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Revision 0

Feasibility Study for the Plutonium/Organic-Rich Process Condensate/ Process Waste Group Operable Unit: Includes the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units

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

U.S. DEPARTMENT OF ENERGY
Richland Operations Office

P.O. Box 550
Richland, Washington 99352

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Approval Page

Title *Feasibility Study for the Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit: Includes the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*

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Executive Summary

This feasibility study (FS) addresses 16 *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*[1] (CERCLA) past practice liquid waste disposal sites within three operable units (OUs)—the 200-PW-1, 200-PW-3, and 200-PW-6 OUs—which are located in the 200 West and 200 East Areas of the Hanford Site within the industrial land use boundary. The purpose of this FS is to develop a comprehensive, defensible, and balanced analysis of remedial alternatives—cleanup actions—that adequately address the risks to human health and the environment from the soil contamination associated with these waste sites.

Three contaminant impact assessments typically included as part of the remedial investigation (RI) phase of the RI/FS—the baseline risk assessment, the ecological risk assessment, and the fate and transport evaluation for groundwater protection—were completed during the FS phase and are therefore included as appendices to this report.

Previous remedial action at these OUs consists of an Expedited Response Action to address high concentrations of carbon tetrachloride in the vadose zone beneath several 200-PW-1 OU sites (216-Z-1A, 216-Z-9, and 216-Z-18) using soil vapor extraction (SVE). This action was initiated in 1992 and continues through the present time. Removal of the abovegrade structures at the 216-Z-9 Trench was initially planned to be addressed as a removal action; these structures are now included in this FS for the 200-PW-1 OU.

The final soil contaminants of potential concern (COPCs) that are considered to be *principal threat* contaminants include the following:

- Plutonium-239/240, americium-241, and cesium-137 (based on toxicity and baseline risk results)
- Carbon tetrachloride and methylene chloride (based on toxicity and mobility)

The remaining final COPCs (neptunium-237, radium-226, cadmium, manganese, and thallium) are considered to be *low-level threat* contaminants. Technetium-99 and nitrate were retained as potential threats to the groundwater. Additional sampling for mobile

[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.

contaminants is warranted to improve the approximate distribution of these contaminants in the vadose zone and to improve estimates of the potential threat to the groundwater.

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 concluded that with no remedial action, and under an assumed unrestricted land use scenario at the locations of the 200-PW-1, 200-PW-3, and 200-PW-6 waste sites, there could be risks above the CERCLA acceptable risk range to future human populations. Carbon tetrachloride and other potential contaminants could continue to migrate downward and contaminate groundwater above CERCLA response levels. There is no identified or projected ecological risk.

The 200-PW-1, 200-PW-3, and 200-PW-6 waste sites are all located within the approximately 52 km^2 (20 mi^2) Central Plateau area that has been designated as an industrial land use area for the treatment, storage, and disposal of hazardous, dangerous, radioactive, and nonradioactive wastes, and related industrial activities. The industrial land use area was officially designated in DOE/EIS-0222-F, *Final Hanford Comprehensive Land Use Plan Environmental Impact Statement*,[2] and its accompanying 64 FR 61615, "Record of Decision: Hanford Comprehensive Land Use Plan Environmental Impact Statement (HCP EIS)."[3]

Because the current and the reasonably anticipated future land use for the 200-PW-1, 200-PW-3, and 200-PW-6 areas at the completion of remediation is industrial use, a industrial worker scenario was used to guide the development of remedial action objectives (RAOs) and formulation of remedial action alternatives. The industrial worker exposure scenario assumes that the workplace is the key source of contaminant exposure with 6 hours per day spent indoors and 2 hours per day spent outdoors for 250 working days per year and a 25-year exposure duration. Potential routes of exposure to soil include direct external exposure, incidental soil ingestion, and inhalation of dust

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

[3] 64 FR 61615, "Record of Decision: Hanford Comprehensive Land Use Plan Environmental Impact Statement (HCP EIS)," *Federal Register*, Vol. 64, No. 218, pp. 61615-61625, November 12, 1999. Available at: http://gc.energy.gov/NEPA/nepa_documents/rods/1999/61615.pdf.

generated from wind or maintenance activities. The routes of industrial activity exposure were conservatively estimated to occur from ground surface to a depth of 4.6 m (15 ft), to accommodate the possibility of occasional subsurface construction or maintenance activities along utility corridors by workers as part of the industrial scenario.

The RAOs (Figure ES-1) were established to evaluate whether the remedial alternatives achieve compliance with potential applicable or relevant and appropriate requirements (ARARs) and/or an acceptable reduction of risk for the industrial worker scenario. A range of remedial alternatives applicable to source control actions at the waste sites were developed and evaluated to protect human health and the environment as stated in the RAOs. In addition, the development of remedial alternatives also considered the feedback obtained from an early involvement public workshop that was held on April 15, 2008, to present draft remedial alternatives for the 200-PW-1 OU waste sites. As a result of that workshop, the Hanford Advisory Board issued Consensus Advice #207 on June 6, 2008, containing considerations that the Board believes are important to the development of the Proposed Plan for this OU. This FS report incorporates the criteria provided by the Board and the remedial alternatives evaluated in this FS are summarized in Table ES-1.

RAO 1. Prevent or mitigate unacceptable risk to human health and ecological receptors associated with radiological exposure to wastes or soil contaminated above risk-based criteria by removing the source or eliminating the pathway.

RAO 2. Prevent or mitigate unacceptable risk to human and ecological receptors associated with nonradiological exposure to wastes or soil contaminated above risk-based criteria by removing the source or eliminating the pathway.

RAO 3. Control the sources of potential groundwater contamination to support the Central Plateau groundwater goal of restoring and protecting the beneficial uses of groundwater, including protecting the Columbia River from adverse impacts.

Figure ES-1. Remedial Action Objectives

All of the remedial alternatives, except the No Action Alternative, include several common components, including the following:

- Institutional controls, long-term monitoring, and maintenance will be required where residual contamination remains above cleanup acceptable risk levels.
- Soil vapor extraction will be required to continue at 216-Z-1A Tile Field, 216-Z-9 Trench, and 216-Z-18 Crib
- Waste sites remediated under Removal, Treatment and Disposal (RTD) will be sampled to confirm that cleanup goals have been achieved

- Sampling of technetium-99 and/or nitrate will be required at some sites to determine if action is required.
- Sludge will be removed from the Settling Tanks and then they will be grouted.
- No Action is required at the 216-Z-8 French Drain and 216-Z-10 Injection/Reverse Well.
- Environmental surveillance and groundwater monitoring would be performed to ensure the remedy is protective of HHE.

Table ES-1. Remedial Alternatives Evaluated for 200-PW-1, 200-PW-3, and 200-PW-6 OUs

Alternative	Description
"No Action"	The National Contingency Plan (NCP) requires consideration of a No Action Alternative. This alternative would leave a waste site "as-is" in its current state, with no additional remedial activities or access restrictions.
Alternative 1–Barrier	This alternative provides no treatment for radionuclides, but prevents and controls exposure to hazardous substances through engineering controls and institutional controls to protect human health and the environment.
Alternative 2–In Situ Vitrification (ISV)	This alternative uses in situ vitrification to reduce the mobility of hazardous substances as a principal element. It is primarily considered applicable for the 200-PW-1 OU waste sites that contain plutonium and americium. Institutional controls are also a component of this alternative at waste sites where the treatment process leaves residual contamination that will require long-term controls.
Alternative 3–Removal, Treatment and Disposal (RTD)	This alternative removes waste site soil, sludge, and/or debris, treating it as necessary to meet ARARs, and then disposing of it at Hanford (Environmental Restoration Disposal Facility [ERDF]) or offsite (Waste Isolation Pilot Plant [WIPP]) as appropriate. Five RTD options, listed below, were developed to achieve different removal objectives. For the RTD options that leave residual contamination above risk levels, institutional controls and evapotranspiration barriers are incorporated as components to protect human health and the environment.
RTD Option 3A	Remove the highest concentrations of contaminated soils to 0.6 m (2 ft) below the base of a waste site.
RTD Option 3B	Remove contaminated soils that could be a direct contact risk to industrial workers and that are less than 4.6 m (15 ft) below the current ground surface.
RTD Option 3C	Remove a significant portion of plutonium contamination based on an evaluation of soil contaminant concentration with depth. A significant portion of Cs-137 contamination would be removed at the Cs-137 waste sites based on a similar evaluation.
RTD Option 3D	Remove contaminated soils containing greater than 100 nCi/g of transuranic radionuclides.
RTD Option 3E	Remove contaminated soils with greater than a 10^{-4} risk level so that long-term institutional controls at a waste site are not necessary.

