRGs may also be developed to protect designated groundwater or surface water beneficial uses. Soil to water protection PRGs are frequently calculated from site-specific information.

7.1.4.2 Soil PRGs

PRGs are used to support the evaluation of remedial alternatives for the 200-MW-1 OU. PRGs corresponding to industrial worker direct-contact exposure of 10^{-4} ELCR are calculated in Appendix F. The industrial worker scenario represents an RME scenario for the current land use at the sites, and a level of protectiveness equal to 10^{-4} ELCR is used for consistency with EPA's target risk threshold value.

Exposures assessed for the direct contact exposure scenarios are used to reflect an RME under current land use within the industrial (exclusive) zone of the Central Plateau. The direct-contact exposure routes evaluated for the scenarios are external gamma radiation, incidental soil ingestion, and inhalation of dust particulates. Based on the reasonably anticipated future land use of permanent perpetual care by DOE, PRGs developed for industrial direct-contact exposure provide conservative exposure assumptions.

The PRGs are developed using the analytes detected in 216-A-5 Crib for the individual radionuclides and non-radionuclides. This list also captures the COPC identified at the 216-A-2 and 216-A-4 Cribs. The COPC identification process is described in Chapter 6. Table 7-2 lists the radionuclide COPCs identified during the RI at each crib and the exposure point concentration (EPCs) for each COPC. The EPCs represent the maximum measured radionuclide soil concentrations encountered within the identified depth intervals during RI characterization drilling at each crib. The EPCs are the soil concentration values used in the RESRAD analysis for the RI.

Results of the BRA indicate that under current site configurations, there is no radiological risk to an industrial worker at either crib because the direct-contact pathway is incomplete (i.e., the receptor cannot come into direct contact with contamination). This is because the uncontaminated soil cover layer at each crib (8 m [27 ft] at the 216-A-2 Crib, 5.6 m [18.5 ft] at the 216-A-4 Crib) shields the ground surface and prevents exposure from the external gamma radiation exposure route. Additionally, the direct-contact inhalation and incidental ingestion exposure routes are incomplete as long as the soil covers remain in place.

Although the cribs in their current configurations are protective for industrial direct-contact soil exposure, a need to take remedial action is established in the BRA based on analysis of an RME; in this case, the RME scenario is based on the assumption that direct-contact exposure pathways to the industrial worker are complete.

Table 7-2 provides the individual industrial direct-contact PRGs calculated for each radionuclide COPC identified at the 216-A-2 Crib. This table provides PRG numerical values (i.e., soil concentrations in units of pCi/g) corresponding to an ELCR value of 10^{-4}. The COPCs at the 216-A-4 Crib are a subset of those identified at the 216-A-2 Crib; therefore, Table 7-2 includes all COPCs identified at the two cribs.

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Table 7-2. Summary of Soil Preliminary Remediation Goals

		Point of Compliance 0 to 0.91 m (0 to 3 ft) bgs		Point of Compliance 0 to 3 m (0 to 10 ft) bgs	Point of Compliance 0 to 4.6 m (0 to 15 ft) bgs
Constituent	Units	Trespasser (Unauthorized User)[3,6]	Maintenance and Surveillance Worker (Authorized User)[4,7]	Ecological Soil Screening Value[1,8]	Construction Worker (Authorized User)[2,5]
Aluminum	mg/kg	2.49E+06	1.80E+06	50	2.55E+06
Antimony	mg/kg	1,014	751	5.0	1,032
Arsenic	mg/kg	9.5	3.2	7.0	110
Barium	mg/kg	491,090	344,587	102	502,400
Beryllium	mg/kg	5,029	3,674	10	5,127
Cadmium	mg/kg	2,057	1,627	4.0	2,290
Chromium	mg/kg	3.80E+06	2.82E+06	42	3.87E+06
Copper	mg/kg	101,389	75,147	50	103,232
Hexavalent Chromium	mg/kg	19	10	42	357
Iron	mg/kg	1.77E+06	1.32E+06	--	1.81E+06
Lead [9]	mg/kg	250	250	50	250
Manganese	mg/kg	289,450	161,087	1,100	303,180
Mercury	mg/kg	760	65	0.10	774
Nickel	mg/kg	49,801	35,777	30	50,842
Selenium	mg/kg	12,673	9,393	0.30	12,904
Thallium	mg/kg	--	--	1.0	--
Uranium	mg/kg	7,600	5,620	5.0	7,740
Americium-241	pCi/g	12,900	937	3,890	78,740
Carbon-14	pCi/g	1.99E+08	1.17E+07	4,760	1.03E+07
Cesium-137	pCi/g	260	18	21	1,550
Cobalt-60	pCi/g	158	9.5	692	334
Curium-243	pCi/g	1,550	106	--	8,857
Europium-152	pCi/g	178	12	1,520	750
Europium-154	pCi/g	215	13	1,290	691
Europium-155	pCi/g	16,257	975	15,800	32,722
Iodine-129	pCi/g	37,610	2,545	5,670	81,566
Neptunium-237	pCi/g	581	42	3,860	4,750
Nickel-63	pCi/g	1.40E+07	1.00E+06	--	3.18E+07
Niobium-94	pCi/g	65	4.7	--	534
Plutonium-238	pCi/g	45,170	3,223	5,270	145,285
Plutonium-239	pCi/g	38,120	2,782	6,110	139,280
Plutonium-239/240	pCi/g	38,120	2,782	6,110	139,280
Potassium-40	pCi/g	600	44	119	4,840

Table 7-2. Summary of Soil Preliminary Remediation Goals

		Point of Compliance 0 to 0.91 m (0 to 3 ft) bgs		Point of Compliance 0 to 3 m (0 to 10 ft) bgs	Point of Compliance 0 to 4.6 m (0 to 15 ft) bgs
Constituent	Units	Trespasser (Unauthorized User)[3,6]	Maintenance and Surveillance Worker (Authorized User)[4,7]	Ecological Soil Screening Value[1,8]	Construction Worker (Authorized User)[2,5]
Radium-226	pCi/g	56	4.1	51	446
Radium-228	pCi/g	147	8.9	44	518
Silver-108	pCi/g	71	5.1	--	543
Technetium-99	pCi/g	7.95E+06	478,240	4,490	6.56E+06
Thorium-228	pCi/g	676	40	530	589
Thorium-230	pCi/g	239	17	9,980	1,272
Thorium-232	pCi/g	38	2.8	1,510	308
Total Beta Radiostrontium	pCi/g	28,662	1,962	23	123,470
Tritium	pCi/g	4.24E+06	250,000	174,000	886,525
Uranium-233/234	pCi/g	37,340	2,726	4,830	68,074
Uranium-235	pCi/g	965	69	2,770	6,862
Uranium-238	pCi/g	4,440	316	1,580	29,507
Fluoride	mg/kg	101,364	75,095	200	103,211
Nitrate	mg/kg	4.06E+06	3.01E+06	--	4.13E+06

Notes:

The potential for soil concentrations to impact groundwater was evaluated at the 216-A-4 Crib and the 216-A-5 Crib. The results of this evaluation indicate that groundwater concentrations from migration of COPCs through the vadose zone do not exceed federal MCLs or State groundwater cleanup levels within a 1,000 year time frame (see Appendix C).

[1] DOE-STD-1153-2002, A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota, U.S. Department of Energy, Washington, D.C.

[2] ECF-200MW1-10-0043, Calculation of Nonradiological Preliminary Remediation Goals in Soil for a Construction Worker (Authorized User) Exposure Scenario.

[3] ECF-200MW1-10-0044, Calculation of Nonradiological Preliminary Remediation Goals in Soil for a Trespasser (Unauthorized User) Exposure Scenario.

[4] ECF-200MW1-10-0045, Calculation of Nonradiological Preliminary Remediation Goals in Soil for a Maintenance and Surveillance Worker (Authorized User) Exposure Scenario.

[5] ECF-200MW1-10-0046, Calculation of Radiological Preliminary Remediation Goals in Soil for a Construction Worker (Authorized User) Exposure Scenario.

[6] ECF-200MW1-10-0047, Calculation of Radiological Preliminary Remediation Goals in Soil for a Trespasser (Unauthorized User) Exposure Scenario.

[7] ECF-200MW1-10-0048, Calculation of Radiological Preliminary Remediation Goals in Soil for a Maintenance and Surveillance Worker (Authorized User) Exposure Scenario.

[8] WAC 173-340-740(3), "Model Toxics Control Act--Cleanup," "Unrestricted Land Use Soil Cleanup Standards," "Method B Soil Cleanup Levels for Unrestricted Land Use," Washington Administrative Code, Washington State Department of Ecology, Olympia, Washington.

[9] WAC 173-340-900, "Model Toxics Control Act--Cleanup," "Tables," Table 740-1.

Groundwater Protection PRGs

The groundwater impacts evaluation performed in Chapter 6 and Appendix C identified only one non-radionuclide contaminant that exceeded the soil concentration protection of groundwater. None of the radionuclide groundwater COPCs were found to exceed the soil concentration protective of groundwater.

Based on these findings, a PRG of 1.32 mg/kg uranium is the only PRG identified for groundwater protection. Because this value is less than the Hanford Site background value of 3.21 mg/kg, the PRG defaults to the background concentration.

7.1.4.3 Preliminary Classification of Material Exceeding PRGs

Intrusive remedial actions at the 200-MW-1 OU waste sites may generate a variety of solid waste streams that will have to be managed in accordance with federal, state, and DOE regulations. The characterization and classification of contaminated soil is needed to assist in the development and evaluation of remedial alternatives in subsequent chapters of this FS report to ensure compliance with the action-specific ARARs identified in Section 7.1.2.4. Because non-radiological compounds exceeding Ecology dangerous waste criteria were not detected in the soil samples collected from the 216-A-2, 216-A-4, and 216-A-21 Cribs, it is anticipated that a majority of these waste streams can be designated as LLW, thus allowing for transport and disposal at ERDF located in the 200 Areas, if necessary. However, a final determination will be made at the time the waste is generated based on laboratory analysis of representative waste samples. All waste generated from CERCLA remediation activities conducted at the 200-MW-1 OU will be managed in accordance with applicable regulations.

This section reviews radioactive and hazardous/dangerous waste classifications that may apply to the contaminated soil present at 200-MW-1 OU waste sites, and presents a preliminary waste determination for planning purposes.

Radioactive Waste Classifications

In general, there are three primary waste classifications that apply to contaminated environmental media present at DOE - CERCLA sites: LLW, mixed waste, and TRU waste. The waste classification begins once the contaminated soil is removed (generated) from the ground and concludes following receipt and evaluation of the representative sampling laboratory analysis results.

LLW is soil and debris not classified as high-level waste, spent nuclear fuel, TRU, or byproduct material. Depending on the concentration of short-and long-lived radionuclides present, LLW is further subdivided into four classes: Class A, Class B, Class C, and Greater Than Class C. Short-lived radionuclides are those with a half-life of less than 100 years, while long-lived radionuclides are those with a half-life of more than 100 years. The short-lived radionuclides detected most frequently in soil at the 200-MW-1 OU waste sites include Sr-90 and Cs-137. The long-lived radionuclide detected most frequently is Pu-239.

Mixed waste is soil and debris containing radionuclides at concentrations meeting LLW criteria and hazardous chemicals at concentrations exceeding levels specified in federal or state hazardous/dangerous waste regulations. LLW and mixed waste generated from CERCLA remediation activities at the Hanford Site are eligible for disposal at ERDF subject to the concentration limits specified in the facility's operating permit.

TRU waste is soil and debris containing alpha-emitting TRU radionuclides having half-lives greater than 20 years at concentrations greater than or equal to 100 nCi/g at the time of assay. Transuranic radionuclides include elements with atomic numbers greater than 92 such as neptunium, plutonium, americium, and curium. TRU waste must be packaged and shipped to the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico.

TRU Evaluation

The soil underlying the 200-MW-1 OU waste sites contains TRU compounds (among other radioactive constituents). If contaminated soils were excavated as part of the selected remedial action, the work would be conducted using a gridded-cell approach such that the concentration of TRU constituents in contaminated soil removed from the excavation would be less than the maximum detected concentrations. At the 216-A-4 Crib, the excavation process is expected to reduce the concentration of TRU constituents below 100 nCi/g and ERDF acceptance criteria.

Preliminary 200-MW-1 OU Radioactive Waste Classification

Based on laboratory analysis of soil samples collected from the 216-A-4 and 216-A-21 Cribs, all contaminated soil and debris (crib piping and gravel greater than 60 mm in size) is expected to be classified as LLW Class A or Class B. The majority of waste at the 216-A-2 Crib is also expected to be classified as LLW Class A or Class B.

CERCLA Section 104(d)(4) states that where two or more non-contiguous facilities are reasonably related on the basis of geography, or on the basis of the threat or potential threat to the public health or welfare or the environment, the facilities can be treated as one for purposes of CERCLA response actions. Consistent with this, the 200-MW-1 OU and ERDF would be considered to be onsite for purposes of Section 104 of CERCLA, and waste may be transferred between the facilities without requiring a permit.

CERCLA – Principal and Low-Level Threat Waste

40 CFR 300.430(a)(1)(iii), "Introduction," "Expectations," states that treatment will be used to address the principal threats posed by a site, wherever practicable, and engineering controls such as containment for waste that poses a relatively low long-term threat. The concept of "principal threat waste" applies to the characterization of "source materials" at a Superfund site. Source materials are any material containing hazardous substances that acts as a reservoir for ongoing contaminant release to groundwater, surface water, or air, or represents a source for direct exposure. In general, principal threat wastes are source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to HHE should exposure occur. Conversely, low-level threat wastes are source materials that can be reliably contained and would present only a low risk in the event of exposure. The manner in which principal threats are addressed generally determines whether the statutory preference for treatment is satisfied. The decision to treat principal and low-level threat wastes is made on a site-specific basis through a detailed analysis of remedial alternatives using the remedy selection criteria described in40 CFR 300.

Radionuclides present in the soil underlying the cribs and within the 200-E-102 Trench could pose a significant risk to industrial workers if exposure occurred. However, because the primary radionuclides are relatively immobile, this soil is not viewed as source material because the soil does not represent a reservoir for ongoing release of contaminants to groundwater, surface water, or air. Therefore, the soil does not represent a principal threat waste but does represent a high-risk, low-level threat waste.

7.2 General Response Actions

In accordance with the RAOs, the area and volume of contaminated soil exceeding PRGs at each waste site is estimated, and the soil's waste characteristics are reviewed to assist with identifying management options. The information contained in this section forms the basis for the remedial action technology screening and development of remedial action alternatives presented in Chapter 8 of this report.

A primary objective of the FS is to identify remedial technologies and process options that meet the RAOs for the waste sites in the 200-MW-1 OU, and then combine them into a range of remedial alternatives for further evaluation. This section discusses the technology selection process.

The potential remedial technologies are selected for evaluation based on their ability to mitigate the identified risks or achieve compliance with the potential ARARs for the remedial action. Those selected for evaluation are assessed with respect to their implementability, effectiveness, and relative cost in accordance with EPA, 1989, *The Feasibility Study: Development and Screening of Remedial Action Alternatives*, OSWER 9355.3-01FS3, Fact Sheet; EPA/540/G-89/004; and 40 CFR 300.430(e).

CERCLA guidance (EPA/540/G-89/004) suggests development and evaluation of a range of responses, including a no action alternative, to ensure that an appropriate remedy is identified and selected. The selected final remedy must comply with ARARs and must protect HHE. The technology screening process consists of a series of the following steps:

1. Identify GRAs that may meet RAOs, either individually or in combination with other GRAs.
2. Identify, screen, and evaluate remedial-technology types for each GRA.
3. Select one or more representative process option(s) for each technology type.

Following the technology screening, the representative process options are assembled into remedial alternatives (Chapter 8) that are evaluated further in the detailed and comparative analyses of alternatives (Chapter 9).

Seven GRAs, listed below, were selected to implement the RAOs:

1. No action–baseline GRA as required by 40 CFR 300 and consistent with CERCLA Guidance (EPA/540/G-89/004).
2. ICs–to mitigate risk by controlling access to, and use of, the contaminated sites.
3. Engineering controls–to mitigate risk by physically controlling access to the contaminated sites and inhibiting direct contact with contaminants.
4. Containment–to mitigate risks by physically inhibiting direct contact with contaminants, and by controlling migration of contaminants.
5. Removal of contaminated media, treatment as necessary, and disposal–to mitigate risks by excavating contaminated media, treating it as necessary, and disposing of it.
6. Ex situ treatment of contaminated media–to mitigate risks by removing the waste and then treating it to reduce contaminant toxicity, mobility, or volume.
7. In situ treatment of contaminated media–to mitigate risks by treating contaminated media in place to reduce contaminant toxicity, mobility, or volume.

7.3 Identification and Screening of Technology Types and Process Options

The GRAs and potential implementing technologies were first addressed in the Implementation Plan (DOE/RL-98-28). This document provided an initial framework to guide the RIs in the 200 Areas and documented a preliminary screening of remedial technologies appropriate to the contaminants, media, and conditions found in the arid environment in the 200 Areas (Appendix D Sections D5.0 to D5.6 and Table D-1 of the Implementation Plan).

This section discusses subsequent evaluation of remedial technologies, and focuses more specifically on the contaminants and conditions encountered at the 200-MW-1 OU waste sites and the associated risks.

Where currently available, site characterization data are not sufficient to determine whether a specific technology has application or do not support meaningful assessment of a promising technology, so that technology may be carried forward as a "supplementary technology." This approach is intended to allow pre-ROD scrutiny of the technology and its potential application by the public and regulators. The expectation is that this approach will facilitate post-ROD evaluation and, where appropriate, implementation of the technology without significant revision to the ROD.

7.3.1 Identification and Screening of Technologies

The potential remedial technologies retained in the Implementation Plan were reviewed based on the contaminant distribution models presented in Chapters 5 and 6. The list of technologies retained was then subjected to a final screening, based on the results of the BRA. The following sections describe the remedial technologies, grouped by the GRA they implement. Although the no action response, ICs, and engineering controls are not technologies, they are discussed here as potential response actions.

7.3.1.1 No Action

40 CFR 300 requires that a no action alternative be evaluated as a baseline for comparison with other alternatives. This alternative proposes that the site be left as it is, with no need for additional remedial activities, monitoring, or access restrictions. The no action alternative does not preclude non-remedial activities, and the EPA specifically allows environmental monitoring as part of a no action response (EPA, 1989). At the Hanford Site, this would be implemented as a component of the site-wide environmental monitoring program. That program has administrative controls that would trigger appropriate responses if monitoring indicated conditions contrary to the RAOs.

7.3.1.2 Institutional Controls

ICs are administrative controls and legal restrictions imposed on land use to prevent or reduce exposure to hazardous wastes or hazardous constituents and/or protect the integrity of a remedy. They are intended to act as administrative barriers to separate the public from levels of contamination that exceed acceptable health risks. ICs may include land-use restrictions, natural resource-use restrictions, groundwater use restriction areas, deed restrictions, deed notices, declaration of environmental restrictions, access controls, monitoring requirements, site posting requirements, information distribution, notification in closure letter, restrictive covenants, and federal/state/county/local registries. These activities are implemented at the Hanford Site through DOE/RL-2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions*.

The use of an IC to meet a performance standard must include a mechanism to ensure its maintenance for protectiveness over time, or until exposure to hazardous substances would no longer result in unacceptable risks. Only certain types of ICs have such mechanisms (i.e., easements, zoning, and use restrictions). ICs that do not have these mechanisms require alternatives for maintaining protectiveness.

7.3.1.3 Engineering Controls

Engineering controls are physical measures used to prevent access and exposure to hazardous wastes or hazardous constituents. Engineering controls may include signs, entry control, and artificial or natural barriers. Physical restrictions are effective in protecting human health by reducing the potential for contact with contaminated media. Engineering controls require ongoing monitoring and maintenance, and may require ICs to ensure that specific controls are not compromised by land use activities. For example, excavation activities would need to be restricted where surface barriers (soil caps) are present.

7.3.1.4 Containment

This section discusses technologies intended to mitigate risk by blocking potential exposure pathways. These include technologies that inhibit direct contact with residual contaminants or that control migration of the contaminants. The discussion includes arid-climate engineered surface barriers and vertical subsurface barriers.

Arid-Climate Engineered Surface Barrier

Arid-climate engineered surface barriers are constructed over waste sites to reduce the amount of precipitation that infiltrates into contaminated media, thereby reducing the potential for leaching soluble waste, and reducing the driving force that could accelerate downward migration of contaminants dissolved in water. They also may serve as impediments to intrusion by potential human and ecological receptors. To be considered as viable remedies, engineered surface barriers must be maintained. Therefore, in addition to environmental monitoring, barriers may require administratively controlled long-term operations and maintenance programs that include surveillance and monitoring, to ensure their physical integrity and functionality. Surface barriers address all contaminants by reducing infiltration of water (typically precipitation) from the ground surface into the contaminated media.

There are several barrier designs, of which three are evaluated and screened out early in the process primarily based on implementability and cost. These three barrier designs are the Hanford barrier, asphalt/cement cap, and RCRA Subtitle C barriers. Relative to the other technologies, the complexities in design and construction of the Hanford barrier place it last with respect to implementability and cost. The asphalt/concrete cap was screened out because of limited duration of integrity (design life). The RCRA Subtitle C barrier was screened out because of implementability, cost, and uncertainty of the barriers' useful life in arid climates as a result of desiccation cracking, breakdown caused by freeze thaw cycles, and biointrusion (DOE/EM-0558, *Alternative Landfill Cover*, page 1).

Several additional barrier designs were considered that incorporate an evapotranspiration (ET) process into their design, including monofill and capillary-break ET barriers (EPA 542-F-03-015, *Evapotranspiration Landfill Cover Systems Fact Sheet*).

An ET barrier concept was chosen as the primary surface-barrier technology for the 200-MW-1 OU. The functional components of an ET barrier are soil(s) and vegetation. Barrier soils retain infiltrating water primarily by absorption until plant transpiration and evaporation from the near surface can return it to the atmosphere. Engineered fill typically is emplaced before barrier construction is begun to provide a stable foundation. The uppermost portion of the barrier typically includes materials (for example, pea gravel) to impede erosion.

The ET barriers are effective in semiarid and arid environments, where precipitation is limited and ET potential is high. Water-balance studies at the Hanford Site have shown that vegetation and soil type are the primary factors that control the downward movement of precipitation, and for finer-grained soils with a healthy plant cover of shrubs and grasses, estimated net recharge in the 200 East Area ranges from 1.5 to 4 mm/yr (0.06 to 0.16 in/year) (PNNL-14702, Table 4-15). The recharge estimate for an ET barrier is 0.1 mm/yr (0.004 in./yr) (PNNL-14702, Table 4-16).

The monofill ET barrier is a type of simplified RCRA barrier. For the purposes of the FS, the monofill barrier will be considered, and design and construction complexities can be addressed during the remedial-design process.

Monofill Evapotranspiration Barriers

Monofill ET barriers use a single layer of a uniform soil type, covered with native vegetation, to control infiltration. The only design parameter that can be varied to achieve functional requirements is the thickness of the soil layer(s) and the presence or absence of a bio-barrier. As a result, when designed to meet the same performance criteria, monofill ET barriers tend to be thicker than capillary-break ET barriers. All ET barriers typically include an upper layer intended to limit erosion.

A monofill barrier consisting of a pea-gravel/silt-loam surface layer overlaying the silt-loam layer has been designed for use at the Hanford Site (Figure 7-1). The thickness of the barrier has been designed to eliminate downward flux from precipitation from some plausible extreme events or conditions. The monofill barrier sits atop an engineered fill base that has a minimum thickness of 51 cm (20 in.), and has side slopes with a 3:1 slope constructed from soil-filled basalt (8 to 20 cm [3 to 8 in.] of basalt) that is 30 cm (12 in.) thick. The surface is planted with native sagebrush and rabbitbrush as well as native bunchgrasses.