The remedial alternatives were evaluated with respect to the first seven of the nine CERCLA criteria (EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*)[4] in a detailed analysis (Chapter 6.0) and in a comparative analysis (Chapter 7):

- *Threshold Criteria*
  - Overall protection of human health and the environment
  - Compliance with ARARs
- *Balancing Criteria*
  - Long-term effectiveness and permanence
  - Reduction of toxicity, mobility, or volume through treatment
  - Short-term effectiveness
  - Implementability
  - Cost

The key findings of these FS evaluations are the following:

- Alternatives 1, 2, and 3 are protective and would comply with potential ARARs.
- Alternatives 1, 2, and 3 require long-term institutional controls for residual contamination, except for Alternative 2 at the Low-Salt waste sites and the Alternative 3 RTD options where excavation from 6.7 to ≥27.4 m (22 to ≥90 ft) at some waste sites would be required before institutional controls are not necessary for long-term protection of human health and the environment.

The remedial action footprint from waste site excavation, soil stockpile, and haul roads, contaminated soil handled, and backfill volumes required, the short-term impacts to remedial action workers and the environment, implementability issues, and costs all increase with RTD depth in Alternative 3 without a proportionate increase in long-term effectiveness and permanence.

The remedial alternatives, which are summarized in Table ES-2 and the Proposed Plan (DOE/RL-2009-117, *Proposed Plan for 200-CW-5, 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*),[5] consider the key trade-offs between the remedial alternatives identified

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[4] EPA/540/G-89/004, 1988, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, Interim Final, OSWER Directive 9355.3-01, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://epa.gov/superfund/policy/remedy/pdfs/540g-89004-s.pdf.

[5] DOE/RL-2009-117, in process, *Proposed Plan for 200-CW-5, 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

in this FS, risk management judgments, and the cost-effectiveness of each alternative. The two CERCLA modifying criteria (State acceptance and Community acceptance) will be evaluated by the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE) through the public review process of the Proposed Plan (EPA/540/G-89/004) and documented in a Record of Decision for the 200-CW-5, 200-PW-1, 200-PW-3, and 200-PW-6 OUs. In addition, specific pipelines connected to the waste sites would be remediated as a part of the remedial decision for these four OUs.

Table ES-2. Comparative Analysis Summary for the 200-PW-1, 200-PW-3, and 200-PW-6 Sites

Alternatives	Threshold Criteria		Balancing Criteria				
	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume	Short-term Effectiveness	Implementability	Cost[a,d] (Present Worth in $ Million)
High-Salt Waste Group 216-Z-1A Tile Field, 216-Z-9 Trench, and 216-Z-18 Crib							
No Action	No	No	Not Ranked[b]				$0
Barrier	Yes	Yes	◐	◐[c]	○	○	$19.1
ISV	Yes	Yes	◐	◐[c]	◐	●	$94.0
RTD Option A	Yes	Yes	◐	◐[c]	◐	◐	$112
RTD Option B	Yes	Yes	◐	◐[c]	◐	◐	$77.5
RTD Option C	Yes	Yes	◐	◐[c]	◐	◐	$642
RTD Option D	Yes	Yes	◐	◐[c]	◐	●	$917
RTD Option E	Yes	Yes	○	◐[c]	◐	●	$896
Low-Salt Waste Group 216-Z-1&2 Cribs, 216-Z-3 Crib, 216-Z-12 Crib and 216-Z-5 Crib							
No Action	No	No	Not Ranked[b]				$0
Barrier	Yes	Yes	◐	●	○	○	$10.1
ISV	Yes	Yes	◐	●	◐	●	$23.7
RTD Option A	Yes	Yes	◐	●	◐	◐	$61.8
RTD Option C	Yes	Yes	○	●	◐	◐	$81.4
RTD Option D	Yes	Yes	○	●	◐	●	$81.4
RTD Option E	Yes	Yes	○	●	◐	◐	$81.4

Table ES-2. Comparative Analysis Summary for the 200-PW-1, 200-PW-3, and 200-PW-6 Sites

Alternatives	Threshold Criteria		Balancing Criteria				
	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume	Short-term Effectiveness	Implementability	Cost[a,d] (Present Worth in $ Million)
Cesium-137 Waste Group 216-A-7 Crib, 216-A-8 Crib, 216-A-24 Crib, 216-A-31 Crib and UPR-200-E-56 Unplanned Release							
No Action	No	No	Not Ranked [b]				$0
Barrier (ET)	Yes	Yes	◐	●	○	○	$12.2
Barrier (MEESC)	Yes	Yes	◐	●	○	○	$11.1
RTD Option B	Yes	Yes	◐	●	◐	◐	$19.6
RTD Option C	Yes	Yes	◐	●	◐	◐	$29.1
Settling Tanks 241-Z-361 Settling Tank and 241-Z-8 Settling Tank							
No Action	No	No	Not Ranked[b]				$0
RTD—Remove Tank Contents	Yes	Yes	○	●	◐	◐	$39.6
Other 216-Z-8 French Drain and 216-Z-10 Reverse Well							
No Action	Yes	Yes	Not Ranked				$0.16
Barrier	Not Evaluated						
ISV	Not Evaluated						
RTD	Not Evaluated						

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

b. The No Action Alternative is not ranked because it does not meet the threshold criteria.

c. Carbon tetrachloride and other volatile organic compounds removed by soil vapor extraction are subject to treatment.

d. Disposal costs to the Waste Isolation Pilot Plant (WIPP) are included here. Costs for confirmatory sampling (about $30 million) for mobile contaminants and pipeline removal costs (about $4.9 million) are not included here. DOE-RL pays for transporting transuranic waste to WIPP, but WIPP disposal costs are paid through a different DOE budget.

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

The *Hanford Site Cleanup Completion Framework* (DOE/RL-2009-10) presents a description of how the remediation of the 200-CW-5, 200-PW-1, 200-PW-3, and 200-PW-6 OUs fits within DOE's overall cleanup and risk management strategy for Hanford. The Cleanup Completion Framework outlines DOE's proposals to do the following:

- Contain and remediate contaminated groundwater
- Implement a geographic cleanup approach that guides remedy selection from a plateau-wide perspective
- Evaluate and deploy viable treatment methods for deep vadose zone contamination
- Conduct essential waste management operations in coordination with cleanup actions

One aspect of the Cleanup Completion Framework is to put in place a process to identify the "final footprint" for long-term waste management and containment of residual contamination. The overall cleanup objective is to make the final footprint of the Inner Area as small as practical. DOE intends for this final footprint to remain under federal ownership and control for as long as a potential hazard exists.

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Terms

ac	acre
ARAR	applicable or relevant and appropriate requirement
bgs	below ground surface
BNI	Bechtel National, Inc.
BRA	baseline risk assessment
CCU	Cold Creek Unit
CDF	controlled density fill
CEM	conceptual exposure 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
CPM	counts per minute
CSM	conceptual site model
CT	carbon tetrachloride
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CWC	Central Waste Complex
D&D	decontamination and decommissioning
DBBP	dibutyl butyl phosphate
DNAPL	dense, nonaqueous phase liquid
DOE	U.S. Department of Energy
DOE-RL	DOE Richland Operations Office, also known as RL
DSA	documented safety analysis
Ecology	Washington State Department of Ecology
ECR	ecological compliance review
ELCR	excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
ERH	electrical resistance heating
ESA	*Endangered Species Act of 1973*
ET	evapotranspiration

FS	feasibility study
FY	fiscal year
GAC	granular activated carbon
GRA	general response action
ha	hectare
HAB	Hanford Advisory Board
HCP EIS	Hanford Comprehensive Land Use Plan Environmental Impact Statement
HEPA	high-efficiency particulate air
HI	hazard index
HHE	human health and the environment
HMS	Hanford Meteorological Station
HQ	hazard quotient
IC	institutional control
ISV	in situ vitrification
MCL	maximum contaminant level
MEESC	maintain and enhance existing soil cover
MNA	monitored natural attenuation
NCP	National Contingency Plan
NDA	non-destructive analysis
NEPA	*National Environmental Policy Act of 1969*
NPH	normal paraffin hydrocarbon
NPL	National Priorities List
O&M	operations and maintenance
OSWER	Office of Solid Waste Emergency Response
OU	operable unit
PCB	polychlorinated biphenyl
PFP	Plutonium Finishing Plant
PNNL	Pacific Northwest National Laboratory
ppmv	parts per million by volume
PRF	Plutonium Reclamation Facility
PRG	preliminary remediation goal
PUREX	Plutonium Uranium Extraction

RAO	remedial action objective
RBC	risk based concentration
RCRA	*Resource Conservation and Recovery Act of 1976*
RCW	Revised Code of Washington
RECUPLEX	Recovery of Uranium and Plutonium by Extraction
RESRAD	RESidual RADioactivity (dose model)
RfD	reducing reference dose
RI	remedial investigation
RME	reasonable maximum exposure
ROD	record of decision
RTD	removal, treatment, and disposal
SLERA	screening level ecological risk assessment
SPV	subsurface planar vitrification
SST	stainless steel
SVE	soil vapor extraction
SWB	standard waste box
TBP	tributyl phosphate
TSD	treatment, storage, and disposal
UPR	unplanned response
USFWS	U.S. Fish and Wildlife Service
VCP	vitrified clay piping
VOC	volatile organic compound
WAC	*Washington Administrative Code*
WCH	Washington Closure Hanford, LLC
WIPP	Waste Isolation Pilot Plant

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1 Introduction

The Hanford Site, managed by the U.S. Department of Energy (DOE), encompasses approximately 1,517 km^2 (586 mi^2) in the Columbia Basin of south-central Washington State. In 1989, the U.S. Environmental Protection Agency (EPA) placed the 100, 200, 300, and 1100 Areas of the Hanford Site on the 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan" (National Contingency Plan [NCP]), Appendix B, "National Priorities List" (NPL), pursuant to the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA). The process for characterization and remediation of waste sites at the Hanford Site is addressed in Ecology et al., 1989, *Hanford Federal Facility Agreement and Consent Order*, commonly referred to as the Tri-Party Agreement. Submittal of Draft A of this feasibility study (FS) by September 30, 2007, met TPA Milestone M-015-45B.

The 200 Area NPL site is in a region referred to as the Central Plateau and consists of the 200 West Area and 200 East Area (Figure 1-1). The 200 Area contains approximately 800 waste sites that include waste management facilities and inactive irradiated nuclear fuel reprocessing facilities. These sites are managed by the DOE Richland Operations Office, also known as RL (DOE-RL), excluding sites assigned to the Tank Farms Waste Management Area. Several waste sites in the 600 Area, located near the 200 Area, also are included in the 200 Area NPL.

As part of the approach to waste site cleanup, RL, EPA, and the Washington State Department of Ecology (Ecology), known as the Tri-Parties, agreed to consolidate the 23 process-based operable units (OUs) into 12 groups based on similarities between contaminant sources (TPA Milestones M-13-02-01 and M-15-02-01, approved in June 2002). As a result of this process, the Plutonium/Organic-Rich Process Condensate/Process Waste Group OU (200-PW-1 OU), the Organic-Rich Process Condensate/Process Waste Group OU (200-PW-3 OU), and the Plutonium Process Condensate/Process Waste Group OU (200-PW-6 OU) were consolidated into one group—the Plutonium/Organic-Rich Group OU—because the waste sites in all three OUs received Plutonium and/or Organic-Rich process condensates and process wastes. All of the waste sites in these three OUs are located in the 200 East and 200 West Areas (Figures 1-2 through 1-4).

During the remedial investigation (RI), reported in DOE/RL-2006-51, *Remedial Investigation Report for the Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit: Includes the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units* (hereafter referred to as the RI Report), data were collected in accordance with DOE/RL-2001-01, *Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit RI/FS Work Plan: Includes the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units* (hereafter referred to as the PW Work Plan) to characterize the nature and extent of chemical and radiological contamination and physical conditions in the vadose zone underlying two waste sites: the 216-Z-9 Trench and the 216-A-8 Crib. The RI summarizes the characterization data for all of the waste sites in the three OUs, which is sufficient to support the evaluation of remedial alternatives presented in this FS report.

The 16 waste sites in the three OUs addressed in this FS report were organized into four waste groups based on process waste type, primary contaminants, and similarities in the distribution of contaminants in the subsurface. As shown in Table 1-1, the four waste groups include High-Salt, Low-Salt, Cesium-137 (Cs-137), and Settling Tank. The remediation of waste sites in this OU will also address the pipelines which conveyed the wastes to their respective waste units. Detailed pipeline information is located in Appendix H of this document. Characterization data from the well-characterized liquid waste disposal sites revealed a clear, consistent correlation between the type of waste disposed and the current distribution of contaminants in the subsurface.