Vertical Subsurface Barriers (Slurry Walls and Grout Curtains)

Slurry walls and grout curtains were retained in the Implementation Plan (DOE/RL-98-28, Table D-2). Both have potential application in the vadose zone to limit the horizontal movement of moisture into contaminated materials or to limit the horizontal migration of contaminants. A slurry wall is a nonstructural underground wall, constructed by placing a cement-bentonite mixture into a trench excavated to the desired depth. Formulation of the slurry can be varied to affect permeability, durability, and compatibility with site soils and contaminants. Grout curtains are formed by injecting grout, under pressure, directly into the soil matrix (permeation grouting), or in conjunction with drilling (jet grouting) at regularly spaced intervals to form a continuous low-permeability wall. If the grout is injected vertically, like the slurry wall, it forms a continuous low-permeability barrier to the horizontal movement of moisture and contaminants.

7.3.1.5 Excavation

Excavation usually uses earthmoving equipment to remove overburden and contaminated media from the site to reduce site-specific long-term risks. In combination with appropriate treatment and disposition options, it can be used to reduce residual risk to acceptable levels, achieve PRGs and compliance with ARARs, eliminate or reduce the need for long-term maintenance at the site, and likely reduce the level of long-term environmental monitoring required. Earthmoving equipment is used to remove clean overburden, which can be staged for later use in backfilling, and to remove contaminated media and stage it for appropriate waste management activities. Contaminated media typically are removed in lifts (layers of uniform thickness) to allow screening for contamination. Field screening supports waste designation and helps determine when remedial goals are achieved. The following potential limitations are associated with excavation:

1. Handling of contaminated media could pose significant short-term exposure risks to workers, and the environment.
2. With conventional open pit excavation methods, side-slope angles to maintain slope stability result in significant lateral expansion of the excavation as depth increases, and may encroach on other waste sites, facilities, or infrastructure (Note: Shoring can be used in some instances to limit the lateral extent of excavation, but this adds to costs.).
3. Working near deep excavations could pose significant safety risks to workers.
4. Heterogeneous subsurface conditions could increase the complexity of deep excavations.
5. Disturbance of natural and cultural resources may occur.
6. Contaminated soil removal with disposal at ERDF has been the preferred alternative for waste sites in the 100 Areas and 300 Area and has been demonstrated to be effective at the Hanford Site (DOE/RL-98-28, page D-8). Given the same type of contamination, the suitability of this alternative is enhanced for the 200 Areas, because haul distances to ERDF would be substantially reduced.

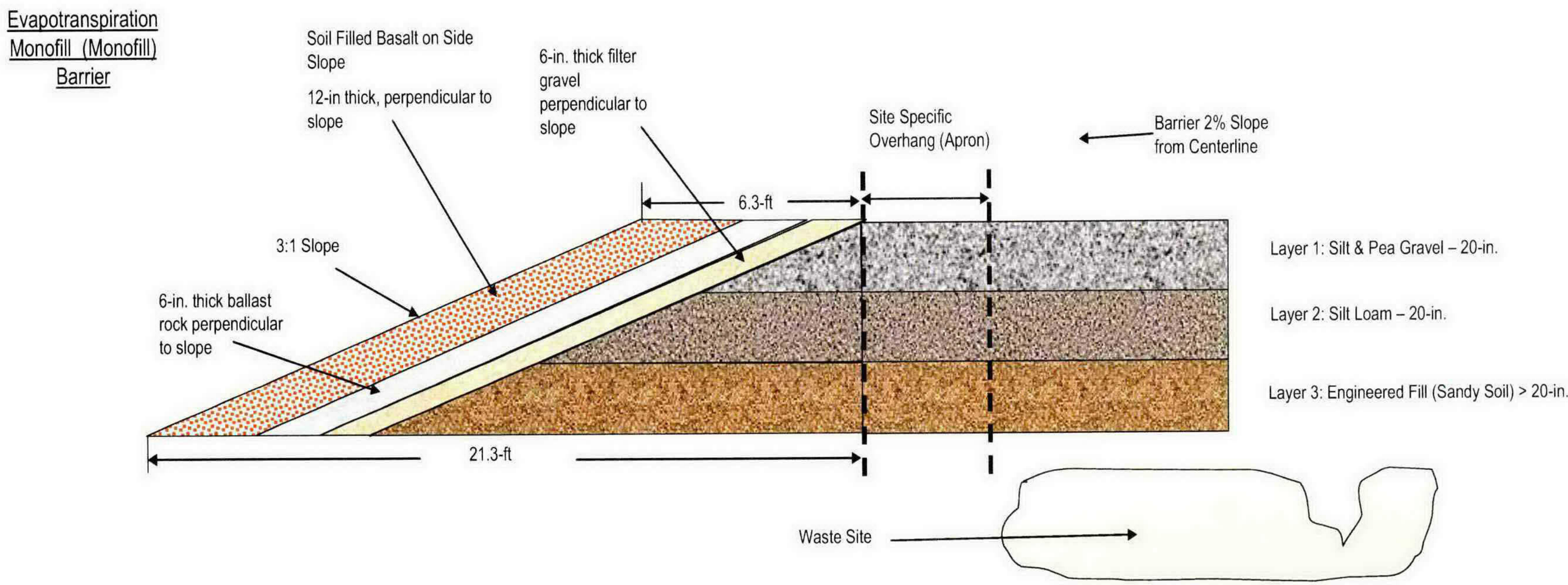

Figure 7-1. Conceptual Cross-Section: Monofill Evapotranspiration Barrier

Conventional Open Pit Excavation

Conventional open-pit excavation, employing standard earthmoving equipment such as backhoes and front-end loaders, is a viable technology for all subject waste sites, although access issues, worker safety concerns, and contaminant depth may preclude its use for portions of some sites. Conventional open-pit excavation does not require that the extent of contamination be precisely known before excavation. Rather, additional characterization can occur as the excavation proceeds, and the extent of contamination can be determined using an observational approach (DOE/RL-98-28, page 2-28).

Vertically Shored Deep Excavation

Vertically shored deep excavation consists of several technologies that involve installation of vertically shored walls that can be implemented more cost-effectively at great depths than conventional open-pit excavation. Vertically shored excavation technologies include sheet pile walls, soldier pile walls, jet-grout walls, diaphragm walls, deep shafts, and caissons. Each of these technologies involves installation of the vertical wall shoring designed to support the existing soil formation during excavation of contaminated material. Each of these technologies requires use of specialty construction equipment, and may require additional support of the vertically shored wall with internal bracing or tie-backs (for example, soil nailing) to anchor the wall into the surrounding soil formation. After contaminated material is excavated and disposed of, the vertical shoring system would remain in place permanently and the excavation would be backfilled.

Conventional Drilling

Conventional drilling is applicable to decommissioning of the reverse wells to meet ARARs. Multiple drilling methods are available that are capable of reaching significant depths in the unconsolidated sediments found at the Hanford Site. Cable tool, fluid rotary, and resonant sonic drilling methods are all capable of reaching depths of 152 m (500 ft) or greater. These methods differ in terms of penetration rate and volume of cuttings or secondary waste generated. Cable tool drilling is relatively slow. Rotary drilling is relatively rapid; however, drilling fluids in addition to drill cuttings must be captured and managed. Sonic methods afford high penetration rates and produce 20 percent of the drill cuttings generated by cable tool and rotary methods. Sonic methods eliminate the down-hole introduction of air, water, mud, or other drilling fluids.

7.3.1.6 Ex Situ Treatment

Characterization data presented in Chapter 4 suggest that no treatment will be necessary to meet disposal facility waste acceptance criteria. However, ex situ treatment technologies have been considered in this section for their ability to minimize the volume or mobility of material that may require disposal. These technologies (vitrification, soil washing, automated segregation based on radioactivity, and solidification/stabilization) are described in detail in the following subsections.

Thermal desorption and vapor extraction were retained in the Implementation Plan (DOE/RL-98-28). These technologies are applicable for the removal of VOCs from excavated soil. These technologies are not considered in this section because contaminants at the 200-MW-1 OU waste sites do not include VOCs.

Vitrification (Ex Situ)

Vitrification addresses all contaminants for all representative waste sites by melting excavated materials to form glass or other crystalline solids. Vitrification of excavated material can be conducted at a facility or on site using in-container vitrification. The in-container vitrification process mixes silica-rich contaminated soil with sand and insulation in a large steel box. Electric current is used to heat the mixture to over 1,300 °C to melt the waste material. Upon cooling, the vitrified material is chemically stable and leach-resistant. Radionuclides and most heavy metals are retained within the vitrified product. The entire container with glass and electrodes then can be disposed of.

Soil Washing

Soil washing involves removal of contaminants by dissolving, suspending, or concentrating them from the soil using a washing solution. Contaminants sorbed onto fine soil particles are separated from bulk soil in an aqueous-based system on the basis of particle size. This process separates and concentrates the contaminants into a smaller volume of soil that can be further treated or disposed of. The wash water may be augmented with a basic leaching agent, surfactant, pH adjustment, or chelating agent to help remove organics or heavy metals.

Automated Segregation Based on Radioactivity

Soil segregation technologies separate clean soil fractions from contaminated soil fractions. Systems have been developed that convey excavated soil past radioactivity sensors, and soil can be segregated based on threshold radioactivity levels. Such technology uses proven soil-handling, screening, and conveying equipment with radiation detection sensors integrated into the process.

Solidification/Stabilization

Solidification/stabilization involves mixing soil with a stabilizing agent to physically bind or enclose contaminants within a stabilized mass (solidification), or induce a chemical reaction to reduce mobility (stabilization). As assessed here, solidification/stabilization addresses inorganic and radionuclide contaminants by mixing extracted soil with a binding agent to form an encapsulated mass that inhibits contaminant mobility. Multiple process options exist, including bituminization, emulsified asphalt, modified sulfur cement, polyethylene extrusion, pozzolan/portland cement, sulfide-forming compounds, and soluble phosphates. The target contaminant group is inorganics, including radionuclides.

7.3.1.7 In Situ Treatment

In situ treatment technologies include soil mixing, vitrification, and monitored natural attenuation (MNA). These technologies are described in detail in the following subsections. These processes address a range of contaminants including inorganics, radionuclides, and metals.

Vapor extraction was retained in the Implementation Plan (DOE/RL-98-28). This process option is not considered in this section because it is only applicable to VOCs, which are not found at the 200-MW-1 OU waste sites.

Soil Mixing

Soil mixing addresses shallow subsurface inorganic and radionuclide contaminants, using a large-diameter auger to mix cement or a binding agent with the soil to provide physical encapsulation or chemical binding of contaminants. This process requires surface access at all locations where soils are affected, and is particularly suited to shallow applications (up to about 13 m [45 ft] below the surface).

In Situ Vitrification

In situ vitrification (ISV) technology, as assessed here, is the AMEC GeoMelt® vitrification process. In GeoMelt® applications, a mixture of waste and glass formers, usually soil, is electrically melted to destroy, remove, or immobilize contaminants. Melt temperatures generally are between 1,200 and 2,000 C (2,200 to 3,600 °F), depending on the composition of the mixture being melted. Organic materials are destroyed and/or removed during the melting process. Nonvolatile hazardous metals and radionuclides are immobilized in a semi-crystalline glass. This glass is durable and has excellent long-term leach characteristics. Figure 7-2 provides a conceptual representation of the ISV process.

® GeoMelt is a registered process of AMEC plc, Cheshire, England.

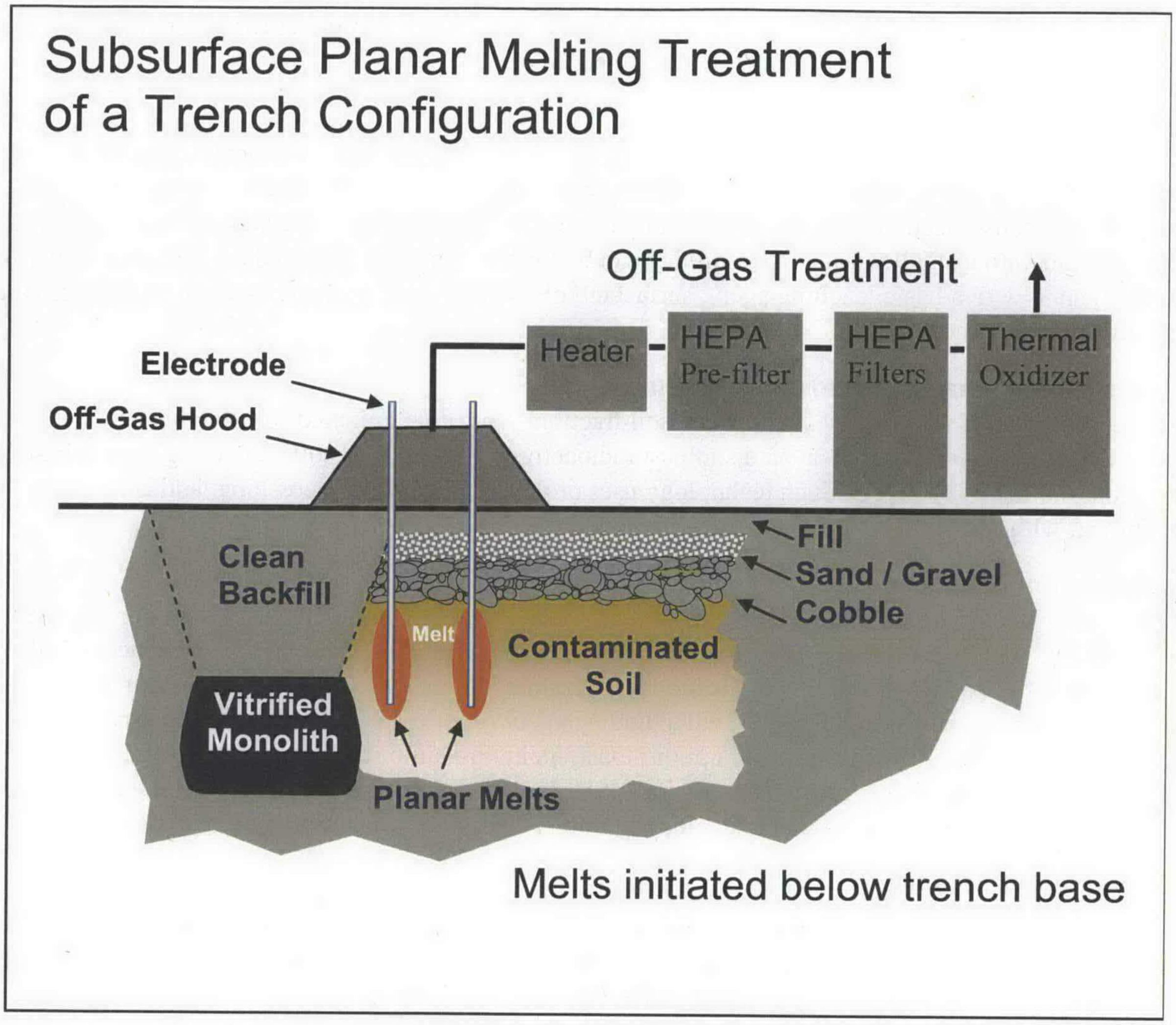

Figure 7-2. Conceptual Cross-Section: In Situ Vitrification

The process involves the in-place electric melting of contaminated soils, sludges, or other earthen materials and debris for the purpose of permanently destroying, removing, and/or immobilizing hazardous and radioactive contaminants. To accommodate soil densification, clean overburden is placed over the melt zone before the melt is initiated, thereby avoiding subsidence issues while increasing thermal efficiency and radionuclide retention.

Organic contaminants are destroyed by pyrolysis, which occurs as the temperature increases before the actual melting, and by catalytic dechlorination reactions, which occur as contaminated soils approach melt temperatures under reducing conditions. Heavy metals and radionuclides are distributed throughout the melt because of the relatively low viscosity of the molten glass and the convective flow that occurs within the melt. The radionuclides and heavy metals are retained within the melt. When electrical power is shut off, the molten mass cools and solidifies into a vitreous rock-like monolith with excellent physical, chemical, and weathering properties. The resulting product typically is 10 times stronger than concrete, and 10 to 100 times more resistant to leaching than glasses typically used to immobilize high-level wastes.

Monitored Natural Attenuation

Remedies relying on MNA processes are implemented following EPA/540/F-99/009, *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites November 1997, Draft Interim Final*, OSWER 9200.4-17P.

Natural attenuation of metals and radionuclides in soil can occur through several processes including sorption, oxidation reduction reactions, and radioactive decay. Radioactive decay changes the physical character and composition of a waste, making it less hazardous or nonhazardous. When relying on natural attenuation processes for site remediation, EPA prefers processes that degrade or destroy contaminants (EPA/600/R-07/139, *Monitored Natural Attenuation of Inorganic Contaminants in Ground Water: Volume 1 – Technical Basis for Assessment*). Therefore, MNA is an important component of the overall remedy, especially for waste sites with short-lived radionuclides.

To demonstrate effectiveness and protectiveness of MNA, the existence and irreversibility of mechanisms responsible for reductions in contaminant toxicity or mobility must be determined. For radionuclides with short half-lives, natural radiological decay can achieve substantial reductions in contaminant mass in a relatively short period of time. These include Cs-137 (half life of 30 years) and Sr-90 (half life of 29 years), which are two of the primary contaminants at the 200-MW-1 OU waste sites. Although radiological decay is well-understood, MNA would be employed at waste sites to verify that vadose zone contamination has remained immobile while decay is reducing concentrations.

7.3.2 Evaluation of Technologies and Selection of Representative Technologies

This section evaluates the technologies identified in Section 7.3.1 and screens them based on their effectiveness, implementability, and relative cost. Technology screening results are summarized in Table 7-3. Retained remedial technologies and their associated process options are listed in Table 7-4. The technology evaluation and screening are discussed in the sections below.

7.3.2.1 No Action

40 CFR 300 requires that a no action alternative be evaluated as a baseline for comparison with other alternatives. No action is retained for further consideration.

7.3.2.2 Institutional Controls

Operations at the Hanford Site are expected to terminate in approximately 2050, and active ICs are assumed to continue under permanent perpetual care under DOE. Remedies that leave contaminants in place and rely on ICs to mitigate the associated risk will need to maintain those controls for the duration of the risk. ICs are retained for further consideration.

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Table 7-3. Summary of Technology Screening Results

General-Response Action	Technology Type	Process Option	Target Contaminants	Evaluation	Results
No Action	No Action	No action, with supplemental environmental monitoring	None	Retained as baseline.	Retained
Institutional Controls	Entry Restrictions	Procedural requirements for access Excavation permits	IMR	Effectiveness: Does not reduce contamination. Effective in supporting mitigation of potential for direct contact with residual contaminants if consistently well-implemented for duration of elevated risk. Prevents disturbance of ongoing remedies. Implementability: Easy to implement, requires ongoing surveillance and maintenance. Cost: Low	Retained
	Land-Use Management	Land use and real property controls (e.g., proprietary controls including easements and covenants)	IMR	Effectiveness: Does not reduce contamination. Effective in mitigating potential for direct contact with residual contaminants if consistently well-implemented for duration of elevated risk. Ensures compatible land use. Implementability: Easy to implement, must identify and comply with all necessary legal requirements. Cost: Low	Retained
	Groundwater Use Management	Groundwater controls	IMR	Effectiveness: Ensures no improper use of groundwater. Implementability: Easily implemented, but requires ongoing action. Cost: Low	Rejected – to be addressed under the groundwater OU remedy
	Waste Site Information Management	Administrative	IMR	Effectiveness: Ensures access to information on the location and nature of contamination. Implementability: Readily implemented, but requires ongoing action. Cost: Low	Retained
Engineering Controls	Surface Barriers	Maintain existing soil cover	IMR	Effectiveness: Does not reduce contamination. Effective in supporting mitigation of potential for direct contact with residual contaminants if consistently well-implemented for duration of elevated risk. Implementability: Easy to implement, requires ongoing surveillance and maintenance. Restrictions on future land use will be necessary. Cost: Low	Retained
	Access Controls	Signs Fencing	IMR	Effectiveness: Does not reduce contamination. Effective in supporting mitigation of potential for direct contact with residual contaminants if consistently well-implemented for duration of elevated risk. Implementability: Easy to implement, requires ongoing surveillance and maintenance. Restrictions on future land use will be necessary. Cost: Low	Retained
		Entry Restrictions (Guard/Monitoring system)	IMR	Effectiveness: Does not reduce contamination. Effective in supporting mitigation of potential for direct contact with residual contaminants. Must be maintained for duration of elevated risk. Implementability: Easy to implement. Cost: Low	Retained
Containment	Surface Barriers	Arid-climate engineered cap (Monofill ET Barrier)	IMR	Effectiveness: Effective, but requires surveillance and maintenance for duration of risk. Monofill barrier is self-healing. All engineered surface caps are susceptible to weathering. Implementability: Easily implemented, although design and construction complexity varies greatly. Cost: Moderate capital and maintenance costs for ET barriers; Monofill barrier generally costs less because design, construction, and maintenance are less complex.	Retained
	Vertical Barriers	Vertical barriers are not effective in addressing the risk scenarios			

Table 7-3. Summary of Technology Screening Results

General-Response Action	Technology Type	Process Option	Target Contaminants	Evaluation	Results
		Grout curtains	IMR	Effectiveness: Not effective because little evidence of lateral migration and potential future lateral migration exists. Implementability: implementable, but can be difficult to verify continuity of barrier. Cost: Cost varies with depth, orientation, thickness of grout curtain, and composition of grout. Low to moderate capital cost.	Not Retained
Containment	Vertical Barriers (cont.)	Slurry walls (cement-bentonite slurry)	IMR	Effectiveness: Not effective because little evidence of lateral migration and potential future lateral migration exists. Implementability: easily implemented. Cost: Low to moderate capital cost (dependent on depth and thickness of wall and need for specialized slurry formulations. No maintenance costs.	Not Retained
Removal	Excavation	Conventional excavation	IMR	Effectiveness: Effective. Implementability: Readily implemented, although as low as reasonably achievable (ALARA) considerations may add to the complexity. Cost: Moderate capital costs, moderate operations and maintenance costs; ALARA issues may increase cost substantially.	Retained
		Vertically Shored (Deep) Excavation	IMR	Effectiveness: Effective only for deep excavation where conventional excavation techniques are not readily implemented. Implementability: Implementable, although ALARA considerations may add to the complexity. More detailed site characterization and engineering design required. Requires a wider/deeper excavation to install shoring in clean material and account for contamination outside of anticipated excavation limits. Shoring system cannot be easily expanded laterally or vertically once installed. Cost: Moderate to high capital costs, moderate operations and maintenance costs; ALARA issues may increase cost substantially.	Not Retained
		Drilling	IMR	Effectiveness: Effective Implementability: Readily implemented Cost: Moderate	Retained
Disposal	Landfill Disposal	Onsite landfill (ERDF)	IMR	Currently the only path forward for onsite disposal of hazardous waste, LLW, and mixed LLW generated by CERCLA activities. Effectiveness: Effective Implementability: Readily implemented Cost: Moderate	Retained
		Offsite landfill	IM/IMR	Effectiveness: Effective Implementability: Offsite activity, so both substantive and administrative requirements apply. Offsite waste transportation imparts additional costs and risks. Cost: Moderate to high, depending on distance to facility, treatment required to meet acceptance criteria.	Because of the implementability issues, offsite disposal is retained only for use as contingent action if disposal at ERDF is not possible.
		Offsite repository (Waste Isolation Pilot Plant)	IMR (as transuranic waste)	Effectiveness: Effective. Implementability: implementable, but it is an offsite activity so both substantive and administrative requirements apply. Work must be coordinated through the Hanford Transuranic Waste Certification Program. Cost: High relative to transport and disposal at other facilities.	Wastes are not anticipated to be WIPP-regulated. Not Retained.
Ex Situ Treatment (assumes excavation)	Thermal Treatment	Ex situ vitrification	IMR	Effectiveness: Effective for removing organics and stabilizing waste form. Implementability: moderately difficult to implement because of the power requirements. Cost: Relatively expensive because of the infrastructure necessary and the power requirements.	Do not anticipate a need to stabilize excavated soils. Not retained.