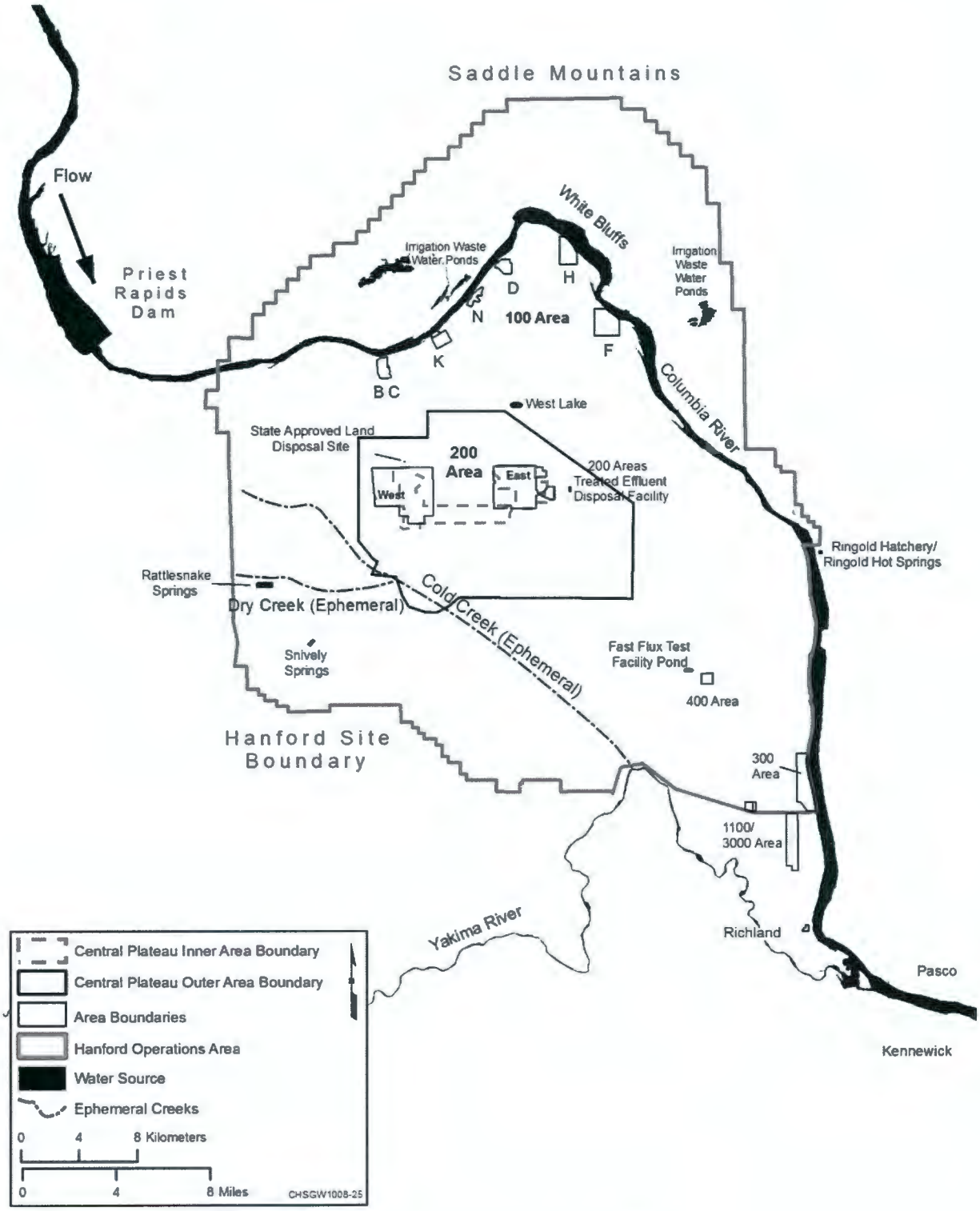

Figure 1-1. Location of the Hanford Site

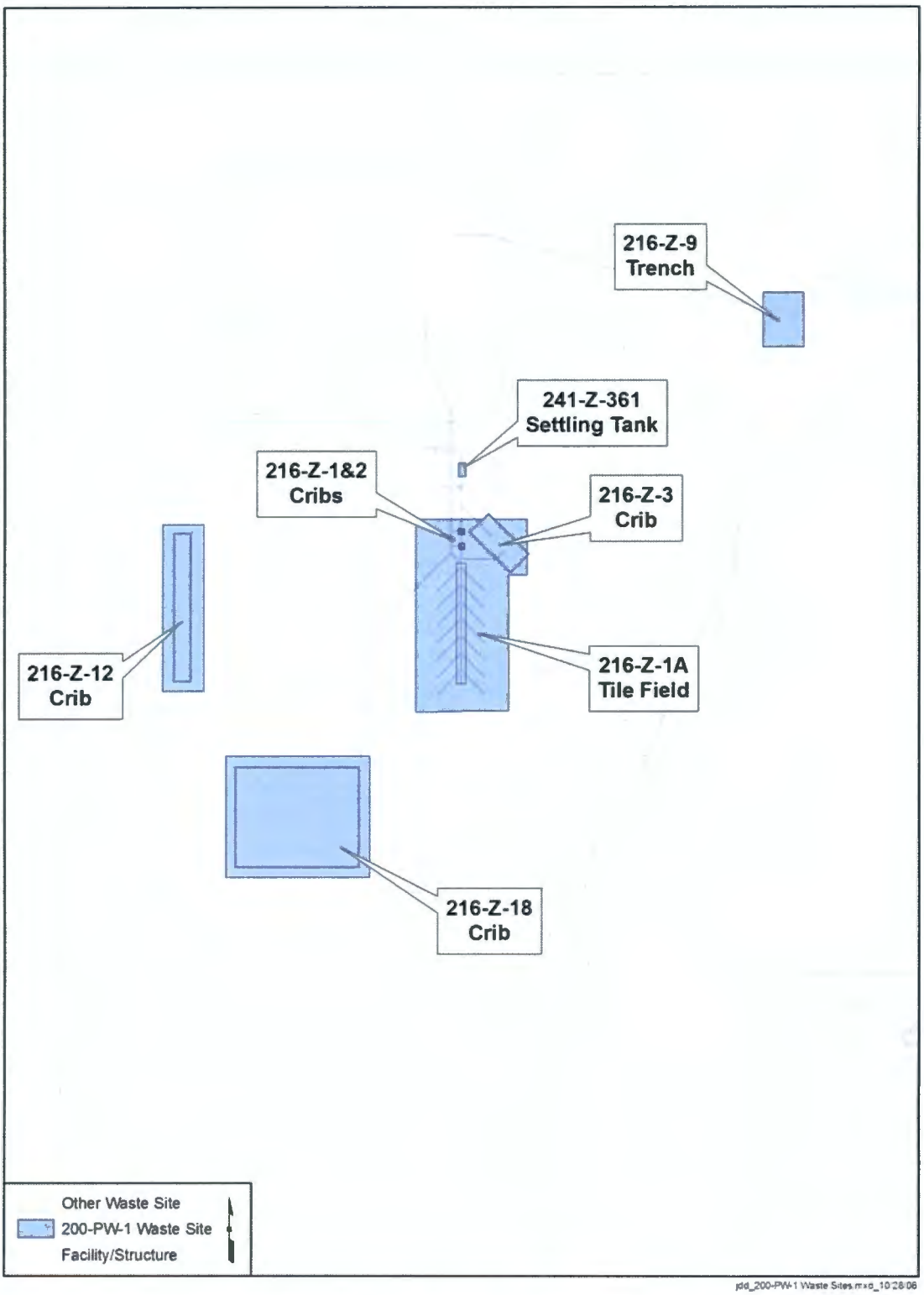

Figure 1-2. 200-PW-1 Operable Unit Waste Sites in the 200 West Area

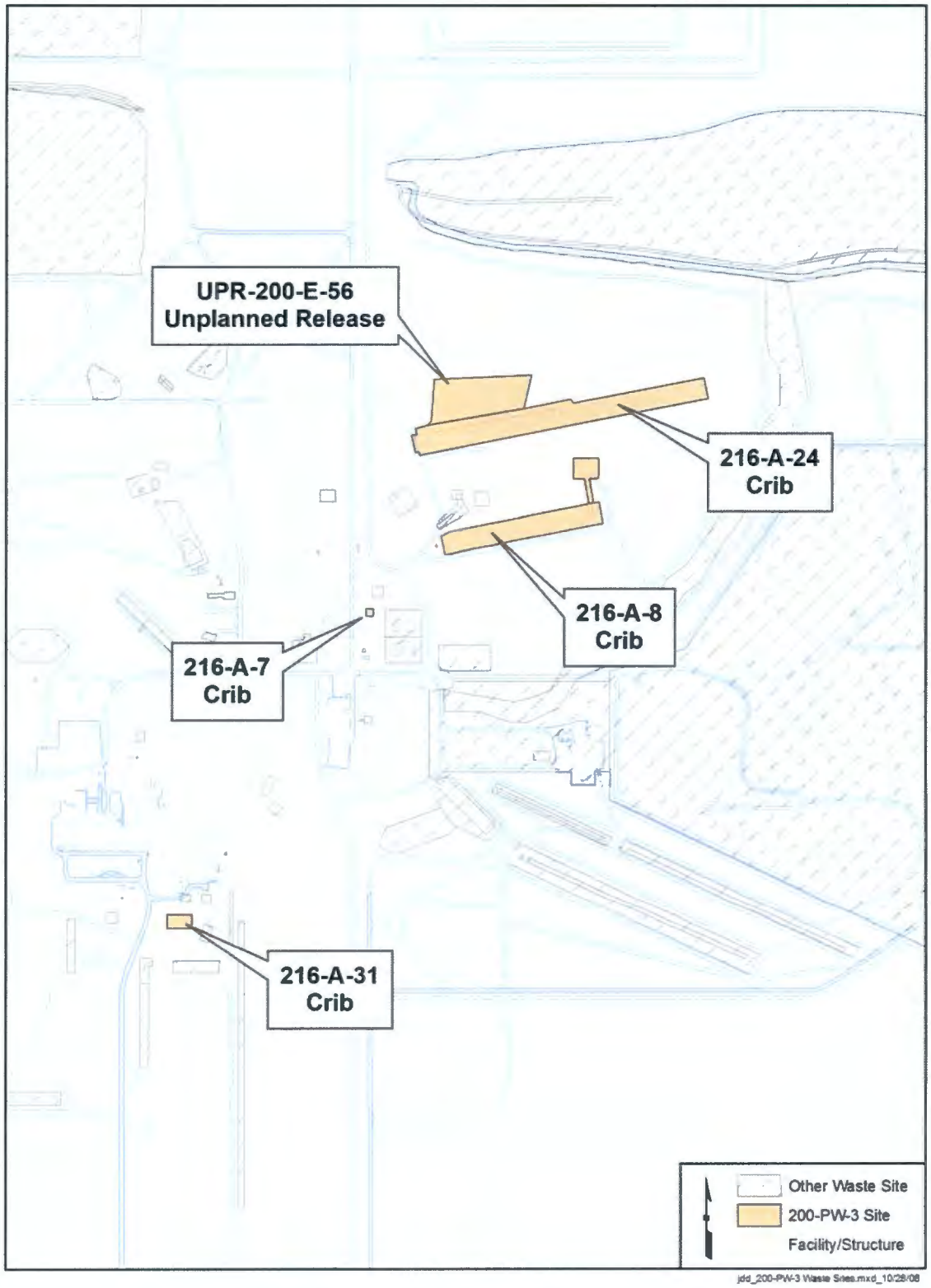

Figure 1-3. 200-PW-3 Operable Unit Waste Sites in the 200 East Area

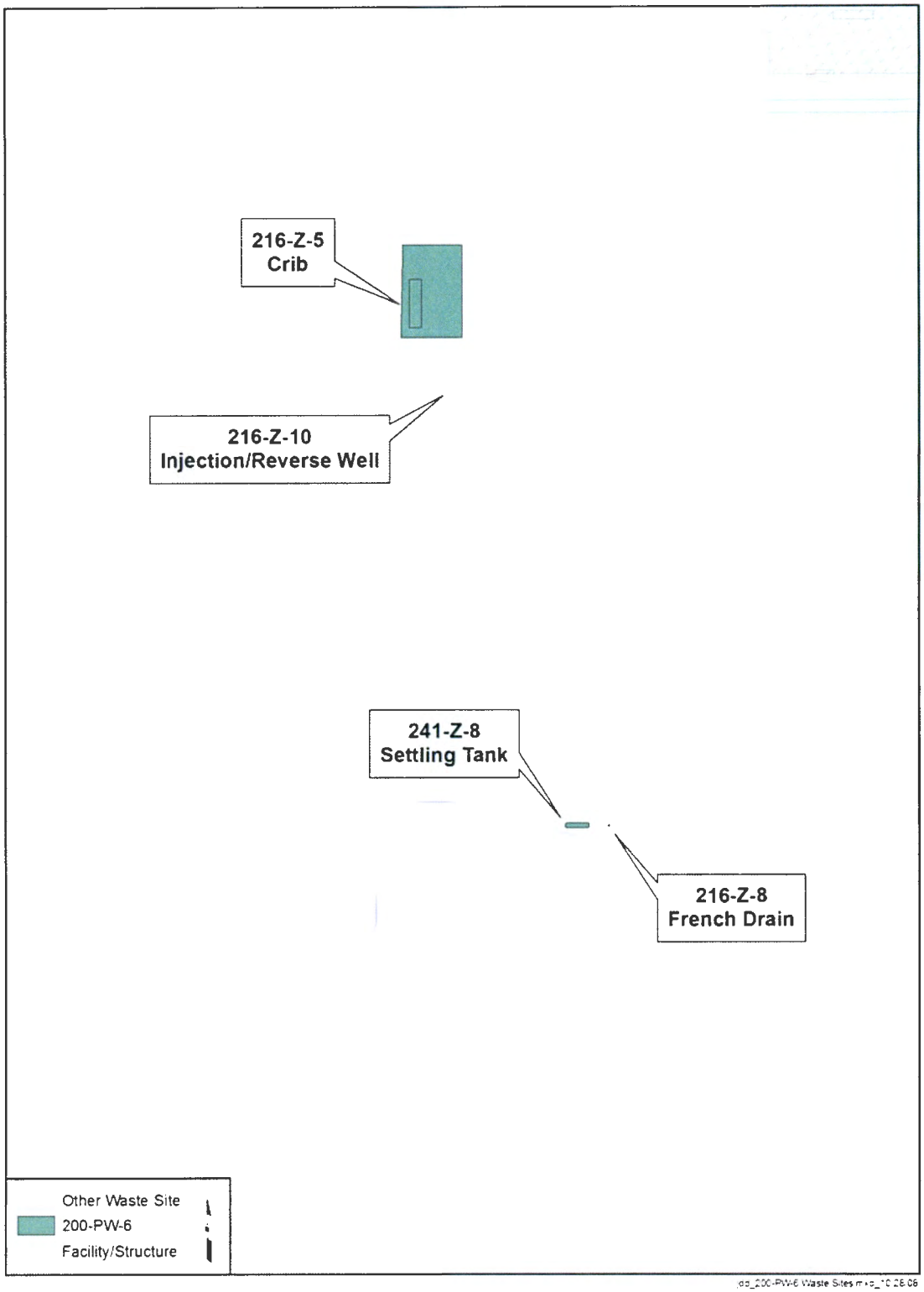

Figure 1-4. 200-PW-6 Operable Unit Waste Sites in the 200 West Area

Table 1-1. Alignment of 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units, Waste Groups, and Waste Sites

Operable Unit	Waste Group	Waste Site
200-PW-1	High-Salt	216-Z-1A Tile Field
		216-Z-9 Trench
		216-Z-18 Crib
	Low-Salt	216-Z-1&2 Cribs
		216-Z-3 Crib
		216-Z-12 Crib
	Settling Tank	241-Z-361 Settling Tank
	Pipelines	200-W-174-PL and 200-W-206-PL (connected to High-Salt waste sites)
		200-W-208-PL and 200-W-210-PL (connected to Low-Salt waste sites)
		200-W-205-PL and 200-W-220-PL (connected to settling tank)
200-PW-3	Cesium-137	216-A-7 Crib
		216-A-8 Crib
		216-A-24 Crib
		216-A-31 Crib
		UPR-200-E-56 Unplanned Release
200-PW-6	Low-Salt	216-Z-5 Crib
		216-Z-8 French Drain
		216-Z-10 Injection/Reverse Well
	Settling Tank	241-Z-8 Settling Tank
	Pipelines	200-W-205-PL and 200-W-220-PL (connected to settling tank)

Knowledge of this correlation made it possible to estimate residual contaminant distribution, at the sites that are not as thoroughly characterized, with an acceptable level of confidence.

1.1 Purpose

The purpose of this FS is to develop and evaluate alternatives for remediation of the 16 waste sites and pipelines in the 200-PW-1, 200-PW-3, and 200-PW-6 OUs. This FS refines preliminary applicable or relevant and appropriate requirements (ARARs), remedial action objectives (RAOs), and general response actions (GRAs) initially identified in the Implementation Plan (DOE/RL-98-28, *200 Area Remedial Investigation/Feasibility Study Implementation Plan—Environmental Restoration Program*). Technology screening and development of alternatives initially performed in this plan have been reviewed and refined, as necessary, based on the site-specific data reported in the RI Report (DOE/RL-2006-51), other sources of existing information, and the feedback obtained from a public workshop that was held on April 15, 2008, to present draft remedial alternatives for the 200-PW-1 OU waste sites. As a result of that workshop, the Hanford Advisory Board (HAB) issued Consensus

Advice #207, "Criteria for Development of the Proposed Plan for 200-PW-1, 3, and 6," on June 6, 2008, containing considerations that HAB believes are important to the development of the Proposed Plan for this OU. This FS report incorporates the criteria provided by HAB regarding remedial alternatives and their evaluation.