Table 7-3. Summary of Technology Screening Results

General-Response Action	Technology Type	Process Option	Target Contaminants	Evaluation	Results
	Physical/ Chemical Treatment	Soil washing	IMR	Effectiveness: Not shown to be effective with plutonium or americium or with very high concentrations of Cs-137. Implementability: Implementable, significant actions for worker protection and environmental protection, generates secondary liquid waste stream. Cost: Moderate	Not Retained
		Automated segregation based on radioactivity	R	Effectiveness: Not a treatment, per se, so minimal impact on achieving protectiveness. Facilitates segregation of radiologically contaminated soils, which helps to minimize waste volume and related management and disposal costs. Implementability: Readily implemented. Cost: Low cost; however, not warranted at the 200-MW-1 waste sites.	Not Retained
Ex Situ Treatment (assumes excavation)	Physical/ Chemical Treatment (cont)	Solidification/ stabilization	IMRO	Effectiveness: Not effective because primary contaminants are relatively immobile. Implementability: Readily implemented Cost: Moderate, but not warranted because primary contaminants are relatively immobile.	Not Retained
In Situ Treatment	Chemical/ Physical Treatment	Soil mixing	IMR	Effectiveness: Limited effectiveness because primary contaminants are relatively immobile. Effectiveness depends on site conditions and additives used. Not effective for deeper contamination. Implementability: Implementable and well-demonstrated. Services available from several vendors. Treatability studies required to select proper additives. Thorough characterization of subsurface conditions and continuous monitoring required. Waste volumes are increased. Cost: Moderate, but not warranted because primary contaminants are relatively immobile.	Not Retained
	Thermal Treatment	In situ vitrification	IMRO	Effectiveness: Limited effectiveness because primary contaminants are relatively immobile. Provides little reduction in mobility or volume. Implementability: Moderate to high level of technical difficulty. Moderately difficult to implement because of the power and infrastructure requirements. May need treatability studies. Not previously implemented at required depths of treatment. Cost: Moderate to high, but not warranted because primary contaminants are relatively immobile.	Not Retained
	Natural Attenuation	Monitored natural attenuation	IMRO	Effectiveness: Effective for organics, metals, and short-lived radionuclides. Effective for Cs-137, reducing contaminant mass by 50% roughly every 30 years (radiological decay). Implementability: Readily implemented, requiring only monitoring for verifying progress toward preliminary remediation goals. Cost: Low	Retained for short-lived radionuclides.

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
EPA = U.S. Environmental Protection Agency
ERDF = Environmental Restoration Disposal Facility
I = inorganic, nonmetallic contaminants
M = heavy metals contaminants
R = radionuclide contaminants
O = organic contaminants

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Table 7-4. Retained Remedial Technologies

General-Response Action	Technology Type	Remediation Technology	Target Contaminants
No Action	No Action	No Action	IMR
Institutional Controls	Land Use Management	Deed Restrictions	IMR
		Deed Notices	IMR
		Declaration of Environmental Restrictions	IMR
		Information Distribution	IMR
		Restrictive Covenants	IMR
		Federal/state/county/local registries	IMR
	Entry Restrictions	Procedural Requirements for Access, Excavation Permits	IMR
	Waste Site Information Management	Administrative	IMR
	Monitoring	Monitoring	IMR
Engineering Controls	Surface Barriers	Maintain Existing Cover	IMR
	Access Controls	Signs / Fences	IMR
	Entry Restrictions	Guard/Monitoring System	IMR
Containment	Surface Barriers	Monofill ET Barrier	IMR
Removal	Excavation	Conventional Excavation	IMR
	Drilling	Drilling (well abandonment)	NA
Disposal	Landfill Disposal	Onsite Landfill	IMR
		Offsite Repository	IMR
	Natural Attenuation*	Monitored Natural Attenuation	R

* Not a treatment process
ET = evapotranspiration
I = inorganic, nonmetallic contaminants
M = heavy metal contaminants
R = radionuclide contaminants
NA = not applicable

7.3.2.3 Engineering Controls

Remedies that leave contaminants in place and rely on engineering controls to mitigate the associated risk will need to maintain those controls for the duration of the risk. Engineering controls are considered effective, readily implementable, and cost effective and are retained for further consideration.

7.3.2.4 Containment

Monofill Evapotranspiration Barriers

Advantages of the monofill ET barrier include simplicity in design and construction, demonstrated effectiveness in arid and semiarid climates, and relatively low cost. Additionally, because this type of barrier does not rely on structural features to control infiltration, it is not as likely to be compromised by differential settlement, subsidence, or seismic events. This is an especially important consideration for barriers intended to last for hundreds of years. In addition, because monofill ET barriers tend to be thicker, they provide additional separation between residual contaminated media and potential human and ecological receptors.

Barrier design establishes specific side-slope requirements to ensure slope stability and barrier integrity. One disadvantage of monofill barriers is that, compared to multilayer barriers, monofill ET barriers would have a relatively greater thickness, resulting in a larger footprint because of slope stability requirements, and they may be more likely to encroach on adjacent sites, facilities, or infrastructure.

Vertical Subsurface Barriers (Slurry Walls and Grout Curtains)

Neither slurry walls nor grout curtains will be effective to mitigate identified risks. Horizontal migration of contaminants is not expected to be significant in the vadose zone at the 200-MW-1 waste sites as noted in the conceptual contaminant distribution models provided in Chapter 4. This technology is not retained for further consideration.

7.3.2.5 Excavation

Open-Pit Excavation

Conventional open-pit excavation, employing standard earthmoving equipment, such as backhoes and front-end loaders, is a viable technology for crib and trench waste sites; however, the depth of contamination precludes its use for reverse well sites. Conventional open-pit excavation does not require that the extent of contamination be precisely known before excavation. Rather, additional characterization can occur as the excavation proceeds, and the extent of contamination can be determined using an observational approach (DOE/RL-98-28, pg. 2-28).

Open-pit excavation is most practical at sites with shallow contamination. Depth of the excavation typically is up to 7.6 m (25 ft); however, deeper depths can be achieved with proper side slopes and benching.

Deeper excavations using conventional open-pit excavation methods result in larger surface footprints because of the need to maintain safe side slopes. This makes deep open-pit excavation less practical because the excavation would encroach on adjacent sites, facilities, and/or infrastructure. Preliminary evaluation of adjacent facilities and structures indicates that open-pit excavation methods are implementable at a depth of about 12.2 m (40 ft). Significantly greater excavation depths would require additional planning and design, and most of the systems require engineered retaining and support systems to secure the excavation.

Vertically Shored Deep Excavation

The primary advantage over conventional excavation is the reduction of excavation volumes, because sloping and benching are not required. Vertical shoring systems require a more detailed understanding of subsurface conditions and contaminant distribution. Vertical shoring systems cannot be easily or cost effectively extended deeper or wider, once installed, if an increase in the lateral footprint or depth of contamination is found at levels exceeding PRGs at the limits of excavation. Therefore, more detailed characterization and design efforts would be needed to establish appropriate design excavation limits for the shoring system. Additional area and depth would need to be incorporated into the design to account for the potential for contamination extending beyond anticipated limits. Furthermore, vertical shoring technologies require highly specialized construction equipment, and the shoring system would need to be installed outside the known footprint of contaminated soil. This increased complexity and conservatism could lead to substantial cost increases over conventional open-pit excavation.

Based on the limited depth of excavation required to meet PRGs, and the technical complexity and cost of vertical shoring methods, this technology is not retained for further consideration.

Conventional Drilling

Drilling will be required to decommission the reverse wells in accordance with state requirements. Drilling is retained for further consideration.

7.3.2.6 Ex Situ Treatment

Characterization data presented in Chapter 4 suggest that no treatment will be necessary to meet disposal facility waste acceptance criteria. However, ex situ treatment technologies have been considered in this section for their ability to minimize the volume or mobility of material that may require disposal. These technologies (vitrification, soil washing, automated segregation based on radioactivity, and solidification/stabilization) are described in detail in the following subsections.

Thermal desorption and vapor extraction were retained in the Implementation Plan (DOE/RL-98-28). These technologies are applicable for the removal of VOCs from excavated soil. These technologies are not considered in this section because contaminants at the 200-MW-1 OU waste sites do not include VOCs.

Vitrification (Ex Situ)

Ex situ vitrification would provide only limited benefit in terms of reduction of mobility and volume because the primary contaminants at the 200-MW-1 waste sites are not highly mobile, and vitrification would not provide a significant reduction in volume of contaminated media. Because of the high cost and power requirements for this technology and limited benefit, it is not retained for further consideration.

Soil Washing

Soil washing is a media transfer technology where contaminants are transferred from the soil matrix to a wash water solution that is subsequently treated. Complex waste mixtures (for example, metals with organics) make formulating washing fluid difficult. No previous studies were identified that showed this process to be potentially effective with Pu-239/240 or Am-241, or with the very high concentrations of Cs-137 anticipated at 200-MW-1 waste sites. Soil washing is not retained for further consideration.

Automated Segregation Based on Radioactivity

A segmented gate system has been demonstrated by Eberline Corporation. Radionuclides measured by the system include cesium-137, cobalt-60, radium-226, thorium-232, uranium-238, and americium-241. The effectiveness, implementability, and cost for this technology have been demonstrated and are well defined. However, because of the contaminant distribution found at the 200-MW-1 OU waste sites, where the majority of contaminant mass is located directly beneath the bottom of the crib structures in a thin layer, an automated segregation system is not warranted and is not retained for further consideration.

Solidification/Stabilization

Because of the relatively limited mobility of the contaminants found at the 200-MW-1 waste sites, the need for solidification/stabilization to reduce mobility in not warranted. Furthermore, solidification/ stabilization increases the mass and volume of contaminated media; therefore, solidification/stabilization is not retained for further consideration.

7.3.2.7 In Situ Treatment

Soil Mixing

This technology is potentially applicable at the 216-A-4 Crib where the highest observed contaminant concentrations are relatively shallow. Although this technology is implementable, the primary contaminants at the 200-MW-1 waste sites are not highly mobile. The added cost for limited reduction in mobility indicates that this technology is not well suited to the 200-MW-1 waste sites. Soil mixing is not retained for further evaluation.

In Situ Vitrification

ISV has been effectively implemented to only approximately 9 m bgs (30 ft bgs) (Thompson, 2002, *Mixed Waste Treatment Cost Analyses for a Range of Geomelt Vitrification Process Configurations*). It is theoretically possible to melt contamination to depths up to 18 m (60 ft) by performing the melt in two lifts. Electrodes would be set, and the contamination would be melted from 9 to 12.2 m (30 to 40 ft) bgs. The electrodes would then be raised, and the 0 to 9 m (0 to 30 ft) bgs zone would be melted. This has not been done in practice. The melt zones are limited to approximately 7.6 m (25 ft) square (58 m^2 [625 ft^2]).

Although the relative cost of ISV may be more appropriate for addressing the highest concentrations of contaminants located near the base of the cribs, these layers are relatively thin and only represent a small percentage of the overall volume of contaminated soils. Although ISV could potentially be implemented near the base of the cribs, the objective to treat soils at lower concentrations to meet PRGs for groundwater protection, industrial direct-contact exposure, and unrestricted exposure scenarios would be prohibitively expensive. In addition, because ISV may not be implementable to the full depth of contamination, other remedial technologies (for example, ET barrier) would be required to meet groundwater protection or risk-based PRGs. Furthermore, ISV does not destroy radionuclides or reduce activity and, therefore, does not necessarily limit exposure to the gamma-emitting radionuclides (for example, Cs-137). ISV of shallow-zone contamination would still require ICs to limit the potential for direct-contact exposure to the monolith, and ISV at deeper depths could still pose a risk to inadvertent exposure (for example, drilling through the monolith) at deeper depths. ISV primarily provides benefit for immobilization of contaminants that may affect groundwater, through binding up contaminants such as plutonium where inhalation poses a risk. As noted, at 200-MW-1 the potential for further migration of contaminants to groundwater could be mitigated more cost effectively with an ET barrier.

ISV is not retained for further consideration because of its unproven ability to reach the required depths and because of the high implementation cost. Although the contamination at the 200-E-102 Trench is believed to be confined to the original 1.2-m (4-ft) depth of the trench, and ISV is therefore technically feasible, removing the waste and disposing of it at ERDF is a more practical and far less expensive alternative.

Monitored Natural Attenuation

MNA is effective, readily implementable, and cost effective, and is retained for all waste sites and all contaminants that are amenable to MNA processes in reasonable timeframes.

8 Development and Screening of Alternatives

This chapter discusses the development of remedial alternatives for the 200-MW-1 OU waste sites. Primary inputs for this process were 1) site characterization information (Chapter 4), 2) the identified risks and RAOs (Chapters 6 and 7), and 3) the remedial technology screening results (Chapter 7).

8.1 Development of Alternatives

The development of remedial action alternatives takes the remedial technologies retained in Chapter 7 and assembles them into remedial alternatives that address the RAOs. The remedial alternatives developed provide a range of alternatives to give decision makers flexibility in selecting a preferred remedy.

40 CFR 300.430 provides guidance on remedy selection during the RI/FS process. 40 CFR.430(a) states, "The purpose of the remedy selection process is to implement remedies that eliminate, reduce, or control risks to human health and the environment."

40 CFR 300.430(a)(1)(iii) sets the following expectations for alternative development:

- *EPA generally shall consider the following expectations in developing appropriate remedial alternatives:*
  - (A) EPA expects to use treatment to address the principal threats posed by a site, wherever practicable. Principal threats for which treatment is most likely to be appropriate include liquids, areas contaminated with high concentrations of toxic compounds, and highly mobile materials.
  - (B) EPA expects to use engineering controls, such as containment, for waste that poses a relatively low long-term threat or where treatment is impracticable.
  - (C) EPA expects to use a combination of methods, as appropriate, to achieve protection of human health and the environment. In appropriate site situations, treatment of the principal threats posed by a site, with priority placed on treating waste that is liquid, highly toxic or highly mobile, will be combined with engineering controls (such as containment) and institutional controls, as appropriate, for treatment residuals and untreated waste.
  - (D) EPA expects to use institutional controls such as water use and deed restrictions to supplement engineering controls as appropriate for short- and long-term management to prevent or limit exposure to hazardous substances, pollutants, or contaminants. Institutional controls may be used during the conduct of the remedial investigation/feasibility study (RI/FS) and implementation of the remedial action and, where necessary, as a component of the completed remedy. The use of institutional controls shall not substitute for active response measures (e.g., treatment and/or containment of source material, restoration of ground waters to their beneficial uses) as the sole remedy unless such active measures are determined not to be practicable, based on the balancing of trade-offs among alternatives that is conducted during the selection of remedy.
  - (E) EPA expects to consider using innovative technology when such technology offers the potential for comparable or superior treatment performance or implementability, fewer or lesser adverse impacts than other available approaches, or lower costs for similar levels of performance than demonstrated technologies.
  - (F) EPA expects to return usable ground waters to their beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site. When

restoration of ground water to beneficial uses is not practicable, EPA expects to prevent further migration of the plume, prevent exposure to the contaminated ground water, and evaluate further risk reduction.

- Considering the goals and expectations for development and selection of remedial alternatives, the remedial technologies retained in Chapter 7 must be adapted to the specific site conditions at the waste sites these alternatives will be applied to. This section provides a discussion of individual remedial action components adapted from the remedial technologies retained in Chapter 7.

8.1.1 Remedial Action Components

The remedial action technologies retained in Chapter 7 provide the building blocks used to assemble comprehensive remedial alternatives. In addition to the remedial technologies retained, additional activities that are integral parts of comprehensive remedial actions (for example, O&M, verification sampling) are also included as components of the remedial action alternatives. The following subsections provide discussion of each of the remedial action components used to develop remedial alternatives later in this chapter.

8.1.1.1 No Action

40 CFR 300.430(e)(6) requires that a no action alternative be evaluated as a baseline for comparison with other remedial alternatives. The No Action Alternative represents a situation where no legal restrictions, access controls, or active remedial measures are applied to the site. No action implies that the wastes are allowed to remain in their current configuration, affected only by natural processes. No maintenance or other activities would be instituted or continued. Selecting the No Action Alternative would require that a waste site pose no unacceptable risk to HHE.

Although a "true" no action alternative would not consider any legal restrictions or access controls, the 200-MW-1 OU waste sites currently fall under site-wide ICs, which are expected to remain in place for the foreseeable future.

8.1.1.2 Institutional Controls

Based on the expectations set forth in 40 CFR 300.430(a)(1)(iii)(D), ICs are a common component of every alternative with the exception of alternatives that are fully protective of human and ecological receptors to the extent that the site can be released for unrestricted future use. ICs may be implemented on a temporary basis during remedy implementation or until the remedy achieves PRGs, or as a permanent component of the remedy specific to each waste site. These waste site-specific ICs are recorded in CERCLA decision documents that are part of the Administrative Record.

ICs generally include non-engineered restrictions on activities and access to land, groundwater, surface water, waste sites, waste disposal areas, and other areas or media that contain hazardous substances to minimize the potential for human exposure to those substances. Common types of ICs include procedural restrictions for access, fencing, warning notices, permits, easements, deed notifications, leases and contracts, and land-use controls. Site-wide ICs are outlined in DOE/RL-2001-41, which divides ICs at the Hanford Site into the following categories:

- Warning Notices
- Entry Restrictions
- Land-Use Management
- Groundwater-Use Management

- Waste Site Information Management

The DOE anticipates that the Hanford Site will remain in federal ownership for the foreseeable future (DOE/RL-2001-41).

8.1.1.3 Confirmatory Sampling

Confirmatory sampling is included as a remedial action component for waste sites where the nature and extent of contamination within the vadose zone is not fully defined. It is necessary to define the horizontal and vertical limits of contamination exceeding PRGs to reliably design and implement a remedial alternative that ensures PRGs are achieved. Additional sampling within the vadose zone will validate the conceptual contaminant distribution models presented in Chapter 4. Confirmatory sampling also establishes a baseline to assess progress in achieving RAOs and PRGs.

A site-specific data quality objective (DQO) and sampling and analysis plan (SAP) will identify any data gaps required for the design of the selected remedial alternative. Confirmatory sampling may include additional vadose zone boreholes, collection of analytical samples for laboratory analysis, and geophysical logging of vadose zone boreholes.

8.1.1.4 Monitored Natural Attenuation

The primary component of natural attenuation at the 200-MW-1 OU waste sites is radiological decay, which is a well-understood process. Radiological decay of contaminants will help achieve PRGs, particularly for short-lived radionuclides such as Cs-137 and Sr-90, which are prevalent at the 200-MW-1 OU waste sites.

The purpose of the monitoring component is to ensure that the distribution of contaminants within the vadose zone has reached a steady state and that further migration of contaminants is not occurring. A site-specific DQO and SAP will identify any data gaps required for design of the vadose zone monitoring network for each site. Existing boreholes will be used to the extent practical in addition to new vadose zone boreholes installed to perform geophysical logging. MNA will use both existing characterization data and confirmatory sampling data to establish a baseline for long-term monitoring of contaminant distribution.

Groundwater monitoring may also be used to assess whether any further migration of contaminants to groundwater has occurred; however, groundwater in the PUREX area is already being monitored under the 200-PO-1 OU groundwater monitoring program. Furthermore, based on the RESRAD and STOMP modeling presented in Chapter 5, the potential for adverse impact to groundwater from the 200-MW-1 waste sites is low.

MNA will be included as a component of remedies where contamination left in place will require a long duration to achieve PRGs.

8.1.1.5 Well Decommissioning

The State of Washington's decommissioning process for resource protection wells (WAC 173-160-460, "What Is the Decommissioning Process for Resource Protection Wells?") is identified as an ARAR. This requirement applies to both of the reverse wells in the 200-MW-1 OU; therefore, well decommissioning is a necessary component of each remedial alternative to meet compliance with ARARs.

Decommissioning of the wells will prevent potential migration of water from the surface and migration of contaminants within the vadose zone. Well decommissioning may include perforating and pressure grouting of the casing, or removal of the casing and grouting of the borehole.

8.1.1.6 Engineering Controls

Engineering controls are physical measures used to prevent access and exposure to hazardous waste or hazardous constituents. Engineering controls may include signs, entry controls (for example, fencing), and artificial or natural barriers. Engineering controls require monitoring and maintenance for the duration of unacceptable risk, for alternatives where contamination is left in place above PRGs.

Fencing is currently in place to restrict access to the 200-MW-1 waste sites; however, the existing fencing would require regular maintenance and/or replacement for the duration of alternatives where engineering controls are a long-term component of the remedy.

Each of the four 200-MW-1 cribs and the 200-E-102 Trench are currently covered by an existing gravel soil cover. This cover provides a physical separation between shallow zone soil contamination and potential human and ecological receptors. Maintenance of this soil cover is required to ensure long-term protectiveness where shallow zone soil contamination exists at levels above PRGs. Maintenance of the existing soil cover includes routine monitoring for surface radiological contamination, visual inspection of the cover to detect erosion or disturbance, and implementation of pest and vegetation control programs.

8.1.1.7 Evapotranspiration Barrier

Evapotranspiration (ET) barriers are the preferred containment general response action applicable to 200-MW-1 waste sites that pose a risk to groundwater. The primary function of an ET barrier is to limit infiltration of precipitation and runoff through soil contamination in the vadose zone. ET barriers are applicable where current or future adverse impacts to groundwater are present. In addition to their hydrological performance, an ET barrier may be designed to limit wind and water erosion and prevent biointrusion. Furthermore, an ET barrier would shield radiation to prevent exposure of human and ecological receptors to shallow soil contamination. ICs would be required to prevent disturbance of the area covered by the ET barrier and to prevent activities that might alter the effectiveness of the barrier.

The design of the ET barrier will include determination of appropriate site preparation activities, layer thickness, soil materials, borrow source locations, drainage slopes, side slopes, and vegetative cover appropriate for each waste site. ET barriers need to extend beyond the limits of soil contamination in order to prevent any lateral migration of precipitation from adjacent areas. Remedial alternatives for the 200-MW-1 cribs assume an overlap of 6 m (20 ft) in each direction. Figure 7-1 and Figure 7-2 in Chapter 7 provide conceptual cross-sections for the monofill ET barrier.

8.1.1.8 Operations and Maintenance

O&M activities are required where alternatives include infrastructure (fencing, soil cover, ET barrier) to achieve protectiveness. These activities include both inspection and maintenance components. O&M is included in alternatives that employ engineering controls or ET barriers.

Post-remediation requirements for the surveillance, inspection, maintenance and monitoring of ET barriers will be established using the DQO process and will be defined in an O&M plan. The O&M plan will, as needed, detail performance monitoring needs, post-closure monitoring requirements, monitoring methods, analytes and intervals, maintenance activities and frequencies, and associated procedures.

8.1.1.9 Removal, Treatment, and Disposal

Removal, treatment, and disposal (RTD) consists of excavating the waste site structures and vadose zone soils (where contaminant concentrations are above PRGs) and disposal of excavated material at an approved disposal facility prior to backfilling the excavation to the original ground surface and restoring the site.

Requirements for safety, monitoring, and sampling generally are well understood at the Hanford Site, where numerous RTD actions have been implemented in radiological and hazardous environments. Special precautions would be used to minimize the generation of onsite fugitive dust during excavation.

Excavation activities would start with removal of any clean soil cover and uncontaminated soils, which will be set aside for use as backfill. Excavation would proceed through the waste site structure and contaminated soils until the PRGs are achieved. Removal technologies generally do not require that the precise extent of contamination be known before excavation. Rather, the extent of contamination is assessed using an observational approach (DOE/RL-98-28, pg 2-28) as the excavation proceeds, and the extent of remediation is adjusted accordingly. If contamination above the PRGs is encountered beyond the planned limits of excavation, the extent of removal could be increased. A decision to excavate to a greater depth to protect groundwater would depend on numerous factors, including:

- Amount of risk reduction achieved
- Cost of further remediation
- Volume of soil generated
- Availability of disposal facility capacity
- Impacts on cultural and ecological resources
- Logistics and interference with other onsite activities/structures
- Worker safety issues
- Implementability of the excavation for the deeper contamination

Remedial alternatives developed for the 200-E-102 Trench site, with a proposed excavation depth ranging from 1.5 m (5 ft) bgs, assumes an open pit excavation methodology with conventional excavation equipment. Excavation to this site can be accomplished with conventional excavation equipment and techniques without encroaching upon other site infrastructure or adjacent waste sites.

Soils and debris removed from the excavation will be disposed of at an approved disposal facility. The disposal facility used depends on the level of contamination encountered. The majority of soil and demolition debris (for example, distribution piping and vent risers) will be disposed of at the ERDF, provided soil concentrations are below the ERDF acceptance criteria outlined in WCH-191, *Environmental Restoration Disposal Facility Waste Acceptance Criteria.*

Based on existing information, soil and/or debris removed from the waste sites are not anticipated to require ex situ treatment to meet disposal requirements at the ERDF, or to reduce waste volumes. Contaminated soil will be containerized on site (for example, containers, "burrito wraps," bulk shipment) and transported to the ERDF, located in the 200 West Area. Low-level radioactive waste and/or hazardous waste are acceptable for disposal at the ERDF, in accordance with the waste acceptance criteria.

After the clean cover and contaminated soil are removed and the PRGs are met, the excavation will be backfilled. The backfill material could be found at a variety of sources, including local borrow pits and the excavated material that is determined to be clean (verified as clean by meeting the PRGs). Following remediation, the site will be recontoured, resurfaced, and/or revegetated to establish natural site conditions.

One RTD scenario has been developed to address individual RAOs and provide a range of alternatives for this general response action.

This scenario assumes RTD of shallow zone soils within the 3 m (10 ft) point of compliance for ecological receptors. Within this point of compliance is the human receptor direct contact exposure depth of 1 m (3 ft). Therefore, this scenario addresses direct contact exposure to contaminated soil and is designed to be protective of human receptors (RAO No. 1) and ecological receptors (RAO No. 2). This scenario leaves the majority of contaminant mass in place because RESRAD modeling shows the contaminants do not present a risk to groundwater protection (RAO No. 3).

Verification Sampling

Verification sampling will be used to determine whether PRGs are met. A site-specific DQO and SAP will identify the quantity and quality of data required to ensure that the remedy has achieved PRGs.

Excavation will be guided by the observational approach presented in DOE/RL-98-28, pg 2-28. The observational approach is a method of planning, designing, and implementing a remedial action that relies on information (for example, verification samples) collected during remediation to guide the direction and scope of the effort. Data collected are used to assess the extent of contamination and to make "real time" decisions in the field. Targeted removals could be considered under this alternative if contamination is localized in only a portion of a waste site. Verification sampling is a key element for assessing progress during remedy implementation using the observational approach, and for quantifying whether PRGs have been met.

8.1.2 Assembly of Remedial Action Alternatives

The remedial action components discussed in Section 8.1.1 are assembled into remedial alternatives with the goal of developing a wide and increasingly comprehensive range of alternatives. The following alternatives were identified:

- No Action Alternative
- Alternative 1 – Institutional Controls and Monitored Natural Attenuation
- Alternative 2 – Evapotranspiration Barrier
- Alternative 3 – Removal, Treatment, and Disposal

The following subsections below discuss each of these alternatives.

8.1.2.1 Alternative 1 – Institutional Controls and Monitored Natural Attenuation

40 CFR 300.430(e)(3)(ii) provides for:

> *"One or more alternatives that involve little or no treatment, but provide protection of human health and the environment primarily by preventing or controlling exposure to hazardous substances, pollutants, or contaminants, through engineering controls, for example, containment, and, as necessary, institutional controls to protect human health and the environment and to assure continued effectiveness of the response action."*

Alternative 1 provides a limited response action that consists of implementing ICs and engineering controls that prevent or control exposure to soil contamination at the 200-MW-1 waste sites while allowing radiological contaminants to naturally attenuate to protective levels through radiological decay. This alternative includes the following remedial components:

- Implementation of sitewide and waste site-specific ICs and engineering controls (for example, access restrictions and land-use controls)

- Additional confirmatory sampling to validate the current understanding of the nature and extent of contamination
- Maintenance of existing gravel soil cover over the top of the waste sites (where applicable)
- Decommissioning of reverse wells (where applicable)
- Reduction in contaminant concentrations and volume through radiological decay
- Vadose zone monitoring to confirm that contaminant distribution has not changed

8.1.2.2 Alternative 2 – Evapotranspiration Barrier

Alternative 2 provides a more comprehensive alternative for the containment general response action. If confirmatory sampling shows that deeper contaminated soils greater than 3 m (10 ft) may potentially impact groundwater, then this alternative consists of constructing an ET barrier over contaminated soils. The general components of this alternative include:

- Implementation of sitewide and waste site-specific ICs (for example, access restrictions and land-use controls)
- Additional confirmatory sampling to validate the current understanding of the nature and extent of contamination
- Installation of an ET barrier over the full extent of soils that remain in place at contaminant concentrations that pose a potential to impact groundwater. The ET barrier will also serve to limit human and ecological direct contact exposure to shallow zone soils where contaminant concentrations exceed PRGs
- Reduction in residual contaminant concentrations and volume through radiological decay
- O&M and barrier performance monitoring
- Vadose zone monitoring to confirm that contaminant distribution has not changed

8.1.2.3 Alternative 3 – Removal, Treatment, and Disposal

Alternative 3 consists of excavating shallow zone soils at concentrations above industrial PRGs within the 3 m (10 ft) point of compliance. Alternative 3 provides a comprehensive removal action that addresses the potential for direct contact exposure to contaminants in shallow soil as deep as 3 m (10 ft) will be removed, depending on the specific waste unit, at concentrations above PRGs.

The general components of this alternative include:

- Additional confirmatory sampling to validate the current understanding of the nature and extent of contamination
- Excavation of shallow zone soils at concentrations above industrial PRGs to a maximum depth of 3 m (10 ft)
- Disposal of excavated soils at ERDF
- Backfill of the excavation, with native and imported fill, and site restoration

Because the contaminant concentrations will be removed above PRGs, no ICs will be required for this alternative.

8.1.3 Application of Alternatives to the 200-MW-1 OU Waste Sites

This section provides a summary of the application of general remedial alternatives assembled in Section 8.1.2 to the specific 200-MW-1 OU waste sites. Although a wide range of alternatives is desired, each alternative assembled cannot be applied to all 200-MW-1 OU waste sites because of differences in waste site construction and contaminant distribution. For example, Alternative 3 (RTD) is not an appropriate remedy for reverse wells, where waste was discharged far below the point of compliance for human receptors. Table 8-1 provides an overview of the alternatives applied to each waste site.

For clarity, the application of remedial alternatives to the waste sites is discussed in the following three groups based on similar waste site types and contaminant distribution:

1. **Cribs:** The four cribs in the 200-MW-1 OU share relative similarities in construction and discharge depth, and are located in proximity to one another. As noted in Chapter 4, the 216-A-2 Crib received a different waste stream than the other three cribs in the 200-MW-1 OU. The other three cribs (216-A-4, 216-A-21, and 216-A-27) are believed to be more similar in regard to the wastes received. The distribution of contaminants beneath and around each of the four cribs share similarities; however, the 216-A-2 Crib differs in that no shallow zone soil contamination has been identified. Although there are differences between these cribs, they share many similarities and are decidedly different than the remaining waste sites in this OU, and are discussed as a group.

2. **Trench:** The 200-E-102 Trench is a unique waste site within the 200-MW-1 OU based on the waste received and the distribution of contaminants beneath and around the trench. The trench received contaminated soil and perhaps contaminated asphalt and, as such, is the only waste site in the 200-MW-1 OU that did not receive a liquid waste stream. It is also the only waste site in the OU that had no driving force (water or other liquid in large quantities) that could move and distribute the contaminants outside the waste site.

3. **Reverse Wells:** The 216-B-4 and 216-C-2 Reverse Wells received wastes that were similar to that received by three of the cribs (216-A-4, 216-A-21, and 216-A-27). Based on process knowledge, the wastes received by the reverse wells were most likely aqueous, low-salt, and neutral to basic, as was the waste received by the 216-A-4, 216-A-21, and 216-A-27 Cribs (RHO-CD-673). It is also likely that the wastes received by the reverse wells were more concentrated than the wastes sent to the cribs. Reverse wells were typically constructed for lower volume waste streams that were often more concentrated than waste streams for which cribs were appropriate (DOE/RL-96-81).

The reverse wells are different from the cribs in their geometry and operating parameters (see Table 1-1). The reverse wells have a much smaller footprint than the cribs. The reverse wells also released their wastes deeper in the vadose zone than any of the cribs.

Section 8.1.4 through Section 8.1.6 provide discussion of the rationale used in assembling alternatives for each waste site group, and specific components of each alternative applied for the waste groups. The No Action Alternative applies to all 200-MW-1 waste sites and will not be discussed further in these sections.

8.1.4 Application of Remedial Alternative for 200-MW-1 OU Cribs

All of the general remedial alternatives developed in Section 8.1.2 are applicable to the 200-MW-1 OU cribs to varying degrees. Table 8-2 provides rationale for inclusion of each general component of the remedy applied to the crib grouping, and Table 8-3 provides a detailed summary of each alternative component included in the alternatives. The following sections discuss the application of the general remedial alternatives to each of the 200-MW-1 OU cribs.

Table 8-1. Application of Remedial Alternatives to 200-MW-1 Waste Sites

Alternative No.	Alternative Description	Waste Site: Cribs 216-A-2	Cribs 216-A-4	Cribs 216-A-21	Cribs 216-A-27	Trench 200-E-102	Reverse Wells 216-B-4	Reverse Wells 216-C-2
No Action Alternative	No Action	X	X	X	X	X	X	X
Alternative 1	ICs and MNA	X	X	X	X	X	X	X
Alternative 2	ET Barrier	NA	X	X*	X*	X*	NA	NA
Alternative 3	RTD	NA	X	X*	X*	X	NA	NA

* Subject to confirmatory sampling.
NA = not applicable
IC = institutional control
MNA = monitored natural attenuation
ET = evapotranspiration
RTD = removal, treatment, and disposal

Table 8-2. Crib Alternative Development Rationale

Alternative No.	Alternative Description	Alternative Component	RAO No. 1 Protect Human Receptors	RAO No. 2 Protect Ecological Receptors	RAO No. 3 Protect Groundwater	Other Objective	Rationale for Inclusion in Remedial Alternatives
No Action Alternative	No Action	No Action				X	Required by 40 CFR 300.430(e)(6), "National Oil and Hazardous Substances Pollution Contingency Plan," "Remedial Investigation/Feasibility Study and Selection of Remedy," "Feasibility Study."
Alternative 1	Institutional Controls and Monitored Natural Attenuation	Institutional Controls	X	X			The purpose of implementing ICs is to limit direct contact with site contaminants by human receptors (RAO 1) and maintain existing programs that prevent establishment of terrestrial receptors (RAO 2). The development and selection of an ICs-based alternative as the sole remedy is allowable under 40 CFR 300.430(a)(1)(iii)(D), "General," "Introduction," "Expectations," when active measures are determined to not be practicable based on the balancing of trade-offs among all alternatives.
		Confirmatory Sampling				X	The purpose of confirmatory sampling is to validate the current understanding of the contaminant nature and extent presented in the conceptual contaminant distribution models (see Chapter 4) to support remedy implementation and to establish a baseline for measuring progress in achieving RAOs. Confirmatory sampling does not address specific RAOs.
		Engineering Controls (Maintain Existing Soil Cover)	X	X			The purpose of maintaining the existing soil cover is to provide physical separation between contamination and human and ecological receptors (RAOs 1 and 2).
		Monitored Natural Attenuation	X	X	X	X	Natural attenuation through radiological decay is a well understood natural process. The purpose of the monitoring component is to verify that the current distribution of contaminants in the soils beneath and around each waste site (as documented by existing characterization data and confirmatory sampling included in the remedy) is not changing (i.e., no further migration of contaminants). Natural attenuation would address RAOs 1, 2, and 3 through a reduction in radionuclide contaminate concentrations over time.

Table 8-2. Crib Alternative Development Rationale

Alternative No.	Alternative Description	Alternative Component	Remedial Action Objective Addressed: RAO No. 1 Protect Human Receptors	RAO No. 2 Protect Ecological Receptors	RAO No. 3 Protect Groundwater	Other Objective	Rationale for Inclusion in Remedial Alternatives
Alternative 2	ET Barrier	Institutional Controls	X	X			The purpose of implementing ICs is to limit direct contact with site contaminants by human receptors (RAO 1) and maintain existing programs that prevent establishment of terrestrial receptors (RAO 2).
		Confirmatory Sampling				X	The purpose of confirmatory sampling is to validate the current understanding of the contaminant nature and extent presented in the conceptual contaminant distribution models (see Chapter 4) to support remedy implementation and to establish a baseline for measuring progress in achieving RAOs. Confirmatory sampling does not address specific RAOs.
		ET Barrier	X	X	X		The purpose of an ET barrier is to limit infiltration of precipitation and runoff through underlying contaminated vadose zone soils, which could mobilize contaminants and further impact groundwater. The ET barrier component primarily addresses RAO 3, but it would provide a secondary benefit of limiting the potential for direct contact exposure to site contaminants within shallow zone soil by providing an additional measure of separation between contaminated soil and potential receptors (RAOs 1 and 2).
		Operation and Maintenance	X	X	X	X	Operation and maintenance activities are necessary components of remedial action alternatives that must be implemented to assure long-term protectiveness. Barrier performance monitoring is needed to demonstrate the long-term effectiveness of this alternative.
		Monitored Attenuation	X	X	X	X	Natural attenuation through radiological decay is a well understood natural process. The purpose of the monitoring component is to verify that the current distribution of contaminants in the soils beneath and around each waste site (as documented by existing characterization data and confirmatory sampling included in the remedy) is not changing (i.e., no further migration of contaminants). Natural attenuation would address RAOs 1, 2 and 3 through a reduction in radionuclide contaminate concentrations over time.
		Vadose Zone Monitoring	X	X	X	X	The purpose of vadose zone monitoring is to verify that the current distribution of contaminants in the soils beneath and around each waste site (as documented by existing characterization data and confirmatory sampling included in the remedy) is not changing (i.e., no further migration of contaminants) where contaminants are left in place above PRGs, and to confirm progress in achieving RAOs. Vadose zone monitoring is needed to demonstrate the long-term effectiveness of this alternative.
Alternative 3	RTD	Confirmatory Sampling				X	The purpose of confirmatory sampling is to validate the current understanding of the contaminant nature and extent presented in the conceptual contaminant distribution models (see Chapter 4) to support remedy implementation and to establish a baseline for measuring progress in achieving RAOs. Confirmatory sampling does not address specific RAOs.
		Removal, Treatment and Disposal (RTD)	X	X			The purpose of shallow zone RTD is to remove soil contamination above PRGs within the point of compliance. Removal of contaminated soils would be focused on RAOs 1 and 2.
		Verification Sampling				X	Verification sampling is not specific to individual RAOs, but is a necessary component of this remedial action alternative in order to verify that RAOs have been met.

COC = chemical of concern
RAO = remedial action objective
IC = institutional control
MNA = monitored natural attenuation
ET = evapotranspiration
RTD = removal, treatment, and disposal
PRG = preliminary remediation goal

Table 8-3. Crib Alternative Summary

Alternative No.	Alternative Description	Alternative Summary
No Action Alternative	No Action	No Action: Baseline alternative. (Note that site-wide ICs, surveillance of existing soil cover will continue, but no waste site specific actions or costs are associated with this alternative.)
Alternative 1	ICs and MNA	• ICs. • Implement site-wide ICs within the 200 Areas industrial exclusive land use area. • Implement site-specific ICs (land use management, entry restrictions, and waste site information management). • Confirmatory sampling. • Prepare DQO and SAP and supporting documentation (HSP, Hanford-specific documentation, etc.). • Install direct push vadose zone borings. The number and location of borings, depth of samples and analysis suite will be determined during site-specific DQO process. • Maintain existing soil cover. • Perform annual radiological surveys. • Implement vegetation and pest control program (e.g., spraying of herbicide). • Perform annual inspections to identify differential settlement and erosion. • Repair any settlement or erosion by adding additional gravel cover. • Re-grade and place 6 inches of new cover material once every 25 years. • MNA.
Alternative 2	ET Barrier	• ICs. • Implement site-wide ICs within the 200 Areas industrial exclusive land use area. • Implement site-specific ICs (land use management, entry restrictions, waste site information management). • Confirmatory sampling. • Prepare DQO and SAP and supporting documentation (HSP, Hanford-specific documentation, etc.). • Install direct push vadose zone borings. The number and location of borings, depth of samples, and analysis suite will be determined during site-specific DQO process. • ET barrier. • Prepare subgrade and place engineered fill as needed to provide a suitable subgrade for the ET barrier. • Install an ET barrier 6 m (20 ft) beyond the limits of contaminated soil plus side slopes. • The design of the ET barrier would be determined during remedial design. • Re-vegetate with native plants. • Operation and Maintenance. • ET barrier maintenance. • Perform visual inspections to determine any surface erosion or settlement. • Repair any damage due to erosion or settlement by adding additional soils and re-vegetation. • Performance monitoring. • Document barrier performance monitoring in annual reports and 5 year reviews.
Alternative 3	RTD	• Confirmatory sampling. • Prepare DQO and SAP and supporting documentation (HSP, Hanford-specific documentation, etc.). • Install direct push vadose zone borings. The number and location of borings, depth of samples, and analysis suite will be determined during site-specific DQO process. • RTD. • Excavate shallow zone soils from 0 to 3 m (0 to 10 ft). • Perform verification sampling.

Table 8-3. Crib Alternative Summary

Alternative No.	Alternative Description	Alternative Summary
		• Develop a site-specific DQO and SAP that identifies the quantity and quality of verification sampling required to demonstrate attainment of PRGs. • Collect verification samples at bottom of excavation to ensure that PRGs are met. • Transport of excavated soils to ERDF for disposal. • Backfill with imported fill to original grade. • Identify suitable borrow source for backfill materials. • Place clean soil removed from excavation as backfill. • Place and compact backfill materials in lift to minimize potential for differential settlement. • Perform visual inspections to determine any surface erosion or settlement. • Repair any damage due to erosion or settlement by adding additional soils and re-vegetation.

CDF = controlled density fill
DQO = data quality objective
ERDF = Environmental Restoration Disposal Facility
ET = evapotranspiration
HSP = Health and Safety Plan
RTD = removal, treatment, and disposal
SAP = sampling and analysis plan

8.1.4.1 Alternative 1 – Institutional Controls and Monitored Natural Attenuation

Alternative 1 is applicable to each of the four cribs, the trench, and the reverse wells in the 200-MW-1 OU. Each of the remedial alternative components outlined in Section 8.1.2 can be applied to the four cribs.

Site-wide ICs and engineering controls are applicable to all seven 200-MW-1 OU waste sites based on their location within the industrial exclusive land use area. Waste site-specific ICs will be added to the CERCLA decision documents under this alternative. In addition to these controls, each crib is currently covered by an existing soil cover that must be maintained to be protective of human and ecological receptors. While these controls are currently in place and will be supplemented, the full nature and extent of contamination (both horizontal and vertical extent) is not fully defined, and additional confirmatory sampling would be needed to support implementation of this alternative. Confirmatory sampling information can be used as a baseline for assessing the current distribution of radionuclides in soil associated with the waste site that are subject to natural attenuation through radiological decay. Periodic vadose zone monitoring will validate that no further migration or changes in subsurface contaminant distribution are occurring.

8.1.4.2 Alternative 2 – Evapotranspiration Barrier

Based on confirmation sampling, the ET barrier may be useful at the cribs. Each of the remedial alternative components described in Section 8.1.2.2 are readily implementable. The uncertainty in site characterization data indicate the cribs could have shallow soil contamination exceeding direct contact soil PRGs.

Site-wide ICs and engineering controls are applicable to the cribs based on its location within the industrial exclusive land use area. Waste site-specific ICs will be added to the CERCLA decision documents under this alternative. While these controls are currently in place and will be supplemented, the full nature and extent of contamination (both horizontal and vertical extent) is not fully defined, and additional confirmatory sampling would be needed to support implementation of this alternative. Confirmatory sampling information can be used as a baseline for assessing the current distribution of radionuclides in soil associated with the waste site and defining the barrier footprint for the cribs as necessary.

The ET barrier component of the alternative is applied based on the contaminant distribution at each waste site. If confirmatory sampling indicates a potential risk to groundwater has been identified, then the ET barrier component may be warranted at this waste site.

After construction of the ET barrier, periodic vadose zone monitoring will be used to validate that no further migration or changes in subsurface contaminant distribution are occurring while radionuclides naturally attenuate through radiological decay. Figure 8-1 shows a diagram of the ET Barrier alternative.

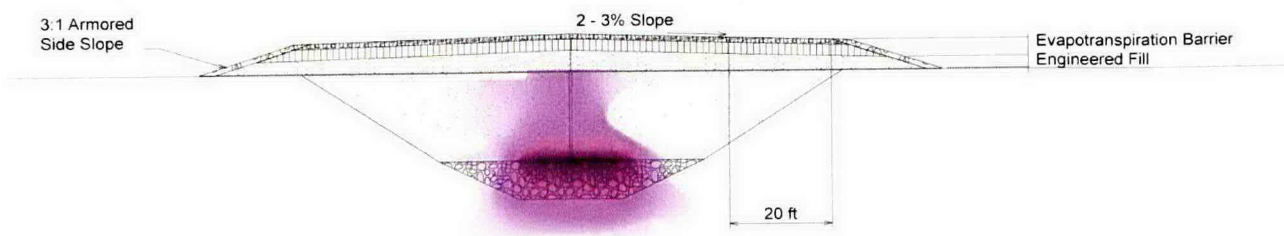

Figure 8-1. Alternative 2: ET Barrier

8.1.4.3 Alternative 3 – Removal, Treatment, and Disposal

Alternative 3 is applicable to the cribs. Uncertainty in the site characterization data indicates that there is a potential that shallow zone soil contamination exceeds PRGs. The 216-A-4, 216-A-21 and 216-A-27 Cribs differ in that no contamination exceeding PRGs has been identified within the human and ecological points of compliance. However, confirmatory sampling is planned to verify this conclusion.

Site-wide ICs and engineering controls are applicable to the cribs based on its location within the industrial exclusive land use area. Waste site-specific ICs will be added to the CERCLA decision documents under this alternative. In addition to these controls, the RTD component of this alternative addresses industrial direct contact and ecological exposure to shallow zone soil contamination. Residual contamination beneath the shallow zone is addressed through a combination of ICs and an ET barrier component, where the potential to impact groundwater has been identified. Additional confirmatory sampling is needed to validate the site conceptual model and support implementation of this alternative to determine the extent of excavation and surface barrier footprint. Figure 8-2 shows a diagram of the RTD alternative.