This section presents a description of how the remediation of the 200-CW-5, 200-PW-1, 200-PW-3, and 200-PW-6 OUs fits within DOE's overall cleanup and risk management strategy for Hanford. This is described in the *Hanford Site Cleanup Completion Framework* (DOE/RL-2009-10). The Cleanup Completion Framework outlines DOE's proposals to do the following:

- Contain and remediate contaminated groundwater
- Implement a geographic cleanup approach that guides remedy selection from a plateau-wide perspective
- Evaluate and deploy viable treatment methods for deep vadose zone contamination
- Conduct essential waste management operations in coordination with cleanup actions

One aspect of the Cleanup Completion Framework is to put in place a process to identify the "final footprint" for long-term waste management and containment of residual contamination. The overall cleanup objective is to make the final footprint of the Inner Area as small as practical. DOE intends for this final footprint to remain under federal ownership and control for as long as a potential hazard exists.

The Cleanup Completion Framework and a related document, *Central Plateau Cleanup Completion Strategy* (DOE/RL-2009-81), set forth DOE's cleanup approach that provides a framework and context for DOE's remedy selection proposals for structures, soil, debris, and groundwater from a plateau-wide perspective. The Completion Strategy organizes the Central Plateau cleanup into the following three major components:

- The Inner Area is approximately 26 km^2 (10 mi^2) in the middle of the Central Plateau encompassing the region where chemical processing and waste management activities occurred.
- The Outer Area is greater than 168 km^2 (65 mi^2) and includes much of the open area on the Central Plateau where limited processing activity occurred. Cleanup levels in the outer area are expected to be comparable to those being used for waste sites along the Columbia River (River Corridor).
- Groundwater Remediation is necessary for approximately 207 km^2 (80 mi^2) of groundwater beneath the Hanford Site contaminated above drinking water standards because of past processing activities that occurred on the Central Plateau. Cleanup that started in 1995 is being expanded to contain contaminant plumes in the Central Plateau, remove contaminants, and restore groundwater to beneficial use.

The FS documents for the 200-CW-5 OU and the 200-PW-1, 200-PW-3, and 200-PW-6 OU were originally prepared in 2003 and 2007, respectively. They used somewhat different assumptions and risk scenarios than those that may be used to make other future Central Plateau cleanup decisions. However, all cleanup decisions will be protective of human health and the environment, meet statutory requirements for remedy selection, and be in compliance with ARARS.

The alternatives considered provide a range of potential response actions (e.g., no action; capping; in situ treatment; and partial to full removal, treatment, and disposal [RTD] with capping) that are appropriate to

address waste site-specific conditions. The alternatives are evaluated against the two threshold and five balancing CERCLA evaluation criteria (EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*, Interim Final, OSWER 9355.3-01). The two modifying criteria will be evaluated through the public review process (EPA/540/G-89/004) of the Proposed Plan (DOE/RL-2009-117, *Proposed Plan for 200-CW-5, 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*).

The FS alternatives evaluation serves as the basis for identifying a preferred alternative(s) remedy consistent with CERCLA. A preferred alternative (or alternatives) will be presented to the public for review and comment in the Proposed Plan (DOE/RL-2009-117). Following public review, DOE will prepare a CERCLA record of decision (ROD) that identifies the remedial alternative(s) to be implemented for the 200-PW-1, 200-PW-3, and 200-PW-6 OUs waste sites.

1.2 Scope

This FS evaluated existing information and data for the 16 waste sites and associated pipelines identified in Table 1-1, screened and selected viable remedial technologies, developed effective remedial alternatives, and compared those remedial alternatives using the guidance provided in EPA/540/G-89/004 and associated documents.

Remediation of the 200-PW-1, 200-PW-3, and 200-PW-6 OU waste sites is a source-control action that addresses contaminated soil and structures (e.g., concrete pads, pipes, timbers) associated with cribs, settling tanks, a tile field, a French drain, an injection/reverse well, a covered trench, and an unplanned release (UPR). Remediation of the 216-Z-9 Trench also includes the abovegrade and belowgrade metal structures used for a prior removal action at that site. Other than the requirement for a source-control action to be protective of groundwater and surface water, the scope of this FS does not include remediation of groundwater beneath these sites.

Because three of the 200-PW-1 OU waste sites (the 216-Z-1A Tile Field, 216-Z-9 Trench, and 216-Z-18 Crib) were the primary sources of the carbon tetrachloride contamination in the 200-ZP-1 Groundwater OU, the FS reports for both the 200-PW-1, 200-PW-3, and 200-PW-6 OUs and the 200-ZP-1 Groundwater OU were prepared by a common project team to ensure that the baseline risk assessment (BRA) and the remedial alternatives in both FS reports that addressed contaminated soil, contaminant migration to groundwater, and groundwater contamination were integrated. As shown in Figure 1-5, other waste sites also overlie the 200-ZP-1 Groundwater OU; some of these waste sites may be sources for the other contaminants found in the groundwater. These other waste sites are being addressed by the CERCLA RI/FS process for other OUs in the 200 West Area or under the *Resource Conservation and Recovery Act of 1976* (RCRA) for the applicable treatment, storage, and disposal (TSD) units. The RI for the 200-ZP-1 Groundwater OU was completed in 2006, the FS was completed in 2008, and the ROD was signed in September 2008.

The 200-PW-3 OU waste sites are located in the 200 East Area (Figure 1-3). Contaminated groundwater beneath these waste sites is being addressed by the 200-PO-1 Groundwater OU.

1.3 Regulatory Status

The following sections describe the regulatory status of the 200-PW-1/3/6 OUs.

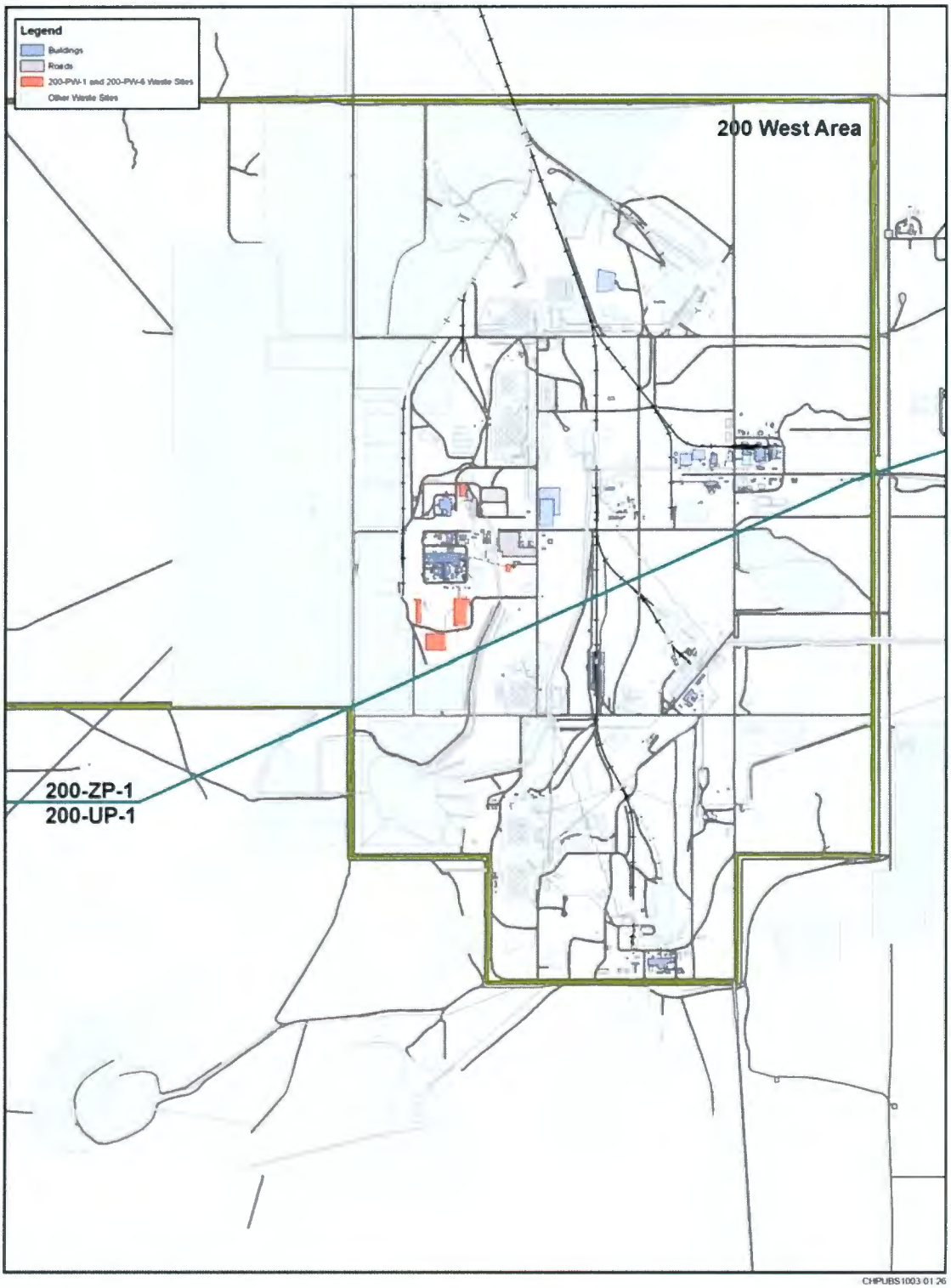

Figure 1-5. Relationship of the 200-PW-1 and 200-PW-6 Operable Unit Waste Sites to the 200-ZP-1 Groundwater Operable Unit and Other Waste Sites in the 200 West Area

1.3.1 Hanford Federal Facility Agreement and Consent Order

The Tri-Party Agreement (Ecology et al., 1989, as amended) addresses the integration of cleanup programs under CERCLA and RCRA to provide a standard approach to directing cleanup activities and to ensure that applicable regulatory requirements are met.

1.3.2 Tri-Party Agreement Milestones

The abovegrade structures at the 216-Z-9 Trench were originally planned to be addressed as a removal action and were included in the Tri-Party Agreement as Milestone M-083-41, "Complete Transition and Dismantlement of the 216-Z-9 Crib Complex." Milestone M-083-41 was deleted in 2008 by Tri-Party Agreement Change Package M-083-08-01. The abovegrade structures at the 216-Z-9 Trench are addressed in this FS for the 200-PW-1 OU.

1.4 Feasibility Study Report Organization

This FS report includes all of the required elements suggested in EPA/540/G-89/004. The report contains the following chapters and supporting appendices:

- Chapter 1 presents the purpose, scope, and regulatory framework for the FS, as well as this overview of report organization.
- Chapter 2 presents descriptions of the physical setting, waste sites, site contamination, and fate and transport and explains the process used to estimate residual contaminant distribution at the sites with limited characterization data.
- Chapter 3 discusses anticipated land use, summarizes the risk assessments and the evaluation of groundwater protection, identifies the final contaminants of potential concern (COPCs), and develops the overall cleanup objectives and media-specific goals for the waste sites.
- Chapter 4 refines the remediation technologies identified for these OUs and waste sites by evaluating new information on existing technologies or promising and relevant emerging technologies. The technologies were broadly screened for applicability to the waste sites in the FS. Screening considerations include effectiveness (likelihood of meeting RAOs for the specific contaminants present at a site), implementability relative to specific site conditions, status of technology development, and relative cost.
- Chapter 5 describes the remedial alternative development process and uses that information in concert with site-specific data from the RI to refine the remedial alternatives retained for the detailed and comparative analyses.
- Chapter 6 presents a detailed analysis of each of the remedial alternatives against seven of the nine CERCLA evaluation criteria (overall protection of human health and the environment [HHE]; regulatory compliance; long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost) as defined in EPA/540/G-89/004. This chapter also assesses each remedial alternative relative to the *National Environmental Policy Act of 1969* (NEPA) values, as required by DOE policy.
- Chapter 7 presents the comparative analysis of the remedial alternatives and identifies relative advantages and disadvantages, based on seven of the nine CERCLA evaluation criteria.
- Chapter 8 provides a summary of the key uncertainties of all analyses included in this report so their impact on the evaluations is explicitly presented and discussed.

- Chapter 9 summarizes the results of the FS. This chapter also discusses the path forward for remediation of the 200-PW-1, 200-PW-3, and 200-PW-6 OUs waste sites.
- Chapter 10 provides the references for the main text of the report; each appendix contains its own reference section.
- Appendix A presents the integrated 200-PW-1, 200-PW-3, and 200-PW-6 OUs and 200-ZP-1 Groundwater OU human health risk evaluations for sites having sufficient characterization data to support risk assessment. This appendix addresses the human health risk assessment methodology, results, and uncertainties.
- Appendix B presents the screening level ecological risk evaluations for all 16 of the 200-PW-1, 200-PW-3, and 200-PW-6 OU waste sites, including the methodology, results, and uncertainties.
- Appendix C presents an analysis of potential regulatory requirements and available guidance with respect to the 200-PW-1, 200-PW-3, and 200-PW-6 OU waste sites.
- Appendix D presents the basis for the comparative cost estimates for the 200-PW-1, 200-PW-3, and 200-PW-6 OUs.
- Appendix E presents the fate and transport evaluation of groundwater protection.
- Appendix F presents the evaluation of future risk reduction for various soil removal alternatives at the 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-12 Crib.
- Appendix G presents an additional human health risk assessment that addresses future Native American exposure scenarios.
- Appendix H presents the pipeline assessment for the 200-PW-1, 200-PW-3, and 200-PW-6 OUs that addresses remedial activities for the pipelines associated with waste transfer operations at these OUs.
- Appendix I presents the cost estimates for Post-ROD sampling activities at the 200-PW-1, 200-PW-3, and 200-PW-6 OUs.

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2 Background Information

This chapter discusses waste sites in the 200-PW-1, 200-PW-3, and 200-PW-6 OUs. The information includes OU background and history; physical setting; natural resources; and waste site description, characterization, and contamination.

2.1 Operable Units Background and History

The 200-PW-1, 200-PW-3, and 200-PW-6 OU waste sites are located within the 200 Area industrial land use area (Figure 1-1). The remediation of waste sites in these OUs will also address the portions of six pipelines (200-W-174-PL, 200-W-205-PL, 200-W-206-PL, 200-W-208-PL, 200-W-210-PL, and 200-W-220-PL). These pipelines were used to transfer waste to 200-PW-1 and 200-PW-6 OU waste sites. Detailed pipeline information is located in Appendix H of this document. This section summarizes the background and history of these OUs.

2.1.1 200-PW-1 Operable Unit

From the time the Z Plant complex (now referred to as the Plutonium Finishing Plant [PFP] Complex) came online in 1949, it generated large volumes of waste effluent. Until 1990, effluents such as cooling water that, under normal operating conditions, contained little or no radiological contamination were discharged to open ditches that drained to the U Pond. From 1949 until May 1973, effluents from chemical processes and plutonium finishing activities that, under normal operating conditions, contained low levels of plutonium and other contaminants were discharged to the soil column at subsurface engineered waste sites. These engineered waste sites were designed to provide effective disposal of effluent to the soil column, but were operated in a manner intended to limit adverse impacts to groundwater. The six subsurface engineered waste sites and an associated subsurface settling tank that received these contaminated process waste streams comprise the 200-PW-1 OU.

Three waste sites (216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib) primarily received waste streams from the Recovery of Uranium and Plutonium by Extraction (RECUPLEX) or the Plutonium Reclamation Facility (PRF) solvent extraction systems. These waste streams included acidic aqueous phase process wastes containing plutonium and americium. This aqueous waste, referred to as High-Salt waste, was a concentrated nitrate solution containing dissolved metal (aluminum, calcium, sodium, magnesium) nitrates. These three sites also received significant volumes of organics (principally carbon tetrachloride, tributyl phosphate [TBP], and lard oil), both entrained in the aqueous phase waste streams and as separate, nonaqueous phase waste streams. These three sites were operated sequentially, being replaced when conditions warranted (Table 2-1).