Periodic vadose zone monitoring will be used to validate that no further migration or changes in subsurface contaminant distribution are occurring while any radionuclide contamination left in place naturally attenuates to protective levels through radiological decay. Operation and maintenance of the ET barrier will also be required to maintain the effectiveness of the remedy and assess its performance until radiological decay reduces contaminant concentrations below PRGs.

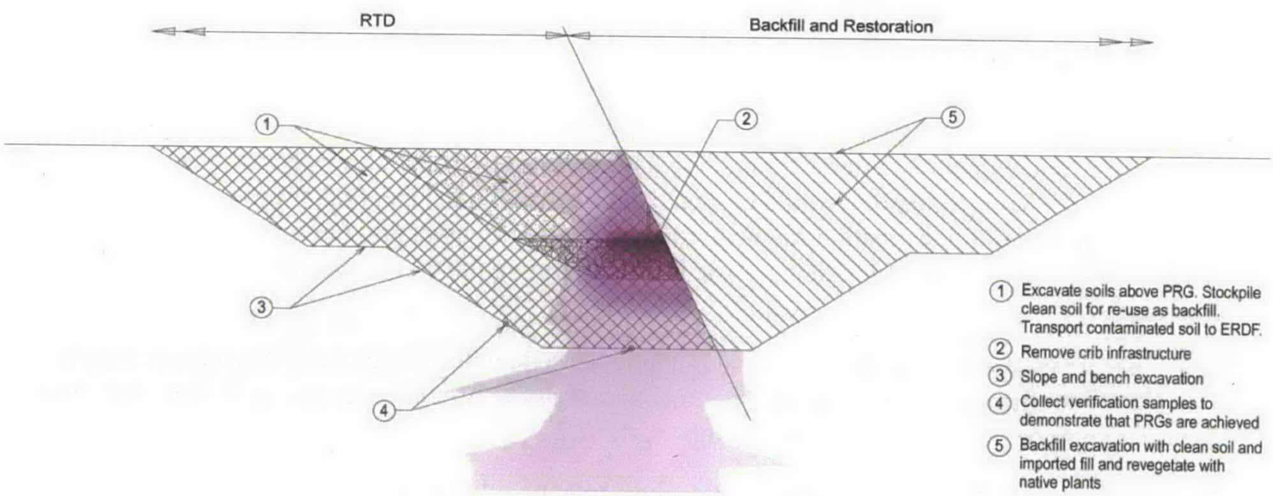

Figure 8-2. Alternative 3: Removal, Treatment, and Disposal

8.1.5 Application of Remedial Alternatives for the 200-E-102 Trench

Alternatives 1, 2, and 3, developed in Section 8.1.2, are applicable to the 200-E-102 Trench. Table 8-4 provides rationale for inclusion of each general component of the remedy applied to the 200-E-102 Trench grouping and Table 8-5 provides a detailed summary of each alternative component included in the alternatives. The following sections discuss the application of the alternatives to the trench.

8.1.5.1 Alternative 1 – Institutional Controls and Monitored Natural Attenuation

Alternative 1 is applicable to the 200-E-102 Trench and the components of this alternative, identified in Section 8.1.2.1, could be easily implemented. The 200-E-102 Trench is currently covered by an existing soil cover. ICs are necessary to restrict access and land use, and maintenance and inspection of the existing soil cover will be needed to maintain its effectiveness.

8.1.5.2 Alternative 2 – Evapotranspiration Barrier

Alternative 2 is not applicable to the 200-E-102 Trench. Due the depth of contamination a potential direct contact issue may exist. However, should verification sampling determine soil impacts, then soil removal would be utilized due to the shallow soil depths anticipated for the trench.

8.1.5.3 Alternative 3 – Removal, Treatment, and Disposal

Alternative 3 is applicable to the 200-E-102 Trench. Because of the shallow depth of contamination at this waste site, a direct contact risk may be present. However, verification sampling is required to determine the presence or absence of shallow soil impacts.

Each of the remedial action components described in Section 8.1.2.4 can be applied at the 200-E-102 Trench. Site-wide ICs and engineering controls are applicable to the 200-E-102 trench based on its location within the industrial exclusive land use area, and site-specific ICs would be included in this remedial alternative and documented as part of the CERCLA decision documents. Because the full nature and extent of contamination (both horizontal and vertical extent) is not fully defined, additional confirmatory sampling is needed to support implementation of this alternative.

Based on historical information regarding the depth of trench construction, the potential exists for contamination at concentrations that exceed industrial PRGs. While the proposed point of compliance of 1 m (3 ft) would achieve RAOs, the 1.2 m (4 ft) depth of trench construction and minimal vertical migration of contaminants anticipated at this site, the proposed depth of excavation for this alternative is 1.5 m (5 ft) bgs. Due to the v-shape of the trench, the additional excavation depth would result in little additional excavation and disposal volume, while most if not all of the contaminated soils could be removed. Excavation at the 200-E-102 Trench can be accomplished with open-pit excavation and standard excavation equipment. Imported fill would be used to restore the site to the original grade.

8.1.6 Application of Remedial Alternative for 200-MW-1 Reverse Wells

Alternative 1 and 3 developed in Section 8.1.2 is applicable to the 200-MW-1 OU reverse wells. Table 8-6 provides rationale for inclusion of each general component of the remedy applied to the reverse well grouping, and Table 8-7 provides a detailed summary of each alternative component applied to the two reverse wells. The following sections discuss the application of the alternatives to the reverse wells.

8.1.6.1 Alternative 1 – Institutional Controls and Monitored Natural Attenuation

Alternative 1 is applicable to both the 216-B-4 and 216-C-2 Reverse Wells, and the applicable remedial alternative components outlined in Section 8.1.1 can be readily and cost effectively implemented. Shallow zone soil contamination within the point of compliance for human receptors and ecological receptors (less than 3 m [10 ft] bgs) is not anticipated at these reverse wells because of the depth of the screened interval where waste was discharged.

Site-wide ICs and engineering controls are applicable based on the reverse wells' location within the industrial exclusive land use area. Waste site-specific ICs will be added to the CERCLA decision documents under this alternative. While these controls are currently in place and will be supplemented, the full nature and extent of contamination (both horizontal and vertical extent) is not fully defined, and additional confirmatory sampling would be needed to support implementation of this alternative. Confirmatory sampling information can be used as a baseline for assessing the current distribution of radionuclides in soil associated with the waste site that are subject to natural attenuation through radiological decay. Periodic vadose zone monitoring will validate that no further migration or changes in subsurface contaminant distribution are occurring. Finally, both reverse wells would be decommissioned in accordance with WAC 173-160-460 under this alternative to meet ARARs.

8.1.6.2 Alternative 2 – ET Barrier

Alternative 2 is not applicable to the reverse wells. An ET barrier is not warranted because no potential to impact groundwater has been identified.

8.1.6.3 Alternative 3 – Removal, Treatment, and Disposal

Alternative 3 is applicable to the reverse wells. Shallow zone soil excavation is not needed because of the depth at which contaminants were discharged at both reverse wells. However, if verification sampling indicates a potential risk to groundwater, then Alternative 3 would be applicable to the reverse wells.

8.2 Screening of Alternatives

Section 8.1 of this chapter uses the retained technologies and process options from Chapter 7 and assembles them into comprehensive remedial alternatives that are then applied to individual 200-MW-1 OU waste sites. This section provides a preliminary screening step based on effectiveness, implementability, and cost prior to performing a detailed and comparative analysis.

8.2.1 Effectiveness

Each of the alternatives was developed to be effective based on a combination of applicable technologies in combination with ICs and engineering controls. The overall effectiveness of the four alternatives in achieving RAOs is summarized as follows:

- Alternative 1 is effective in achieving RAOs 1 and 2 because ICs and engineering controls will limit the potential for human and ecological direct contact while site contaminants decay to protective levels.
- Alternative 2 addresses each of the three 200-MW-1 RAOs. The ET barrier provides additional separation between human and ecological receptors and contaminated soils, thus limiting the potential for direct contact exposure (RAOs 1 and 2). The ET barrier also addresses the potential impact to groundwater (RAO 3) at the cribs.
- Alternative 3 is effective in achieving RAOs 1 and 2 because excavating shallow soil will mitigate the potential for human and ecological direct contact. Excavation of contaminated soils above PRGs within the point of compliance eliminates the exposure pathway to human and ecological receptors thus limiting the potential for direct contact exposure (RAOs 1 and 2).

1

Table 8-4. Trench Alternative Development Rationale

Alternative No.	Alternative Description	Alternative Component	Remedial Action Objective Addressed: RAO No. 1 Protect Human Receptors	RAO No. 2 Protect Ecological Receptors	RAO No. 3 Protect Groundwater	Other Objective	Rationale for Inclusion in Remedial Alternatives
No Action Alternative	No Action	No Action				X	Required by 40 CFR 300.430(e)(6), "National Oil and Hazardous Substances Pollution Contingency Plan," "Remedial Investigation/Feasibility Study and Selection of Remedy," "Feasibility Study."
Alternative 1	ICs and MNA	ICs	X	X			The purpose of implementing ICs is to limit direct contact with site contaminants by human receptors (RAO 1) and maintain existing programs that prevent establishment of terrestrial receptors (RAO 2). The development and selection of an ICs-based alternative as the sole remedy is allowable under 40 CFR 300.430(a)1)(iii)(D), "General," "Introduction," "Expectations," when active measures are determined to not be practicable based on the balancing of trade-offs among all alternatives.
		Confirmatory Sampling				X	The purpose of confirmatory sampling is to validate the current understanding of the contaminant nature and extent presented in the conceptual contaminant distribution models (see Chapter 4) to support remedy implementation and to establish a baseline for measuring progress in achieving RAOs. Confirmatory sampling does not address specific RAOs.
		Engineering Controls (Maintain Existing Soil Cover)	X	X			The purpose of maintaining the existing soil cover is to provide physical separation between contamination and human and ecological receptors (RAOs 1 and 2).
		MNA	X	X		X	Natural attenuation through radiological decay is a well understood natural process. The purpose of the monitoring component is to verify that the current distribution of contaminants in the soils beneath and around each waste site (as documented by existing characterization data and confirmatory sampling included in the remedy) is not changing (i.e., no further migration of contaminants). Natural attenuation would address RAOs 1 and 2 through a reduction in radionuclide contaminate concentrations over time.
Alternative 3	RTD	Confirmatory Sampling				X	The purpose of confirmatory sampling is to validate the current understanding of the contaminant nature and extent presented in the conceptual contaminant distribution models (see Chapter 4) to support remedy implementation and to establish a baseline for measuring progress in achieving RAOs. Confirmatory sampling does not address specific RAOs.
		Removal, Treatment and Disposal (RTD)	X	X			The purpose of shallow zone RTD is to remove soil contamination above PRGs within the point of compliance. Removal of contaminated soils would be focused on RAOs 1 and 2.
		Verification Sampling				X	Verification sampling is not specific to individual RAOs, but is a necessary component of this remedial action alternative in order to verify that RAOs have been met.

COC = chemical of concern
RAO = remedial action objective
IC = institutional control
MNA = monitored natural attenuation
ET = evapotranspiration
RTD = removal, treatment, and disposal
PRG = preliminary remediation goal

2

Table 8-5. Trench Alternative Summary

Alternative #	Alternative Description	Alternative Summary
No Action Alternative	No Action	No Action: Baseline alternative. (Note that site-wide ICs, surveillance of existing soil cover will continue, but no waste site specific actions or costs are associated with this alternative.)
Alternative 1	ICs and MNA	• ICs. • Implement site-wide ICs within the 200 Areas industrial exclusive land use area. • Implement site-specific ICs (land use management, entry restrictions, waste site information management). • Confirmatory sampling. • Prepare DQO and SAP and supporting documentation (HSP, Hanford-specific documentation, etc.). • Install direct push vadose zone borings. The number and location of borings, depth of samples, and analysis suite will be determined during site-specific DQO process. • Maintain existing soil cover. • Perform annual radiological surveys. • Implement vegetation and pest control program (e.g., spraying of herbicide). • Perform annual inspections to identify differential settlement and erosion. • Repair any settlement or erosion by adding additional gravel cover. • Re-grade and place 6 inches of new cover material once every 25 years. • MNA.
Alternative 3	RTD	• Confirmatory sampling. • Prepare DQO and SAP and supporting documentation (HSP, Hanford-specific documentation, etc.). • Install direct push vadose zone borings. The number and location of borings, depth of samples, and analysis suite will be determined during site-specific DQO process. • RTD. • Excavate shallow zone soils from 0 to 3 m (0 to 10 ft). • Perform verification sampling. • Develop a site-specific DQO and SAP that identifies the quantity and quality of verification sampling required to demonstrate attainment of PRGs. • Collect verification samples at bottom of excavation to ensure that PRGs are met. • Transport of excavated soils to ERDF for disposal. • Backfill with imported fill to original grade. • Identify suitable borrow source for backfill materials. • Place clean soil removed from excavation as backfill. • Place and compact backfill materials in lift to minimize potential for differential settlement. • Perform visual inspections to determine any surface erosion or settlement. • Repair any damage due to erosion or settlement by adding additional soils and re-vegetation.

CDF = controlled density fill
DQO = data quality objective
ERDF = Environmental Restoration Disposal Facility
ET = evapotranspiration
HSP = Health and Safety Plan
RTD = removal, treatment, and disposal
SAP = sampling and analysis plan

Table 8-6. Reverse Well Alternative Development Rationale

Alternative No.	Alternative Description	Alternative Component	Remedial Action Objective Addressed: RAO No. 1 Protect Human Receptors	RAO No. 2 Protect Ecological Receptors	RAO No. 3 Protect Groundwater	Other Objective	Rationale for Inclusion in Remedial Alternatives
No Action Alternative	No Action	No Action				X	Required by 40 CFR 300.430(e)(6), "National Oil and Hazardous Substances Pollution Contingency Plan," "Remedial Investigation/Feasibility Study and Selection of Remedy," "Feasibility Study."
Alternative 1	ICs and MNA	ICs	X	X			The purpose of implementing ICs is to limit direct contact with site contaminants by human receptors (RAO 1) and maintain existing programs that prevent establishment of terrestrial receptors (RAO 2). The development and selection of an ICs-based alternative as the sole remedy is allowable under 40 CFR 300.430(a)(1)(iii)(D), "General," "Introduction," "Expectations," when active measures are determined to not be practicable based on the balancing of trade-offs among all alternatives.
		Confirmatory Sampling				X	The purpose of confirmatory sampling is to validate the current understanding of the contaminant nature and extent presented in the conceptual contaminant distribution models (see Chapter 4) to support remedy implementation and to establish a baseline for measuring progress in achieving RAOs. Confirmatory sampling does not address specific RAOs.
		Well Decommissioning			X	X	The purpose of decommissioning the reverse wells is to meet ARARs (WAC 173-160-460, "Minimum Standards for Construction and Maintenance of Wells," "What Is the Decommissioning Process for Resource Protection Wells?") and minimize the potential for water infiltration or contaminant migration through the well structures to deeper portions of the vadose zone.
		MNA	X	X		X	Natural attenuation through radiological decay is a well understood natural process. The purpose of the monitoring component is to verify that the current distribution of contaminants in the soils beneath and around each waste site (as documented by existing characterization data and confirmatory sampling included in the remedy) is not changing (i.e., no further migration of contaminants). Natural attenuation would address RAOs 1 and 2 through a reduction in radionuclide contaminate concentrations over time.
Alternative 3	RTD	Confirmatory Sampling				X	The purpose of confirmatory sampling is to validate the current understanding of the contaminant nature and extent presented in the conceptual contaminant distribution models (see Chapter 4) to support remedy implementation and to establish a baseline for measuring progress in achieving RAOs. Confirmatory sampling does not address specific RAOs.
		Removal, Treatment and Disposal (RTD)			X		The purpose of deep zone RTD is to remove soil contamination above PRGs within the point of compliance. Removal of contaminated soils would be focused on RAOs 1 and 2.
		Verification Sampling				X	Verification sampling is not specific to individual RAOs, but is a necessary component of this remedial action alternative in order to verify that RAOs have been met.

COC = chemical of concern
ET = evapotranspiration
IC = institutional control
MNA = monitored natural attenuation
PRG = preliminary remediation goal
RAO = remedial action objective
RTD = removal, treatment, and disposal

Table 8-7. Reverse Well Alternative Summary

Alternative No.	Alternative Description	Alternative Summary
No Action Alternative	No Action	No Action: Baseline alternative. (Note that site-wide ICs, surveillance of existing soil cover will continue, but no waste site specific actions or costs are associated with this alternative.)
Alternative 1	ICs and MNA	• ICs. • Implement site-wide ICs within the 200 Areas industrial exclusive land use area. • Implement site-specific ICs (land use management, entry restrictions, waste site information management). • Confirmatory sampling. • Prepare DQO and SAP and supporting documentation (HSP, Hanford-specific documentation, etc.). • Install direct push vadose zone borings. The number and location of borings, depth of samples and analysis suite will be determined during site-specific DQO process. • Grout reverse wells in accordance with WAC 173-160-460, "Minimum Standards for Construction and Maintenance of Wells," "What Is the Decommissioning Process for Resource Protection Wells?". • Maintain existing soil cover. • Perform annual radiological surveys. • Implement vegetation and pest control program (e.g., spraying of herbicide). • Perform annual inspections to identify differential settlement and erosion. • Repair any settlement or erosion by adding additional gravel cover. • Re-grade and place 6 inches of new cover material once every 25 years. • MNA. • Document vadose zone monitoring in five year review.
Alternative 3	RTD	• Confirmatory sampling. • Prepare DQO and SAP and supporting documentation (HSP, Hanford-specific documentation, etc.). • Install direct push vadose zone borings. The number and location of borings, depth of samples and analysis suite will be determined during site specific DQO process. • RTD. • Over-drill soils at concentrations above 1x10-4 ELCR PRGs to a maximum depth of contamination below the well screen. • Perform verification sampling. • Develop a site specific DQO and SAP that identifies the quantity and quality of verification sampling required to demonstrate attainment of PRGs. • Collect verification samples at bottom of excavation to ensure that PRGs are met. • Disposal. • Transport of excavated soils to ERDF for disposal. • Backfill with imported fill to original grade. • Re-vegetate with native species. • Closure of site. • Removal of all site contaminants above PRGs would allow closure of the site. • Monitoring and 5 year reviews would not be required.

RTD = removal, treatment, and disposal
PRG = preliminary remediation goal
DQO = data quality objective
SAP = sampling and analysis plan
HSP = Health and Safety Plan
ELCR = excess lifetime cancer risk
ERDF = Environmental Restoration Disposal Facility

8.2.2 Implementability

Each of the alternatives was developed to be implementable based on utilizing remedial technologies retained in Chapter 7 on the basis of effectiveness implementability and cost. The implementability of the alternatives is summarized as follows:

- Alternative 1 is easily implemented as demonstrated by the site-wide ICs and site specific engineering controls (fencing and soil cover) currently in place along with programs to maintain these controls.
- Alternative 2 can be implemented with standard construction equipment and practices while using locally available borrow materials for the ET barrier.
- Alternative 3 is also readily implementable using standard construction equipment and practices while using locally available borrow materials for backfill.

8.2.3 Cost

Each of the alternatives was developed using remedial technologies retained in Chapter Seven on the basis of effectiveness, implementability, and cost. The relative cost of implementing the four alternatives is summarized as follows:

- Alternative 1 would require relatively low initial capital costs; however, continuing costs of operation and maintenance of ICs and engineering controls programs as well as long-term natural attenuation monitoring will add up.
- Alternative 2 provides a moderate cost alternative that addresses each of the three RAOs while balancing initial capital costs and long-term operation and maintenance costs.
- Alternative 3 provides a higher initial capital cost than Alternative 2 while providing total direct contact mitigation.

8.2.4 Alternative Screening Summary

Based on the effectiveness, implementability, and cost analysis presented above, each of the 200-MW-1 OU alternatives will be carried forward for detailed and comparative analysis. Alternative 1 will be retained because it is effective at achieving RAOs at the majority of 200-MW-1 OU waste sites. Alternatives 2 and 3 are retained because they provide a balance of cost-effectiveness and implementability for the cribs and trench where both shallow soil contamination above PRGs may be present and potential groundwater impacts have not been identified. Alternative 2 is the most costly and least implementable of the alternatives, but is also the most effective alternative for addressing potential adverse impacts to groundwater, and as such, will be carried forward.

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9 Detailed Analysis of Alternatives

The remedial alternatives developed in Chapter 8 are analyzed in detail in this section. Results of this analysis will form the basis for comparing alternatives and preparing the PP. After public review and comment on the PP, a final remedy will be selected in the ROD.

9.1 Introduction

This section describes the purpose of the detailed analysis and provides an overview of the CERCLA evaluation criteria. The remedial action alternatives developed in Chapter 8 are analyzed in detail against the CERCLA criteria to form the basis for selecting a final remedial action. The intent of this analysis is to present sufficient information to support preparation of the PP and to allow the selection of an appropriate remedy.

The CERCLA criteria are divided into three categories of weighted importance including threshold, balancing, and modifying criteria. The first two threshold criteria are Overall Protection of HHE and Compliance with ARARs. This means that only those remedial alternatives that provide adequate protection of HHE and comply with ARARs (or justify a waiver) are eligible for selection.

The five primary balancing criteria help describe relative technical and cost trade-offs among the remedial alternatives. The two modifying criteria, State Acceptance and Community Acceptance, can be fully considered only after public comment is received on the PP. Community outreach activities being implemented by DOE can be recognized as items to be considered in the FS. For example, a preliminary summary of any community feedback or HAB input on the remedial alternatives could be included. In the final balancing of the tradeoffs between alternatives for remedy selection (documented in the ROD), the Tri-Parties need to weigh the primary balancing criteria and consider the modifying criteria when making the remedy selection. The nine criteria are briefly summarized in Table 9-1. The two threshold and five balancing criteria evaluated in this document are discussed in more detail in the following sections.

Table 9-1. Summary of CERCLA Criteria

Threshold Criteria	
Overall Protection of HHE	Comparison of baseline human health risk estimates with residual risk estimates Comparison of ecological risk estimates with regulatory risk criteria Evaluation of exposure pathways for human and ecological receptors following implementation of the remedial alternative Draws on assessments conducted under other criteria, especially long-term effectiveness, short-term effectiveness, and ARARs
ARARs	Compliance with location-specific ARARs Compliance with chemical-specific ARARs Compliance with action-specific ARARs
Balancing Criteria	
Long-Term Effectiveness and Permanence	Magnitude of residual risk Adequacy and reliability of controls

Table 9-1. Summary of CERCLA Criteria

Reduction of Toxicity, Mobility, and Volume Through Treatment	Treatment processes used and materials treated Amount of waste material destroyed or treated Degree of expected reduction in toxicity, mobility, or volume Degree to which treatment is irreversible Type and quantity of residuals remaining after treatment
Short-Term Effectiveness	Protection of community during remedial actions Protection of workers during remedial actions Environmental impacts Time to compliance
Implementability	Ability to construct, operate, and monitor the technology Reliability of the technology Ease of undertaking additional remedial action, if necessary Ability to coordinate with and obtain approvals from other agencies Availability of equipment, specialists, technologies, offsite treatment, storage or disposal services, and capacity
Cost	Capital costs Annual operation and maintenance costs Total present value (for example, 30-year basis – needs to reflect remedy or risk duration) Total non-discounted cost (for example, 30-year basis – needs to reflect remedy or risk duration)
Modifying Criteria	
State Acceptance	Indicates whether the state concurs with, opposes, or has no comment on the proposed remedial action
Community Acceptance	Assesses the public response to the proposed remedial action; although public comment is an important part of the decision-making process, EPA is required by law to balance community concerns with the above criteria

9.1.1 Overall Protection of Human Health and the Environment

Alternatives are assessed to determine whether they can adequately protect HHE, in both the short and long term, from unacceptable risks posed by contaminants, by eliminating, reducing, or controlling exposures as established during the development of RAOs and PRGs consistent with 40 CFR 300.430(e)(2)(i). Overall protection of HHE draws on the assessments of the other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

9.1.2 ARARs

Alternatives are assessed to determine whether they meet ARARs, and other "to be considered" requirements, or to determine whether a basis exists for invoking one of the waivers cited in 40 CFR 300.430(f)(1)(ii)(C), "Selection of Remedy," as listed below.

1. The alternative is an interim measure and will become part of a total remedial action that will attain the applicable or relevant and appropriate federal or state requirement.

2. Compliance with the requirement will result in greater risk to HHE than other alternatives.
3. Compliance with the requirement is technically impracticable from an engineering perspective.
4. The alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method or approach.
5. With respect to a state requirement, the state has not consistently applied, or demonstrated the intention to consistently apply, the promulgated requirement in similar circumstances at other remedial actions within the state.

9.1.3 Long-Term Effectiveness and Permanence

Long-term effectiveness and permanence are criteria to evaluate the anticipated ability of the alternatives to maintain reliable protection of HHE for the duration of risk above allowable levels once the RAOs are met. Alternatives are assessed for the long-term effectiveness and permanence they afford along with the degree of certainty that the alternative will prove successful. The following factors may be considered in this assessment:

1. The magnitude of residual risk from untreated waste or treatment residuals remaining at the conclusion of the remedial activities, including their volume, toxicity, and mobility.
2. The adequacy and reliability of controls such as containment systems and ICs necessary to manage treatment residuals and untreated waste (for example, this factor addresses uncertainties associated with land disposal for providing long-term protection from residuals; the assessment of the potential need to replace technical components of the alternative, such as a cap or treatment system; and the potential exposure pathways and risks posed should the remedial action need replacement).

9.1.4 Reduction of Toxicity, Mobility, and Volume through Treatment

The degree to which the alternatives employ treatment or recycling that reduces toxicity, mobility, or volume will be assessed, including how the treatment is used to address the principal threats posed by the release sites. The following factors, as appropriate, are considered.

1. Treatment or recycling processes that the alternatives employ and the materials that they will treat.
2. The amount of hazardous substances, pollutants, or contaminants that will be destroyed or recycled.
3. The degree of expected reduction in toxicity, mobility, or volume of the waste because of the treatment or recycling and the discussion of which reductions are occurring.
4. The degree to which the treatment is irreversible.
5. The type and quantity of residuals that will remain following treatment, taking into consideration the persistence, toxicity, mobility, and propensity of hazardous substances and their constituents to bioaccumulate.
6. The degree to which treatment reduces the inherent hazards posed by the principal threats at the release sites.

9.1.5 Short-Term Effectiveness

Short-term effects during implementation of the remedial action will be assessed, including the following:

1. Short-term risks that might be posed to the community.
2. Potential risks or hazards to workers, and the effectiveness and reliability of protective measures.

3. Potential environmental effects and the effectiveness and reliability of mitigative measures.
4. Time until protection is achieved.

9.1.6 Implementability

The ease or difficulty of implementing the alternatives will be assessed by considering the following types of factors, as appropriate:

1. Technical feasibility, including the technical difficulties and unknowns associated with constructing and operating the technology, the reliability of the technology, the ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the remedy.
2. Administrative feasibility, including activities required to coordinate with other offices and agencies and the ability and time needed to obtain any necessary approvals and permits for off-site actions from other agencies.
3. Availability of required materials and services.

9.1.7 Cost

The types of costs assessed include the following:

1. Management and oversight costs, including 5-year reviews, which would be incurred primarily by the project.
2. Remedial design and construction documentation costs, including remedial design, construction management and oversight, remedial design and remedial action document preparation, and reporting costs.
3. Construction costs, including capital equipment, general and administrative costs, and construction subcontract fees.
4. Operating and maintenance costs.
5. Equipment replacement costs.
6. Surveillance and monitoring costs.
7. Life-cycle costs are presented as net present value dollars for capital, operating and maintenance, and periodic costs for each alternative. Escalation was applied as directed by DOE O 430.1B Chg 1, *Real Property Asset Management*. Guidance was provided by U.S. Department of Energy (DOE) Headquarters, Office of Project and Fixed Asset Management, *Departmental Price Change Index: FY-99 Guidance, Anticipated Economic Escalation Rates*, January 1997 update (DOE, 1997).
8. The alternative cost estimates are for comparison purposes only and are not intended for budgetary, planning, or funding purposes. Estimates were prepared to meet the -30 to +50 percent range of accuracy recommended in EPA, 1988 CERCLA guidance. Detailed cost estimate information is included in Appendix G.

9.2 Individual Analysis of Alternatives

This section presents the detailed analysis of each alternative against the threshold and modifying criteria. Table 9-2 provides a summary of the detailed analysis of alternatives.

9.2.1 No Action

Under 40 CFR 340.430(e)(6), a No Action Alternative is included in the FS to provide a baseline for comparison against the other alternatives. The pre-existing conditions clause would allow for the inclusion of previously implemented measures taken by DOE for the Hanford Site that limit land use in the 200 Areas to industrial, restrict drilling and groundwater use, and employ an array of multi-layered controls (security, badges, fences, signs, excavation permits, and WIDS) to prevent inadvertent exposure to waste sites. For the purposes of this FS, pre-existing conditions have been excluded from the No Action Alternative but are captured within the scope of other alternatives where appropriate. Under the No Action Alternative, no active or passive remedial action would be taken to address potential threats to HHE. However, under the No Action Alternative, natural radioactive decay reduces radionuclide concentrations.

9.2.1.1 Overall Protection of Human Health and the Environment

The No Action Alternative is not protective of human health and ecological receptor exposure at the 200-MW-1 OU waste sites except, 216-A-2 Crib because radionuclide and non-radionuclide constituents are known to be present, or are presumed to occur, in soil at concentrations above unrestricted use/unrestricted exposure levels.

The No Action Alternative is protective of groundwater quality beneath the 216-A-2, 216-A-21, and 216-A-27 Cribs and the 216-B-4 and 216-C-2 Reverse Wells because the potential for adverse impacts to groundwater was not identified, based on fate and transport modeling data. The No Action Alternative is also protective for the 216-A-4 Crib site. However, the conceptual model indicates that uranium metal in downgradient groundwater is above concentrations (Monitoring Well 299-E24-23 detected uranium at 79.5 µg/L) deemed protective based on a drinking water use. This groundwater contamination does not directly correlate to the 216-A-4 Crib.

9.2.1.2 ARARs

Chemical-specific ARARs. The No Action Alternative does not comply with chemical-specific (soil-based) ARARs for protection of HHE at the 200-MW-1 OU waste sites because radionuclides will remain at concentrations above EPA's target ELCR threshold of 1×10^{-4} for more than 1,000 years. Although the concentration of short-lived radionuclides such as Sr-90 and Cs-137 will decay to concentrations corresponding to an ELCR of less than 1×10^{-4} in less than 500 years, long-lived radionuclides (most notably Pu-239) will continue to drive risk for more than 1,000 years.

Based on the RESRAD groundwater impacts evaluation conducted for the 216-A-2 and 216-A-5 Cribs (Appendix C), it is inferred that the No Action Alternative would comply with chemical-specific ARARs for groundwater protection at the 216-A-2, 216-A-4, 216-A-21, and 216-A-27 Cribs, 200-E-102 Trench, and 216-B-4 and 216-C-2 Reverse Wells.

Location-specific ARARs. There is no activity within the scope of this alternative that would disturb the 200-MW-1 OU waste sites. Therefore, the No Action Alternative complies with location-specific ARARs associated with preservation of archaeological or historical data, protection of historic properties, and protection of Native American and archaeological sites.

Action-specific ARARs. The No Action Alternative complies with action-specific ARARs because there is no activity within the scope of this alternative at the crib and trench sites. The No Action Alternative would not comply with action-specific ARARs because the reverse wells have not been decommissioned in accordance with WAC standards.

9.2.1.3 Long-Term Effectiveness and Permanence

This criterion relates primarily to the health risks that remain at the site once RAOs are met, and the extent and effectiveness of controls required to manage the risk posed by untreated soil.

Magnitude of Residual Risk. Under the No Action Alternative, no active measures are taken to control exposure pathways or to reduce the concentration of radionuclides present in subsurface soil. However, radioactive decay naturally decreases radionuclide concentrations in situ, and given adequate time this alternative can reduce concentrations to levels that provide improved protection for HHE.

Based on present conditions, the 216-A-2 Crib ELCR will exceed EPA's target ELCR of 1×10^{-4} until approximately 5,740 years from the present. Similar inventories of Pu-239 reportedly discharged to the 216-A-21 and 216-A-27 Cribs suggest that comparable ELCRs will persist at these waste sites as well. The inventory of long-lived radionuclides reportedly discharged to the 216-A-4 Crib, and the 216-B-4 and 216-C-2 Reverse Wells, is much lower (Table 4-3). Therefore, the magnitude and duration of residual risk at these three waste sites is expected to be less than the 1×10^{-4} target ELCR threshold.

Radionuclides are not present at concentrations above PRGs within the human health and ecological points of compliance at the 216-A-2, 216-A-4, 216-A-21, and 216-A-27 Cribs and the 216-B-4 and 216-C-2 Reverse Wells. Therefore, the residual ELCR to human receptors is less than 1×10^{-6}.

Because no information is currently available on the nature and concentration of radionuclides present in shallow soil at the 200-E-102 Trench, the magnitude of risks associated with this waste site and their duration cannot be determined. It is presumed that the soil is contaminated primarily with gamma-emitting radionuclides such as Sr-90 and Cs-137. Therefore, a majority of the ELCR will likely decay to levels less than 1×10^{-4} within 500 years based on anticipated similarities with the 216-A-4 Crib.

Adequacy and Reliability of Controls. The No Action Alternative contains no provisions for controls to prevent exposure. Therefore, this analysis factor does not apply.

9.2.1.4 Reduction of Toxicity, Mobility, and Volume through Treatment

The No Action Alternative does not employ an active treatment technology. However, toxicity and volume reduction are achieved through radioactive decay, a well understood natural attenuation process that is based on the known half-lives for each individual radionuclide. Radioactive decay under the No Action Alternative can provide effective treatment leading to measurable toxicity and volume reduction for short-lived radionuclides such as Cs-137 and Sr-90, which have half-lives of 30 years and 29 years, respectively. At the 216-A-4 Crib, where Sr-90 was detected at a maximum observed concentration of 3,860,000 pCi/g, radioactive decay reduces the ELCR toxicity to a hypothetical industrial worker through external gamma exposure from 1.4×10^{-1} to 3.9×10^{-3} in 150 years, and to less than 1×10^{-4} within 500 years. Similarly, the ELCR toxicity attributed to Cs-137 is reduced from 3.0×10^{-1} to 9.3×10^{-3} in 150 years and to less than 1×10^{-4} within 500 years. Toxicity and volume reductions at the other cribs sites are expected to be comparable.

Radioactive decay is less effective for long-lived radionuclides such as Am-241 (437 years) and Pu-239 (24,065 years), requiring extended timeframes for a proportionate reduction in toxicity and volume. Based on conditions present at the 216-A-4 Crib, radioactive decay reduces the ELCR toxicity for a hypothetical industrial worker exposure attributed to Am-241 from 2.7×10^{-4} to 2.1×10^{-4} in 150 years, and to less than 1×10^{-4} in 1,000 years.

Table 9-2. Detailed Analysis of Alternatives Summary for 200-MW-1 OU Waste Sites

Alternative	Threshold Criteria		Balancing Criteria				
	1. Overall Protection of Human Health and the Environment	2. Compliance with ARARs	3. Long-Term Effectiveness and Permanence	4. Reduction of Toxicity, Mobility, and Volume Through Treatment	5. Short-Term Effectiveness	6. Implementability	7. Net Present Value Cost
No Action Alternative	Poor. Radionuclide and nonradionuclides are present, or presumed to be present, at most 200-MW-1 OU waste sites at concentrations above unrestricted use and unrestricted exposure levels.	No at most 200-MW-1 OU waste sites.	Radioactive decay reduces risk but rural residential ELCR greater than 1 × 10^{-4} persists for more than 1,000 years. No controls established to prevent exposure.	Yes–toxicity and volume reduction occur through decay of radionuclides. Does not reduce mobility.	No short-term effects to community or workers because there is no activity that would allow exposure to occur. Does not pose an implementation risk to workers because no remedial action construction activities occur. Remedial action objectives (RAOs) not achieved. Timeframe to achieve preliminary remediation goals (PRGs) is greater than 1,000 years.	Easily implemented but state and community acceptance may be challenging.	None
Alternative 1–ICs and MNA	Good at the 216-A-4, 216-A-21 and 216-A-27 Cribs, and 216-B-4 and 216-C-2 Reverse Wells because the exposure pathway is incomplete (soil contamination is below depth of the defined point of compliance 0.9 m (3 ft). Poor at the 216-A-4 Crib and 200-E-102 Trench where contamination above PRGs may be present in soil above the defined point of compliance.	Yes–at 200-MW-1 OU waste sites.	Radioactive decay reduces risk to protective levels. ICs will have to be maintained for more than 1,000 years but can be lifted once PRGs are achieved. No active measures to reduce uranium-metal leaching to groundwater. However, uranium concentrations in groundwater do not exceed MCLs until well after 10,000 years in future.	Yes–toxicity and volume reduction occur through decay of radionuclides. Does not reduce mobility.	Minimal short-term risks to workers during confirmation sampling and monitoring. Controls prescribed in the health and safety plan (HSP) and personal protective equipment (PPE) address worker protection. Due to the site's remote location no adverse risks to community. Timeframe to achieve RAOs is short. PRGs not achieved for more than 1,000 years.	Readily implemented.	Low
Alternative 2–ET Barrier	Good at the 216-A-21, 216 A-27, and 216-A-4 Cribs and 200-E-102 Trench. ET barrier provides an additional layer of separation between receptors and shallow soil contamination. ICs provide an additional level of protection against exposure to soil contamination present at depths greater than the defined point of compliance.	Yes–for all cribs and trench.	Barrier and ICs provide a higher level of protection until radioactive decay reduces ELCR to levels less than 1 × 10^{-4}. Operations and maintenance (O&M) program will ensure that barrier integrity is maintained until RAOs are achieved through radioactive decay. ET cap reduces rainfall and snowmelt infiltration, lessening impacts associated with leaching of contaminants to groundwater.	Yes – toxicity and volume reduction occur through decay of radionuclides. ET cap reduces mobility by limiting rainfall and snowmelt infiltration.	Nominal short-term risks to workers during confirmation sampling and construction of ET cap and intrusion barrier. Risks minimized though HSP and PPE. Ecological risks not expected. Timeframe to achieve RAOs is short. PRGs not achieved for more than 1,000 years.	Easily implemented with standard construction equipment and methods. Large volume of soil would have to be imported to the Hanford Site.	Moderate
Alternative 3–RTD	Provides increased protection for human health and ecological receptors by removing contaminated soil present to a depth of 3 m (10 ft).	Yes–at 200-MW-1 OU waste sites.	Removal of the contaminant mass reduces ecological and rural residential direct contact exposure pathway.	Reduction in toxicity and volume achieved by consolidating material at the ERDF for treatment through decay in place. Contaminants are moved to a less mobile environment designed for secure long-term storage.	Moderate to high short-term risks to workers primarily from exposure during excavation and transport to ERDF. Worker protection provided through measures specified in the HSP, use of PPE, and work place monitoring. Community risks minimized due to crib sites' remote location. Ecological risks not expected. Timeframe to achieve RAO 1 and 2 is short. PRGs not achieved for more than 1,000 years.	Easy to Moderate for all cribs and 200-E-102 Trench. Can be implemented with standard construction equipment and methods due to shallow depth.	Low to High

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The No Action Alternative provides no reduction in mobility for uranium-metal present at the 216-A-4 Crib. As demonstrated through the RESRAD modeling, radionuclides have very limited mobility under the conditions present at the 216-A-2 and 216-A-5 Crib sites.

9.2.1.5 Short-Term Effectiveness

This criterion addresses the effects of the alternative to the community, remedial action workers, and the environment during the construction and implementation phase, and the timeframe required before RAOs are met. Because there is no activity associated with the No Action Alternative, there are no short-term effects to the community or to remedial action workers.

9.2.1.6 Implementability

This criterion addresses the technical and administrative feasibility of implementing a remedial action alternative, and the availability of various services and material required during its implementation. Since the No Action Alternative does not include implementation of any remedial activities at the sites, this criterion is not applicable.

9.2.1.7 Cost

There are no present worth costs associated with the No Action Alternative.

9.2.2 Alternative 1 – Institutional Controls and Monitored Natural Attenuation

The major components of this alternative include:

- **Institutional Controls.** The existing ICs described in Chapter 5 of this FS, and DOE/RL-2001-41, would be reviewed to ensure adequacy for the 200-MW-1 OU sites, and supplemented as needed to meet RAOs. ICs would need to be maintained until PRGs are met.
- **Confirmatory Sampling.** Soil sampling would be performed using direct push methods and the samples analyzed to confirm the contaminant distribution models, and to obtain other information necessary to establish a baseline for assessing progress toward achieving RAOs.
- **Maintain Existing Soil Cover.** This includes maintaining the existing 0.15- to 0.31-m (0.5- to 1-ft) thick gravel (crushed rock) cover over the waste site footprint (cribs and trench only), inspecting the cover annually and placing additional material as needed to offset erosion or subsidence loss, annual radiological surveys, vegetation and pest control, and the placement of 0.15-m (0.5-ft) of new cover material every 25 years.
- **Monitored Natural Attenuation.** New vadose zone boreholes and monitor wells would be installed, potentially within the confirmation borings described above, and periodically logged using geophysical methods to ensure that there is no significant radionuclide migration. The monitoring results would be published in periodic reports and 5-year reviews.
- **Well Decommissioning.** Each reverse well would be decommissioned (if not converted to a monitoring well) in accordance with WAC 173-160-460 requirements.

9.2.2.1 Overall Protection of Human Health and the Environment

Alternative 1 is protective of human and ecological receptors at the 216-A-4, 216-A-21, and 216-A-27 Cribs and 216-B-4 and 216-C-2 Reverse Wells, because radionuclide and non-radionuclide constituents are not present in soil at concentrations above PRGs within their respective points of compliance. Alternative 2 is protective of human health at the 216-A-4 Crib and 200-E-102 Trench because existing IC measures such as visual warning notices, entry restrictions, land and groundwater-use management, and the WIDS provide a multi-layer system to protect against inadvertent exposure to shallow soil contamination that may be present at these sites until RAOs are achieved. Alternative 2 is protective of ecological receptors because maintenance of the existing cover includes a provision that prevents their establishment at the crib sites, thus eliminating the potential for exposure.

Alternative 1 is also protective of groundwater at the 216-A-2, 216-A-4, 216-A-21, and 216-A-27 Cribs and 216-B-4 and 216-C-2 Reverse Wells, because adverse impacts to groundwater were not identified at these sites.

9.2.2.2 ARARs

Chemical-specific ARARs. Alternative 1 complies with chemical-specific (soil-based) ARARs for protection of human health and ecological receptors because radionuclides and non-radionuclides do not occur at concentrations above PRGs within the defined soil exposure horizon at the 216-A-2, 216-A-4, 216-A-21, and 216-A-27 Cribs and 216-B-4 and 216-C-2 Reverse Wells. Alternative 1 complies with chemical-specific (soil-based) ARARs for protection of HHE for the 216-A-4 Crib and 200-E-102 Trench, because existing ICs will prevent exposure until radioactive decay reduces radionuclide concentrations to levels below PRGs.

Based on groundwater impacts evaluations, Alternative 1 complies with chemical-specific ARARs for groundwater protection at the 216-A-2, 216-A-4, 216-A-21, and 216-A-27 Cribs and 216-B-4 and 216-C-2 Reverse Wells, because there is no evidence of adverse groundwater quality impacts associated with leaching of contaminants from vadose zone soil.

Location-specific ARARs. The four crib sites and trench lie within a highly disturbed area south of the PUREX facility. The two reverse well sites are also located within the vicinity of existing facilities and disturbed areas. Installation of new vadose zone monitoring wells, and maintenance of the existing soil covers, will not result in any more disturbance than has already occurred. Therefore, Alternative 1 complies with location-specific ARARs associated with preservation of archaeological or historical data, protection of historic properties, and protection of Native American and archaeological sites.

Action-specific ARARs. Alternative 1 will comply with the identified action-specific ARARs through worker protection and air emission monitoring programs, and through adherence to existing programs associated with the management of investigation-derived waste (IDW) generated from vadose zone monitoring well installation work. Alternative 1 would also comply with action-specific ARARs through decommissioning of the two reverse wells in accordance with WAC standards.

9.2.2.3 Long-Term Effectiveness and Permanence

This criterion relates primarily to the health risks that remain at the site once RAOs are met, and the extent and effectiveness of controls required to manage the risk posed by untreated soil.

The magnitude and duration of ELCR under Alternative 1 for the first 1,000 years will be similar to that described for the No Action Alternative. Additional ELCR reduction will occur beyond 1,000 years in proportion to each radionuclide's half-life until RAOs are achieved. Once RAOs are achieved, the magnitude of ELCR remaining under Alternative 1 will be less than 1×10^{-4}.

Under Alternative 1, existing ICs will be used to protect against inadvertent exposure until radioactive decay reduces concentrations to levels below PRGs. The adequacy and reliability of these controls is expected to be very high because other permitted waste management facilities and CERCLA sites in proximity to the 200-MW-1 OU Crib sites and within the 200 Areas will require ICs for the foreseeable future. Once PRGs are achieved, it is expected that a majority of the ICs can be lifted.

Because hazardous substances would be left in place at concentrations above protective levels for more than 1,000 years, 5-year reviews would be required for all four crib sites.

9.2.2.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Radioactive decay under Alternative 1 will yield significant toxicity (total ELCR less than 1×10^{-4}) and volume reduction within 500 years for the short-lived radionuclides (Sr-90 and Cs-137) that, based on the findings of the BRA, account for a majority of the ELCR at the 216-A-2 and 216-A-4 Crib sites. Because the 216-A-21 and 216-A-27 Cribs contained higher Sr-90 and Cs-137 inventories, significant toxicity and volume reduction within 500 years is also expected at these sites.

Alternative 1 would not reduce the mobility of uranium present in soil beneath the 216-A-4 Crib, because the existing soil cover configuration is not intended to reduce or prevent infiltration. Under Alternative 1, radionuclide mobility will be monitored through periodic geophysical logging of newly installed vadose zone monitor wells. Non-radionuclide mobility will be assessed at the 216-A-4 Crib for uranium metal, through confirmatory sampling to validate the current distribution of contaminants below the crib. Additional information will be provided by the 200-PO-1 OU groundwater monitoring program.

9.2.2.5 Short-Term Effectiveness

This criterion addresses the effects of the alternative to the community, remedial action workers, and the environment during the construction and implementation phase, and the timeframe required before RAOs are met. Under this alternative, DOE workers will conduct surveillance and other activities associated with soil cover maintenance and vadose zone monitoring.

Under Alternative 1, minimal short-term risks are expected because a majority of the maintenance and monitoring activities are non-intrusive. The potential for some exposure may occur during the installation of vadose zone monitoring wells. However, this work would be conducted by experienced workers using appropriate safety precautions. The timeframe until RAOs are achieved, which relies on radioactive decay, is estimated at greater than 1,000 years.

9.2.2.6 Implementability

Alternative 1 is readily implementable and would not present any significant technical or administrative difficulties. Many of the activities contained within this alternative, such as radiation surveys, vegetation and pest control, cover inspection, and maintenance are already being performed at these waste sites, and vadose zone monitoring well installation and geophysical logging are currently being performed at other OUs within the Hanford Site.

9.2.2.7 Cost

This alternative would incur costs for activities similar to those currently being performed at a number of locations across the Hanford Site. The estimated net present worth cost for this alternative is based on an individual waste site and does not reflect economies of scale that might be obtained by implementing this alternative across multiple waste sites or OUs.

Table 9-3 summarizes the total capital, operations and maintenance, and present worth costs for Alternative 1. Detailed backup information for these costs is provided in Appendix G.

Table 9-3. Alternative 1 Cost Summary

	Waste Site						
	216-A-2 Crib	**216-A-4 Crib**	**216-A-21 Crib**	**216-A-27 Crib**	**200-E-102 Trench**	**216-B-4 Reverse Well**	**216-C-2 Reverse Well**
Capital Cost	N/A	$28,320	$28,320	$28,320	$28,320	$278,320	$252,140
Annual and Periodic Costs	N/A	$34,656,000	$34,656,000	$34,656,000	$34,656,000	$34,656,000	$34,656,000
Total Non-Discounted Cost	N/A	$34,684,000	$34,684,000	$34,684,000	$34,684,000	$34,934,000	$34,908,000
Total Present Worth Cost	N/A	$1,285,000	$1,285,000	$1,285,000	$1,285,000	$1,535,000	$1,509,000

N/A = Not applicable

9.2.3 Alternative 2 – Evapotranspiration Barrier

The major components of this alternative include:

Confirmatory sampling. Soil sampling would be performed using direct push methods and the samples analyzed to confirm the contaminant distribution models, to obtain information necessary for remedial design, and to obtain other information necessary to establish a baseline for assessing progress toward achieving RAOs.

Construction of an ET barrier. The ET barrier would be integrated with the physical barrier and extend 6 m (20 ft) beyond the limits of soil contamination.

Operations and Maintenance and MNA. Periodic inspection and maintenance would be performed to ensure that the integrity of the ET barrier is maintained. Lysimeters and vadose zone monitoring wells would be installed at locations determined during remedial design, and periodic monitoring conducted to assess alternative performance. MNA would occur as a result of natural radioactive decay. The monitoring results would be published in periodic reports and 5-year reviews.

The scope of ICs under this alternative would be similar to those described for Alternative 2.

This alternative only applies to the cribs and trench where potential direct contact and adverse impacts to groundwater may be identified.

9.2.3.1 Overall Protection of Human Health and the Environment

Alternative 2 is protective of human health at the cribs because it couples an ET barrier with existing IC measures (as described for Alternative 1) to provide an additional layer of protectiveness if one or more of the IC measures were to fail. This alternative also reduces vadose zone infiltration, so the potential for uranium-metal to leach from soil to groundwater is further reduced. The O&M program would ensure that the integrity of the barrier is maintained, and would provide information to demonstrate its effectiveness.

9.2.3.2 ARARs

Chemical-specific ARARs. Alternative 2 complies with chemical-specific (soil-based) ARARs for protection of human health and the environment for the cribs, because existing ICs coupled with the ET barrier will prevent exposure until radioactive decay reduces radionuclide concentrations to levels below PRGs. Alternative 2 will also comply with chemical-specific ARARs for groundwater protection by reducing infiltration, which in turn will reduce the leaching and transport of uranium-metal to groundwater. Groundwater monitoring performed under the 200-PO-1 OU may be used to assess progress toward compliance with chemical-specific ARARs.

Location-specific ARARs. The crib sites lies within a highly disturbed area south of the PUREX facility. Installation of the surface barrier, and new vadose zone monitoring wells, will not result in any more disturbance than has already occurred. Cultural resource surveys will be performed as warranted to ensure that Alternative 2 complies with ARARs for preservation of archaeological or historical data, protection of historic properties, and protection of Native American and archaeological sites.

Action-specific ARARs. Alternative 2 will comply with action-specific ARARs through worker protection and air emission monitoring programs, and through adherence to existing programs associated with the management of IDW generated from vadose zone monitoring well installation work. All construction work would be conducted under the existing environmental protection program, which is engaged substantively during the remedial design process, and integrated fully into work planning and execution.

9.2.3.3 Long-Term Effectiveness and Permanence

This criterion relates primarily to the health risks that remain at the site once RAOs are met, and the extent and effectiveness of controls required to manage the risk posed by untreated soil.

The magnitude and duration of ELCR under Alternative 2 for the first 1,000 years will be similar to that described for the No Action Alternative. Additional ELCR reduction will occur beyond 1,000 years in proportion to each radionuclide's half-life until RAOs are achieved. Once RAOs are achieved, the magnitude of ELCR remaining under Alternative 2 will be less than 1×10^{-4}.

Alternative 2 will provide an additional measure of long-term effectiveness and permanence because an inspection and maintenance program will be implemented to maintain the integrity of the remedy. The ET barrier would reduce the potential for direct contact with contaminated soil present within the point of compliance, by providing an additional layer of separation between contaminated soil and the ground surface. The ET barrier will reduce rainfall and snowmelt infiltration into the vadose zone underlying the crib, which in turn will reduce the leaching and transport of uranium-metal to groundwater. Because the ET type barrier does not rely on structural features to control infiltration, it is unlikely to be compromised by differential settlement, subsidence, or seismic events.

Under Alternative 2, the ET barrier coupled with existing ICs would be used to protect against exposure until radioactive decay reduces concentrations to levels below PRGs. The adequacy and reliability of these controls is expected to be very high because other permitted waste management facilities and CERCLA sites in proximity to the 200-MW-1 OU Crib sites, and within the 200 Areas, are expected to require ICs for the foreseeable future. Once PRGs are achieved, a majority of the ICs can be lifted and O&M of the surface barrier discontinued.

Because hazardous substances would be left in place at concentrations above protective levels for more than 1,000 years, 5-year reviews would be required for all four crib sites.

9.2.3.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Alternative 2 uses an ET barrier to reduce contaminant mobility by intercepting and diverting rainfall and snowmelt away from the contaminated soil footprint, and by promoting increased ET, thereby reducing the potential for water to leach contaminants from vadose zone soil and transport them to groundwater. This alternative does not include an active treatment process to address toxicity or volume reduction; however, toxicity (and volume) reduction will occur through natural attenuation (radioactive decay) processes.

9.2.3.5 Short-Term Effectiveness

This criterion addresses the effects of the alternative to the community, remedial action workers, and the environment during the construction and implementation phase, and the timeframe required before RAOs are met.

Alternative 2 poses relatively minor short-term risks (airborne dust) to workers during grading and placement of the ET barrier that can be readily controlled through existing worker and environmental protection programs. Barrier construction could be completed within 1 year of a subcontract award; therefore, RAOs 1 and 2 can be achieved in a much shorter timeframe relative to Alternative 1.

Worker exposure to contaminants is not expected to occur because construction will be performed over the top of the existing clean soil cover. However, at the 216-A-4 Crib, where contaminants may reside closer to the surface, additional radiological controls will be necessary. Worker safety would be controlled through adherence to health and safety procedures and Occupational Safety and Health Administration (OSHA) regulations. Air monitoring would address potential air releases (particulates) that could affect workers or visitors during barrier construction.

Construction activities could disrupt wildlife in the area because of increased noise and human activity. However, the waste sites are located in areas already disturbed by earlier facility operations and in areas adjacent to ongoing facility operations, so impacts on biological resources would be low. This alternative would not result in direct exposure to or release of contaminants, so the alternative would not increase the potential for receptor exposure to contaminants. Potential impacts from fugitive dust would be minimized through appropriate control measures during barrier construction. No risks to the community exist, given the isolated location of the waste sites and access restrictions already in place.

Source material used for barrier construction would be transported from borrow areas located on or near the Hanford Site. Hauling of barrier materials to the crib sites from borrow areas and gravel pits within the Hanford Site would increase heavy equipment traffic. However, radioactive or hazardous waste would not be transported to or from the crib sites.

Personnel performing future confirmatory sampling work will incur radiological exposure risks, which can be effectively addressed by existing worker protection programs. These activities also will require controls to mitigate the potential for release of contaminants to the environment, which will be addressed by existing environmental protection programs.

9.2.3.6 Implementability

This criterion addresses the technical and administrative feasibility of implementing a remedial action alternative, and the availability of various services and material required during its implementation. This criterion poses no significant challenges for Alternative 2.

Construction of the barrier would follow standard procedures that have been thoroughly field tested elsewhere at the Hanford Site. For example, DOE/RL-99-11, *200-BP-1 Prototype Barrier Treatability Test Report*, documents constructability and performance test results for a Hanford-type barrier installed and field-tested at the 216-B-57 Crib. Monitoring barrier integrity following construction would be accomplished through routine visual inspections supplemented with evaluation of performance monitoring (lysimeter) data. Based on these inspections, the barriers may require minor repair during their functional lifetime until PRGs are attained.

Future decommissioning of existing facilities and infrastructure (PUREX building and railroad tunnel), and implementation of remedies for adjacent CERCLA OUs could alter the barriers' effectiveness, require their removal, or render them redundant. Therefore, if selected, implementation of Alternative 2 will require planning and coordination with activities planned at adjacent areas.

9.2.3.7 Cost

Table 9-4 summarizes the total capital operations and maintenance and present worth costs for Alternative 2. Detailed backup information for these costs is provided in Appendix G.

Table 9-4. Alternative 2 Cost Summary

	Waste Site						
	216-A-2 Crib	**216-A-4 Crib**	**216-A-21 Crib**	**216-A-27 Crib**	**200-E-102 Trench**	**216-B-4 Reverse Well**	**216-C-2 Reverse Well**
Capital Cost	N/A	$603,454	$528,577	$600,644	N/A	N/A	N/A
Annual and Periodic Costs	N/A	$34,656,000	$34,656,000	$34,656,000	N/A	N/A	N/A
Total Non-Discounted Cost	N/A	$35,259,000	$35,185,000	$35,257,000	N/A	N/A	N/A
Total Present Worth Cost	N/A	$1,860,000	$1,785,000	$1,857,000	N/A	N/A	N/A

N/A = Not applicable

9.2.4 Alternative 3 – RTD

The major components of this alternative include:

- Confirmatory sampling. Direct push vadose zone borings would be advanced and soil samples collected to confirm the contaminant distribution model and to obtain information necessary for remedial design.
- Excavation of contaminated soils within the defined remedial action target area to a depth of 3 m (10 ft) at the cribs. The excavations would be backfilled with clean fill removed during the excavation and imported fill from a local borrow pit.
- Transportation and disposal of excavated material at ERDF.

An open cut excavation method is assumed for the cribs and 200-E-102 Trench. Based on existing information, the contaminant concentrations present at the proposed depths would achieve compliance with human health and ecological direct contact criteria. Verification sampling would be performed once the target excavation depth is reached to ensure that PRGs are met.

9.2.4.1 Overall Protection of Human Health and the Environment

Alternative 3 achieves acceptable risk levels for the current and future anticipated land use; however, the alternative does not reduce risk from contaminated soil leaching to groundwater. This alternative provides a moderate degree of protection for HHE because the soil from 0 to 3 m (10 ft) would be removed. Excavated material would be characterized and transported to the ERDF for disposal.

The residual ELCR to an industrial worker would be less than 1×10^{-6} within the 0-3 m (0-10 ft) depth interval at the cribs, and less than 1×10^{-6} within the 0-1.5 m (0-5 ft) depth interval at the 200-E-102 Trench. Verification sampling would consist of testing the clean overburden removed above the crib structure prior to use as backfill material to ensure that it does not contain contaminants at concentrations above PRGs. Verification sampling would also be performed along the floor of the excavation to confirm that the 1×10^{-4} ELCR PRGs for individual radionuclides are achieved.

Under this alternative, there is potential for remedial action workers to be exposed to contaminants through direct contact or inhalation of airborne particulates. Due to the increased excavation depth, the highest concentrations of soil contamination directly beneath the base of the crib would not be encountered. The duration of this exposure would be short, and the potential for exposure can be reduced through careful planning and execution of the construction work, and through compliance with OSHA and DOE regulations. Perimeter air monitoring, personnel air monitoring, personal protective equipment and dust suppression measures can be used to further reduce the potential for worker exposure.

9.2.4.2 ARARs

Alternative 3 complies with chemical-specific, location-specific, and action-specific ARARs.

Chemical-specific ARARs. Alternative 3 complies with chemical-specific (soil-based) ARARs for human receptor exposure because contaminants are removed from the 0 to 3 m (10 ft) depth.

Compliance with chemical-specific (airborne release) ARARs associated with excavation and barrier construction would be verified through monitoring.

Location-specific ARARs. The crib and trench sites lie within a highly disturbed area south of the PUREX facility. Soil excavation and new vadose zone monitoring wells, will not result in any more disturbance than has already occurred during the original construction of the cribs and trench. Cultural resource surveys will be performed as warranted to ensure that Alternative 3 complies with ARARs for preservation of archaeological or historical data, protection of historic properties, and protection of Native American and archaeological sites.

Action-specific ARARs. Alternative 3 will comply with action-specific ARARs for worker protection and air emissions through monitoring programs, and through adherence to existing requirements associated with management of contaminated materials generated from the soil excavation and vadose zone monitoring well installation work. All construction work will be conducted under the existing environmental protection program, which is engaged substantively during the remedial design process, and integrated fully into work planning and execution.

9.2.4.3 Long-Term Effectiveness and Permanence

This criterion relates primarily to the health risks that remain at the site once RAOs are met, and the extent and effectiveness of controls required to manage the risk posed by untreated soil.

Alternative 3 would provide a moderate level of long-term effectiveness and permanence because subsurface soil from 0 to 3 m (10 ft) within the defined human health and ecological receptor points of compliance would be removed and transported to the ERDF for disposal and in-place treatment through radioactive decay.

Under Alternative 3, the need for ICs would be limited to maintaining land use as industrial, which is already established under DOE/EIS-0222-F. The reliability of this decision document to maintain industrial land use is expected to be very high.

The removal of contaminated soil from the sites for disposal at the ERDF consolidates waste from individual sites at one facility. The ERDF is designed for long-term management of dangerous waste, thus providing a much higher degree of permanence. The ERDF will be monitored and maintained for a long duration compared with an individual site remedy that may not be maintained to the same degree.

This alternative will require that 5-year reviews be conducted, because not all materials above PRGs will be removed.

9.2.4.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Alternative 3 achieves a moderate level of mobility reduction because contaminated shallow soil is moved to a secure facility (ERDF) with limited potential for future release. Toxicity and volume reduction are achieved at the ERDF through natural radioactive decay at rates comparable to those described for the No Action Alternative.

9.2.4.5 Short-Term Effectiveness

This criterion addresses the effects of the alternative to the community, remedial action workers, and the environment during the construction and implementation phase, and the timeframe required before RAOs are met.

Alternative 3 would pose moderate to high short-term risk to remedial action workers from excavation and handling of contaminated soil in the cribs. This risk can be minimized through careful planning and execution of the construction work and through compliance with OSHA and DOE regulations. Industrial worker and ecological receptor RAOs would be achieved from 0 to 3 m (10 ft) across a majority of the excavation footprint once the excavation site is backfilled, which is expected within 1 year of a subcontract award.

Physical disruption of the waste sites during excavation, increased human activity and noise, and generation of fugitive dust (outside the exclusion zone) could affect local biological resources.

9.2.4.6 Implementability

The excavation of contaminated soil to depths of 0 to 3 m (10 ft) poses low to moderate technical difficulty because of the shallow depth of excavation. The open cut excavations for the cribs will not require sloping and benching using conventional equipment. Excavation of the 200-E-102 Trench to 1.5 m (5 ft) poses lower degree of technical difficulty due to the shallow depth and lower anticipated contaminant concentrations.

The ability to expand the excavations if new contamination is discovered during the work may be limited with the open cut style excavation because of the large volume of overburden that has to be removed to expand a bench and deepen the excavation. Additionally, an increase in excavation footprint could encroach upon adjacent waste sites and infrastructure. All of the regulated waste would require disposal at the ERDF.

Future decommissioning of existing facilities and infrastructure (PUREX building and railroad tunnel), and implementation of remedies for adjacent CERCLA OUs could alter the scope of this alternative, potentially making some elements unnecessary or redundant. Therefore, selection and implementation of Alternative 3 will require planning and coordination with activities planned at adjacent areas.

9.2.4.7 Cost

Table 9-5 summarizes the total capital operations and maintenance and present worth costs for Alternative 3. Detailed backup information for these costs is provided in Appendix G.

Table 9-5. Alternative 3 Cost Summary

	Waste Site						
	216-A-2 Crib	216-A-4 Crib	216-A-21 Crib	216-A-27 Crib	200-E-102 Trench	216-B-4 Reverse Well	216-C-2 Reverse Well
Capital Cost	N/A	$1,894,000	$1,286,000	$1,573,000	$663,000	$3,517,000	$2,458,000
Annual and Periodic Costs	N/A	$0	$0	$0	N/A	$0	$0
Total Non-Discounted Cost	N/A	$1,894,000	$1,286,000	$1,573,000	$663,000	$3,517,000	$2,458,000
Total Present Worth Cost	N/A	$1,869,000	$1,286,000	$1,552,000	$663,000	$3,517,000	$2,458,000

Notes:

N/A = Not applicable

9.3 Comparative Analysis of Alternatives

This section provides a comparative analysis of alternatives for the 200-MW-1 OU waste sites. The comparative performance of each alternative against the CERCLA criteria is provided in Section 9.3.1 through Section 9.3.7. Table 9-6 provides a summary of the comparative analysis of alternatives, indicating relative rankings. This analysis provides rationale for identifying a preferred alternative and preparing the PP. The No Action Alternative was not carried forward into the comparative analysis because it did not meet the CERCLA threshold criteria.

9.3.1 Overall Protection of Human Health and the Environment

Based on the detailed analysis provided in Section 9.2, Alternative 3 provides the greatest degree of overall protection of HHE, followed by Alternative 2 and Alternative 1, respectively. The No Action Alternative provides the least degree of overall HHE protection.

Alternative 3 – RTD provides the highest degree of overall HHE protection of the 200-MW-1 OU alternatives. This alternative is applicable to the cribs, reverse wells, and 200-E-102 Trench where shallow soil contamination may exceed soil based PRGs within the defined point of compliance. Under this alternative, human health and ecological receptors are protected by removal of contamination that exceeds PRGs and disposal of excavated material at ERDF.

Alternative 2 – ET Barrier provides a slightly lower degree of overall HHE protection because the exposure pathway is blocked, rather than eliminated, through placement of an ET barrier. This alternative may leave shallow soil contamination in place at the cribs and trench within the defined point of compliance. ICs will also be implemented to provide an additional measure of protection.

Table 9-6. Comparative Analysis Ranking Summary for the 200-MW-1 OU Waste Sites

	Overall Protectiveness of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction in Toxicity, Mobility and Volume Through Treatment	Short-Term Effectiveness	Implementability	Cost[a] (Net Present Worth)
For the 216-A-2 Crib							
No Action	Yes	Yes	Not Ranked[b]				$0
Alternative 1 – ICs and MNA	Yes	Yes	○	○	○	○	NA
For the 216-A-4 Crib							
No Action	No	No	Not Ranked[b]				$0
Alternative 1 – ICs and MNA	Yes	Yes	○	○	○	○	$1,285,000
Alternative 2 – ET Barrier	Yes	Yes	◐	●	◐	◐	$1,860,000
Alternative 3 – RTD	Yes	Yes	○	○	◐	◐	$1,869,000
For the 216-A-21 Crib[a]							
No Action	No	No	Not Ranked[b]				$0
Alternative 1 – ICs and MNA	Yes	Yes	○	○	○	○	$1,285,000
Alternative 2 – ET Barrier	Yes	Yes	◐	●	◐	◐	$1,785,000
Alternative 3 – RTD	Yes	Yes	○	○	◐	◐	$1,286,000
For the 216-A-27 Crib[a]							
No Action	No	No	Not Ranked[b]				$0
Alternative 1 – ICs and MNA	Yes	Yes	○	○	○	○	$1,285,000
Alternative 2 – ET Barrier	Yes	Yes	◐	●	◐	◐	$1,857,000
Alternative 3 – RTD	Yes	Yes	○	○	◐	◐	$1,552,000
For the 200-E-102 Trench							
No Action	No	No	Not Ranked[b]				$0
Alternative 1 – ICs and MNA	Yes	Yes	○	○	○	○	$1,285,000
Alternative 3 – RTD	Yes	Yes	○	○	◐	◐	$663,000
For the 216-B-4 Reverse Well[a]							
No Action	No	No	Not Ranked[b]				$0
Alternative 1 – ICs and MNA	Yes	Yes	○	○	○	○	$1,535,000
Alternative 3 – RTD	Yes	Yes	○	○	●	●	$3,517,000

Table 9-6. Comparative Analysis Ranking Summary for the 200-MW-1 OU Waste Sites

	Overall Protectiveness of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction in Toxicity, Mobility and Volume Through Treatment	Short-Term Effectiveness	Implementability	Cost[a] (Net Present Worth)
For the 216-C-2 Reverse Well [a]							
No Action	No	No	Not Ranked [b]				$0
Alternative 1 – ICs and MNA	Yes	Yes	○	○	○	○	$1,509,000
Alternative 3 – RTD	Yes	Yes	○	○	●	●	$2,458,000

Notes:

a. These cost estimates are based on the best available information for the site-specific anticipated remedial actions. The actual costs are expected to range from -30 percent to +50 percent of these estimated values. Major changes to assumed remedial action scope can result in remedial action costs outside of this range. Net present worth calculations are based on 1,000 years.

b. No Action Alternative not ranked because it does not meet the threshold criteria.

NA = Not applicable

Explanation of Evaluation Metric

● = performs less well against the criterion relative to the other alternatives with significant disadvantages or uncertainty

◐ = performs moderately well against the criterion relative to the other alternatives with some disadvantages or uncertainty

○ = performs very well against the criterion relative to the other alternatives with minor disadvantages or uncertainty

Alternative 1 – ICs and MNA provide a lower degree of protectiveness for the cribs and 200-E-102 Trench where shallow soil contamination may be present within the defined point of compliance for human and ecological receptors. Alternative 1 protects human health and ecological receptors by maintaining ICs that prevent unauthorized access to the waste sites and by controlling ecological receptor encroachment through management programs. There are no active provisions under Alternative 1 for groundwater protection.

9.3.2 ARARs

The ARARs evaluation provided for each alternative in Section 9.2 indicates that each of the alternatives would comply with ARARs with the exception of the No Action Alternative. The primary variation in each alternative's effectiveness in complying with chemical specific ARARs is the duration required to achieve ARARs. Alternative 3 would meet chemical specific ARARs in the shortest duration followed by Alternative 2. Alternative 1 requires a longer duration to achieve chemical specific ARARs through natural attenuation.

9.3.3 Long-Term Effectiveness and Permanence

Based on the detailed analysis provided in Section 9.2, Alternative 3 performs best in terms of long-term effectiveness and permanence, followed by Alternative 2 and Alternative 1, respectively.

Alternative 3 – RTD is the next most favorable alternative in terms of long-term effectiveness and permanence. Removal of contaminated soils above shallow soil PRGs provides an effective and permanent remedy at each of these waste sites. Excavated soils will be disposed of at ERDF where radionuclide contaminants will decay naturally.

Alternative 2 – ET Barrier also provides a high level of effectiveness and permanence for shallow soil contamination above PRGs within the defined point of compliance. The effectiveness of the ET barrier in protecting groundwater is likely not as high as removing the contaminants from the site (see Appendix C). The ET barrier will require operation and maintenance to achieve long-term effectiveness.

Alternative 1 – ICs and MNA provide a lower level of long-term effectiveness and permanence for the cribs and 216-E-102 Trench where shallow soil contamination above PRGs may exist within the defined point of compliance. This alternative only addresses the potential adverse impacts to groundwater through natural attenuation. ICs, however, are effective in minimizing exposure to human and ecological receptors but must be maintained in the long-term until PRGs are reached through natural attenuation. This alternative provides an adequate level of long-term effectiveness at sites (216-A-2, 216-A-4, 216-A-21, 216-A-27, 216-B-4, and 216-C-2) where no shallow contamination above PRGs was identified within the defined point of compliance and no adverse groundwater impacts have been identified.

9.3.4 Reduction of Toxicity, Mobility, and Volume through Treatment

The evaluation provided in Section 9.2 for each alternative indicates that Alternative 3 provides the greatest reduction in toxicity, mobility, and volume, followed by Alternative 2 and Alternative 1, respectively. Reduction in contaminant toxicity and the volume of contaminated media through natural attenuation are equivalent for each alternative.

Alternative 3 – RTD provides the greatest reduction in toxicity mobility and volume for the units. This alternative provides the greatest reduction in contaminant mobility because the largest extent of contaminated soil is removed from the waste site and contained within the ERDF where the potential for further release and migration is much lower than leaving it in place.

Alternative 2 – ET Barrier provides a slightly lower reduction in contaminant mobility compared to Alternative 3, because shallow soils within the defined point of compliance are not removed and disposed of at ERDF.

Alternative 1 – ICs and MNA provides a reduction in mobility of shallow soil contaminants by maintaining a clean soil cover over the waste sites and preventing erosion. This alternative does not directly provide a reduction in contaminant mobility to groundwater outside of that provided by natural attenuation.

9.3.5 Short-Term Effectiveness

The detailed analysis provided in Section 9.2 indicates that Alternative 1 performs best in terms of short-term effectiveness, followed by Alternative 2 and Alternative 3, respectively.

Alternative 1–ICs and MNA protects the community and remedial action workers during remedial action implementation, and has very little environmental impact because the alternative is non-intrusive (i.e., does not disturb contaminated media). ICs and other existing Hanford Site programs are already in place and additional components of the alternative (for example, confirmatory sampling and installation of vadose zone boreholes) could be implemented relatively quickly. The time to achieve PRGs, however, is limited by the rate of natural attenuation.

Alternative 2–ET Barrier protects the community and remedial action workers during remedial action implementation and the alternative is non-intrusive (i.e., does not disturb contaminated media). This alternative has very little environmental impact because the area south of PUREX is highly disturbed. The time to implement the ET barrier is relatively short, and ICs and other existing Hanford site programs are already in place and additional components of the alternative (for example, confirmatory sampling and installation of vadose zone boreholes) could be implemented relatively quickly. The time to achieve PRGs however, is limited by the rate of natural attenuation.

Alternative 3–RTD compares less favorably among all of the alternatives in terms of the risks posed to remedial action workers. Due to the shallow excavation depths, the contaminant concentrations in the cribs and trench will be encountered. Excavation, handling, and transporting this material present more risk to workers and the community than the less intrusive alternatives. These risks can be mitigated during construction, and the alternative does offer a shorter time to achieve PRGs. Alternative 3 disturbs contaminated material posing a potential environmental and cultural resources impact of the 200-MW-1 OU alternatives. However, the area south of PUREX is highly disturbed and currently offers little or no ecological habitat.

9.3.6 Implementability

The evaluation provided in Section 9.2 for each alternative, indicates that Alternative 1 is the most readily implemented alternative, followed by Alternative 2 and Alternative 3, respectively.

Alternative 1 – ICs and MNA is readily implemented as evidenced by the institutional and engineering controls already in place at the Hanford site. Confirmatory sampling and installation of additional vadose zone boreholes can be implemented utilizing equipment and expertise readily available at the Hanford Site.

Alternative 2 – ET Barrier can also be implemented using standard construction methods and equipment with little technical difficulty using locally available materials. While this alternative is readily implementable in a short time frame, it is more technically involved than Alternative 1 and, therefore, ranks lower.

Alternative 3 – RTD presents low to moderate technical difficulty due to excavation of shallow soil contamination beneath the cribs and trench. The excavation can be accomplished using traditional excavation methods and equipment, however, health and safety requirements will need to be implemented to protect workers and prevent migration of contamination through fugitive dust emissions. Also, if the footprint or depth of contamination extends farther laterally or vertically than anticipated, the footprint of the excavation may encroach upon other site infrastructure (e.g., the PUREX railroad tunnel) which could pose significant technical challenges.

9.3.7 Cost

The cost analysis provided in Section 9.2 indicates that Alternative 1 is the lowest cost alternative in terms of present worth cost for the cribs, with Alternatives 2 and 3 being similar in terms of cost. However, because Alternative 3 does not incur any annual or periodic costs, it is the lowest cost alternative in terms of total non-discounted costs.

The cost of implementing Alternative 1 at the 200-E-102 Trench is higher than Alternative 3 in terms of present worth and total non-discounted costs. This is because the cost to excavate the relatively small quantity of contaminated soil is relatively low, and no long-term annual and periodic costs are incurred.

Table 9-7 provides a summary of costs for each of the alternatives applied to the 200-MW-1 OU waste sites.

Table 9-7. Cost Summary Comparison–Net Present Worth Cost Estimates (1,000 Years)

Cost	Alternative 1 Institutional Controls And MNA	Alternative 2 ET Barrier	Alternative 3 RTD to Meet Human and Ecological Use
216-A-2 Crib			
Capital Cost	N/A	N/A	N/A
Operations and Maintenance Cost	N/A	N/A	N/A
Non-discounted Cost	N/A	N/A	N/A
Present Worth Cost	N/A	N/A	N/A
216-A-4 Crib			
Capital Cost	$28,320	$603,454	$1,894,000
Operations and Maintenance Cost	$34,656,000	$34,656,000	$0
Non-discounted Cost	$34,684,000	$35,259,000	$1,894,000
Present Worth Cost	$1,285,000	$1,860,000	$1,869,000
216-A-21 Crib			
Capital Cost	$28,320	$528,577	$1,286,000
Operations and Maintenance Cost	$34,656,000	$34,656,000	$0
Non-discounted Cost	$34,684,000	$35,185,000	$1,286,000
Present Worth Cost	$1,285,000	$1,785,000	$1,286,000
216-A-27 Crib			
Capital Cost	$28,320	$600,644	$1,573,000
Operations and Maintenance Cost	$34,656,000	$34,656,000	$0
Non-discounted Cost	$34,684,000	$35,257,000	$1,573,000
Present Worth Cost	$1,285,000	$1,857,000	$1,552,000
200-E-102 Trench			
Capital Cost	$28,320	N/A	$663,000
Operations and Maintenance Cost	$34,656,000	N/A	$0
Non-discounted Cost	$34,684,000	N/A	$663,000
Present Worth Cost	$1,285,000	N/A	$663,000
216-B-4 Reverse Well			
Capital Cost	$278,320	N/A	$3,517,000
Operations and Maintenance Cost	$34,656,000	N/A	$0
Non-discounted Cost	$34,934,000	N/A	$3,517,000
Present Worth Cost	$1,535,000	N/A	$3,517,000

216-C-2 Reverse Well			
Capital Cost	$252,140	N/A	$2,458,000
Operations and Maintenance Cost	$34,656,000	N/A	$0
Non-discounted Cost	$34,908,000	N/A	$2,458,000
Present Worth Cost	$1,509,000	N/A	$2,458,000

Notes: These cost estimates are based on the best available information for the site-specific anticipated remedial actions. The actual costs are expected to range from -30 percent to +50 percent of these estimated values. Major changes to assumed remedial action scope can result in remedial action costs outside of this range. Net present worth calculations are based on 1,000 years.

The information in this cost estimate summary table is based on the best available information regarding the anticipated scope of the remedial alternatives. Changes in the cost elements are likely to occur as a result of new information and data collected during the engineering design of the remedial alternative. Major changes may be documented in the form of a memorandum in the administrative record file, an explanation of significant differences, or a ROD amendment. This is an order-of-magnitude engineering cost estimate that is expected to be within-30 to +50 percent of the actual project cost.

9.4 NEPA Values

This section addresses the incorporation of the NEPA values into CERCLA documents. This is consistent with DOE Order 451.1B Chg 1 that requires that CERCLA actions address and incorporate NEPA values such as socioeconomic, ecological, off-site, and cumulative impacts in CERCLA documents to the extent practicable.

Alternatives to address the release or threatened release of hazardous substances have been identified and analyzed in this RI/FS (Section 9). The No Action alternative would not mitigate the environmental impacts from the hazardous substances. All other alternatives could mitigate the impacts associated with the release or threatened release as well as provide for the remediation of the hazardous substances. Specifically, the application of the substantive environmental protection standards identified as ARARs would reduce impacts of the hazardous substances on air, surface waters, soil, groundwater, plants, and animals to levels that have been identified by regulation.

NEPA values associated with remediation are based on the detailed information presented in this RI/FS including the area and site characteristics (Sections 1, 2, and 3), contaminants of potential concern (Section 6), and identification and analysis of remedial actions (Sections 4 and 5). Applying a "sliding scale" of NEPA analysis to the 200-MW-1 OU using DOE's NEPA guidance (DOE, 2004, *Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements: Second Edition*), and considering the CERCLA applicable or relevant and appropriate requirements (ARARs) (detailed in Section 7.1.2), the principle resource areas of concern include the contaminants in the soils, solid and liquid radioactive and hazardous waste management, air emissions, potential adverse effects to historic and cultural resources, ecological resources, socioeconomics (including environmental justice concerns), and transportation.

For purposes of implementing the remediation alternative associated with soil removal (Section 9), when soils at a site in this operable unit are found to be contaminated with hazardous substances in concentrations presenting a material threat to HHE, that threat will be mitigated by meeting the applicable ARAR standards as well as following current DOE policy and guidance. The net anticipated effect could be an overall positive contribution to cumulative environmental effects at the Hanford Site through RTD of such hazardous substances and contaminants of concern into a facility that has been designed and legally authorized to safely contain such contaminants. DOE expects that ERDF will be the primary facility to receive contaminated soils. NEPA values specifically associated with ERDF were addressed in DOE-RL-94-41, *NEPA Roadmap for the Environmental Restoration Disposal Facility Regulatory Package*.

The NEPA values (i.e., resource area and relevant NEPA considerations) most relevant to and potentially affected by the actions taken place under this remedial action are described in Table 9-8.

In addition, DOE is including the combined effects anticipated from ongoing CERCLA Agreement (Ecology et al., 1989a) response actions as part of the cumulative impact analysis in DOE/EIS-0391, *Draft Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*. DOE/EIS-0391 includes a site-wide cumulative impact groundwater analysis. This presents the public with a separate opportunity for comment as part of that NEPA process and will be used to inform the public concerning ongoing implementing cleanup actions on the Hanford Site.

Table 9-8. NEPA Values Evaluation

NEPA Values	Description	Evaluation (Includes the Evaluation for Each Alternative)
Transportation	Considers impacts of the proposed action on local traffic (i.e., traffic at the Hanford Site) and traffic in the surrounding region.	Implementation of Alternatives 2 and 3 would be expected to produce short term impacts on local traffic. A majority of the impact is associated with increased truck traffic associated with the aforementioned Alternatives; they would involve transport of barrier material, in addition to removal, treatment, and disposal as contaminated soil is moved from a waste site(s) to ERDF. Transportation impacts were considered in the Environmental Restoration Disposal Facility RI/FS, DOE/RL-93-99, as part of the evaluation of short term effectiveness and implementability. NEPA values specifically associated with ERDF were addressed in DOE-RL-94-41, *NEPA Roadmap for the Environmental Restoration Disposal Facility Regulatory Package*. Transportation impacts associated with a waste site for sampling under Alternative 1, confirmation sampling/no further action, is considerably smaller than for Alternatives 3 since there would be no trips to the ERDF. See the discussion of cumulative impacts for a perspective of transportation to the ERDF.
Air Quality	Considers potential air quality concerns associated with emissions generated during the proposed action.	Airborne releases associated with Alternatives 2 and 3 would be expected to be minor with the use of appropriate work controls (e.g., sampling during favorable wind conditions, use of dust suppressants). Section 1.2 contains the site background for these waste sites. A maximum of 10,000 cubic yards of contaminated soil would be removed (Alternative 3, RTD). Any potential of airborne release of contaminants during alternative remedial actions would be controlled in accordance with DOE radiation control and air pollution control standards, to minimize emissions of air pollutants at the Hanford Site, and protect all communities outside the Site boundaries. Operation of trucks and other diesel-powered equipment for these alternatives would be expected, in the short-term, to introduce quantities of sulfur dioxide,

Table 9-8. NEPA Values Evaluation

NEPA Values	Description	Evaluation (Includes the Evaluation for Each Alternative)
		nitrogen dioxide, particulates, and other pollutants to the atmosphere, typical of similar-sized construction projects. These releases would not be expected to cause any air quality standards to be exceeded and (as needed) dust generated during remedial activities would be minimized by watering or other dust-control measures. Vehicular and equipment emissions would be controlled and mitigated in compliance with the substantive standards for air quality protection that apply to the Hanford Site.
Natural, Cultural, and Historical Resources	Considers impacts of the proposed action on wildlife, wildlife habitat, archeological sites and artifacts, and historically significant properties.	Impacts on ecological resources in the vicinity of the remedial actions would be mitigated in accordance with DOE/RL-96-32 and DOE/RL-96-88, and with the applicable standards of all relevant biological species protection regulations. Because these sites have already been disturbed, and only isolated artifacts could be encountered during project activities, implementation of DOE/RL-98-10 and consultation with area Tribes would help ensure appropriate mitigation to avoid or minimize any adverse cultural or historical resource effects and address any relevant concerns. Impacts to other cultural values will be minimized through implementation of DOE/RL-98-10, DOE/RL-2005-27, and consultation with area Tribes as needed. This will help ensure appropriate mitigation to avoid or minimize any adverse effects to natural and cultural resources and address any other relevant concerns. Potential impacts to cultural and historical resources that may be encountered during the short-term construction activities associated with implementing the action would be mitigated through compliance with the appropriate substantive requirements of the *National Historic Preservation Act of 1966* and other ARARs related to cultural preservation.
Socioeconomic Impacts	Considers impacts pertaining to employment, income, other services (e.g., water and power utilities), and the effect of implementation of the proposed action on the availability of services and materials.	The proposed action is within the scope of current DOE, Richland Operations Office environmental restoration activities and would have minimal impact on the current availability of services and materials. This work would be expected to be accomplished largely using employees from the existing contractor workforce. Even if the remedial activities creates additional service sector jobs, the total expected increase in employment would be expected to be less than 1% of the current employment levels. The socioeconomic impact of the project would contribute to the continuing overall positive employment and economic impacts on eastern Washington communities from Hanford Site cleanup operations.
Environmental Justice	Considers whether the proposed response actions would have inappropriately or disproportionately high and adverse HHE effects on minority or low income populations.	Per Executive Order 12898, DOE seeks to ensure that no group of people bears a disproportionate share of negative environmental consequences resulting from proposed federal actions. There are no impacts associated with proposed activities associated with the 200-MW-1 OU that could reasonably be determined to

Table 9-8. NEPA Values Evaluation

NEPA Values	Description	Evaluation (Includes the Evaluation for Each Alternative)
		affect any member of the public; therefore, they would not have the potential for high and disproportional adverse impacts on minority or low-income groups.
Cumulative Impacts (Direct and Indirect)	Considers whether the proposed action could have cumulative impacts on HHE when considered together with other activities locally, at the Hanford Site, or in the region.	The environmental concern of the 200-MW-1 OU is associated directly with the targeted area. Because of the temporary nature of the activities and their remote location, cumulative impacts on air quality or noise with other Hanford Site or regional construction and cleanup projects would be minimal. When soils at a site in this operable unit are found to be contaminated with hazardous substances in concentrations presenting a material threat to HHE, that threat would be mitigated. The net anticipated effect could be a positive contribution to cumulative environmental effects at the Hanford Site through removal, treatment, and disposal of such hazardous substances and contaminants of concern into a facility that has been designed and legally authorized to safely contain such contaminants, like the ERDF. Contaminated soil removed under any alternative would meet the ERDF waste acceptable criteria as described in WCH-191. The volume of soil that could be generated for disposal during implementation of the remedial action is estimated to be approximately 14,000 cubic yards over the expected duration of this action (the action is anticipated to occur over a 0.5 year period (assuming concurrent activities), resulting in approximately 14,000 cubic yards per year (and attendant transportation requirements). Wastes generated during implementation of the proposed Alternatives would be manageable within the capacities of existing facilities. For perspective, the ERDF received over 700,000 tons of waste in calendar year 2008 and over 430,000 tons in calendar year 2007). Radiological contamination is expected to be minimal; by definition these are waste sites that are believed to be shallow in nature, do not impact groundwater, and have relatively small inventories. The ERDF received approximately 22,500 Ci in calendar year 2008 and approximately 13,000 Ci in calendar year 2007.
Mitigation	Considers whether or not if adverse impacts cannot be avoided, response action planning should minimize them to the extent practicable. This value identifies required mitigation activities.	Compliance with the substantive requirements of the ARARs would mitigate potential environmental impacts on the natural environment, including migratory birds, and endangered species. DOE has also established policies and procedures for the management of ecological and cultural resources when actions might affect such resources (DOE/RL-96-32; DOE/RL-96-88, and DOE/RL-98-10). Cultural resource and biological species reviews/surveys are undertaken that also provide suggested mitigation activities to ensure that adverse effects associated with implementing the actions are minimized or avoided. Health and safety procedures, documented in the Health and Safety Plan, established by site contractors would mitigate risks to workers from the remedial activities.

Table 9-8. NEPA Values Evaluation

NEPA Values	Description	Evaluation (Includes the Evaluation for Each Alternative)
Irreversible and Irretrievable Commitment of Resources	Considers the use of nonrenewable resources for the proposed response actions and the effects that resource consumption would have on future generations. (When a resource [e.g., energy minerals, water, wetland] is used or destroyed and cannot be replaced within a reasonable amount of time, its use is considered irreversible.)	Materials used to backfill the waste site that would be removed under Alternatives 2 and 3 would be taken, if needed, from the surrounding area to contour the backfill to match the surrounding area. For both Alternatives 2 and 3, normal usage of resources during construction activities, such as fuel and water, would be irreversibly used. Restoration of formerly disturbed areas to a more natural state would be expected to result in a net benefit to the ecological and visual resources within the region.

Notes:

DOE/RL-93-99, *Remedial Investigation and Feasibility Study Report for the Environmental Restoration Disposal Facility.*

DOE/RL-94-41, *NEPA Roadmap for the Environmental Restoration Disposal Facility Regulatory Package.*

DOE/RL-96-32, *Hanford Site Biological Resources Management Plan.*

DOE/RL-96-88, *Hanford Site Biological Resources Mitigation Strategy.*

DOE/RL-98-10, *Hanford Cultural Resources Management Plan.*

DOE/RL-2005-27, *Revised Mitigation Action Plan for the Environmental Restoration Disposal Facility.*

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations.*

WCH-191, *Environmental Restoration Disposal Facility Waste Acceptance Criteria.*

9.5 CERCLA and RCRA Corrective Action

The HFFACO states the intent of the Parties that CERCLA remediation at the Hanford Site will also fulfill the corrective action requirements for Hanford as a facility containing permitted TSD units. Ecology et al., 1989a guides integration and coordination of CERCLA and RCRA at federal facilities such as the Hanford Site. Key language specific to past-practice unit cleanup includes the following:

- Article IV, Paragraph 17, which cites the Tri-Parties intent "to integrate DOE's CERCLA response obligations and RCRA corrective action obligations which relate to the release(s) of hazardous substances, hazardous wastes, pollutants and contaminants" covered by Ecology et al., 1989a.
- Article XIV, which applies to the performance of both CERCLA remedial action and RCRA corrective action.
- Article XXIII, which acknowledges the potential for overlap between CERCLA and RCRA cleanup.
- Article XXIV, which specifies the approach for regulatory oversight. Section 5.4 of Ecology et al., 1989b, *Hanford Federal Facility Agreement and Consent Order Action Plan,* which addresses the rationale and approach for past-practice cleanup. Two key objectives are to "ensure that only one past-practice program will be applied at each operable unit" and that the "process selected be sufficiently comprehensive to satisfy the technical requirements of both statutory authorities and the respective regulations."

In accordance with Ecology et al., 1989a, Parts Three and Four, and Ecology et al., 1989b, Sections 5.4, 5.6, and 7.0, past-practice cleanup (remediation) is intended to satisfy both CERCLA remedial action and RCRA corrective action requirements. In addition to fulfilling CERCLA requirements, this preferred remedial action is intended to fulfill DOE's corrective action obligations under RCW 70.105, "Hazardous Waste Management," for the units identified herein. The Tri-Parties agree that the selected preferred alternative is sufficiently comprehensive to satisfy the technical requirements of both statutory authorities and the respective regulations.

The DOE's corrective action obligation on the Hanford Site is addressed in the RCRA Hanford Facility Permit (Ecology, 2007, *Hanford Facility Resource Conservation and Recovery Act Permit*, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste [WA7890008967]), Condition II.Y.2.a, which provides that DOE corrective action obligations are met through adherence to the Tri-Party Agreement. In particular, WAC 173-340-700 through 173-340-760, "Cleanup Standards," function as ARAR standards for CERCLA remedial actions on the Hanford Site. In accordance with the Tri-Party Agreement, past-practice cleanup (remediation) is intended to satisfy both CERCLA remedial action and RCRA corrective action requirements. In addition to fulfilling CERCLA requirements, this preferred remedial action is intended to fulfill DOE's corrective action obligations in the "Hazardous Waste Management Act." The Tri-Parties agree that the selected preferred alternative is sufficiently comprehensive to satisfy the technical requirements of both CERCLA and RCRA corrective action.

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300.430(e)(3)(2).

300.430(e)(6).

300.430(e)(9)(iii), "Detailed Analysis of Alternatives," "Nine Criteria for Evaluation."

300.430(f)(1)(ii)(C), "Selection of Remedy."

40 CFR 302.4, "Designation, Reportable Quantities, and Notification," "Designation of Hazardous Substances," Appendix B, "Radionuclides," *Code of Federal Regulations*. Available at: http://edocket.access.gpo.gov/cfr_2009/julqtr/40cfr302.4.htm.

40 CFR 761, "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions," *Code of Federal Regulations*. Available at: http://www.access.gpo.gov/nara/cfr/waisidx_08/40cfr761_08.html.

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Appendices are provided on disk.

Appendices A – G

(Provided on CD)

Appendix A

Analytical Data for Split-Spoon and Grab Samples from the 216-A-4 and 216-A-2 Cribs

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A1 Introduction

This appendix provides data from the analyses performed from split-spoon and grab samples collected at the 216-A-4 Crib (Table A1-1 and Table A1-2) and at the 216-A-2 Crib (Table A1-3 and Table A1-4). Parameters for the sample analyses performed at each borehole are presented in each of the tables. The distance between the sample intervals generally increased below depths of about 9.14 to 13.7 m (30 to 45 ft) because these depths were below the zone of highest contamination.

Samples collected from depths greater than 4.6 m (15 ft) below ground surface (bgs) were used to verify conceptual contaminant distribution models and to evaluate remedial action alternatives (RAOs) and groundwater impacts.

A total of 67 split-spoon samples were collected from the five boreholes, including 37 primary samples, seven duplicate/split samples, and 23 quality control (QC) samples. This sample data set was used for risk assessment evaluation. A total of 327 grab samples were collected from the boreholes, and a subset of these were analyzed. The results were used to provide additional information on the vertical distribution of contaminants of concern (COCs) and general geochemistry of the subsurface.

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