Table 2-1. Waste Sites 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib

Waste Site	Period of Operation	Primary Waste Stream
216-Z-9 Trench	1955-1962	Acidic High-Salt aqueous wastes and organic nonaqueous wastes, containing plutonium and americium
216-Z-1A Tile Field*	1964-1969	
216-Z-18 Crib	1969-1973	

* The 216-Z-1A Tile Field received neutral to basic aqueous phase process and laboratory waste from 1949 to 1959 as overflow from the 216-Z-1 Crib and the 216-Z-3 Crib.

The other 200-PW-1 OU waste sites (216-Z-1&2 Cribs, 216-Z-3 Crib, 216-Z-12 Crib, and 241-Z-361 Settling Tank) primarily received neutral to basic aqueous waste streams that contained plutonium and americium, with negligible amounts of organics and no nonaqueous phase liquids. This aqueous waste, referred to as Low-Salt waste, was primarily a dilute sodium fluoride and sodium nitrate solution when discharged. These cribs were operated sequentially, being replaced when conditions warranted (Table 2-2). The 241-Z-361 Settling Tank remained online for discharges to all four cribs, limiting pass-through of suspended solids; it had no design capability to discharge wastes directly to the soil column.

Table 2-2. Waste Sites 216-Z-1&2, 216-Z-3, 216-Z-12, and 241-Z-361

Waste Site	Period of Operation	Primary Waste Stream
216-Z-1&2 Cribs*	1949-1952	Neutral to basic Low-Salt aqueous wastes, containing plutonium and americium
216-Z-3 Crib	1952-1959	
216-Z-12 Crib	1959-1973	
241-Z-361 Settling Tank	1949-1973	

* Waste was discharged to the 216-Z-2 Crib, which overflowed to the 216-Z-1 Crib, which overflowed to the 216-Z-1A Tile Field. These two cribs also were used for limited discharges of acidic aqueous and/or uranium waste streams from 1966 to 1969.

In the 1970s, 0.3 m (1 ft) of soil was removed from the floor of the 216-Z-9 Trench, which was contaminated with relatively high concentrations of plutonium and americium, to reduce the risk of a nuclear criticality reaction. Approximately 58 kg (128 lb) of plutonium and a significant (but undocumented) amount of americium were removed from the floor of the 216-Z-9 Trench.

Since 1992, an expedited response action in the 200-PW-1 OU has used SVE to minimize the migration of carbon tetrachloride in the vadose zone away from the 216-Z-9 Trench, the 216-Z-1A Tile Field, and the 216-Z-18 Crib. Three SVE systems—with capacities of 14.2 m^3/min (500 ft^3/min), 28.3 m^3/min (1,000 ft^3/min), and 42.5 m^3/min (1,500 ft^3/min)—were used for continuous full-scale operations at each of the three sites from 1992 through 1997. Since 1998, only the 14.2 m^3/min (500 ft^3/min) SVE system has been in use; it typically was operated from April through September and alternated between the 216-Z-9 Well Field and the combined 216-Z-1A/216-Z-18 Well Field. Between April 1991 (the pilot test) and September 2008, approximately 79,380 kg (175,003 lb) of carbon tetrachloride have been removed using the SVE systems (SGW-40456, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Fiscal Year 2008*). Remediation using SVE is continuing.

Carbon tetrachloride concentrations in soil vapor extracted from the 216-Z-9 Well Field have declined from approximately 30,000 parts per million by volume (ppmv) at startup in March 1993 to 14 ppmv in fiscal year (FY) 2008. Carbon tetrachloride concentrations in soil vapor extracted from the combined 216-Z-1A/216-Z-18 Well Field have declined from approximately 1,500 ppmv at startup in February 1992 to 14 ppmv in FY 2008. The remaining carbon tetrachloride mass likely is held in fine-grained layers in the vadose zone, where it is less easily removed using SVE.

Carbon tetrachloride vapor concentrations measured near the groundwater during the 1996 to 1997 200-PW-1 OU rebound study were compared to groundwater concentration data collected from nearby groundwater wells as part of the 200-ZP-1 Groundwater OU pump-and-treat project. Based on this

comparison, the carbon tetrachloride concentration gradient in 1997 would drive the contaminant from the groundwater to the vadose zone.

Between 1996 and 2007, the carbon tetrachloride concentrations in the upper portion of the unconfined aquifer underlying the primary source waste sites have also been reduced. This reduction likely has resulted from the dual application of SVE remediation in the vadose zone and the 200-ZP-1 Groundwater OU pump-and-treat interim remedy in the groundwater in the vicinity of the source waste sites (216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib).

The reduction of carbon tetrachloride vapor concentrations in the area remediated using SVE has reduced the threat to human health and to groundwater. In addition to the SVE system, the vadose zone in the area of the SVE system is monitored monthly with monitoring wells, probes, and penetrometers. However, as carbon tetrachloride concentrations in both groundwater and the vadose zone change, the direction of contaminant movement between these media may change based on the carbon tetrachloride concentration gradients (SGW-37111, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Fiscal Year 2007*).

Passive SVE systems were installed on eight wells in the 216-Z-1A/216-Z-18 Well Field in FY 1999. Passive SVE is a natural process driven by barometric pressure fluctuations and often is referred to as "barometric pumping." Between October 1999 and September 2008, approximately 90 kg (198 lb) of carbon tetrachloride has been removed using passive SVE (SGW-40456).

2.1.2 200-PW-3 Operable Unit

The 200-PW-3 OU is located in the 200 East Area and consists of five waste sites: the 216-A-8 Crib, the 216-A-24 Crib, the 216-A-7 Crib, the 216-A-31 Crib, and a UPR site (UPR-200-E-56). The four cribs received effluent derived directly or indirectly from Plutonium Uranium Extraction (PUREX) operations (Table 2-3). The 216-A-8 Crib and the 216-A-24 Crib received vapor condensate from waste storage tanks in tank farms associated with PUREX. The 216-A-7 Crib received sump waste from a tank farm associated with PUREX and a one-time discharge of organic inventory, consisting of a hydrocarbon compound that may have contained TBP, from the PUREX chemical storage area. The 216-A-31 Crib received process waste from PUREX.

Waste streams discharged to these cribs contained fission products (primarily cesium-137 [Cs-137]), and both aqueous and nonaqueous phase organics. The principal organic constituents were refined kerosene (normal paraffin hydrocarbon [NPH]), TBP, and butanol. Wastes were discharged directly to the soil column. The UPR-200-E-56 site was contaminated by liquids migrating laterally from the 216-A-24 Crib. Cs-137 and NPH are the primary constituents of interest at these sites.

2.1.3 200-PW-6 Operable Unit

The 200-PW-6 OU contains four waste sites: the 216-Z-10 Injection/Reverse Well, the 216-Z-5 Crib, the 216-Z-8 French Drain, and the 241-Z-8 Settling Tank (Table 2-4). These waste sites received wastes from the Plutonium Isolation Facility or the PFP Complex that contained plutonium but did not include organics. The 216-Z-10 Injection/Reverse Well and the 216-Z-5 Crib received aqueous, neutral to basic process and laboratory wastes from the Plutonium Isolation Facility (231-Z Building). The 241-Z-8 Settling Tank received aqueous silica gel waste from back flushes of the feed filters at RECUPLEX; overflow from the tank went to the 216-Z-8 French Drain.

Table 2-3. 200-PW-3 Operable Unit Waste Sites

Waste Site	Period of Operation	Primary Waste Stream
216-A-8 Crib[a]	1955–1958 1966–1985 (intermittent)	Neutral to basic Low-Salt aqueous waste, containing organics and Cs-137
216-A-24 Crib[a]	1958–1966	Neutral to basic Low-Salt aqueous waste, containing organics and Cs-137
UPR-200-E-56 Unplanned Release Site[b]	1979 (discovery date)	Neutral to basic Low-Salt aqueous waste, containing organics and Cs-137
216-A-7 Crib	1956–1957	Neutral to basic Low-Salt aqueous waste, containing Cs-137
	1966	Nonaqueous phase organic liquid
216-A-31 Crib	1964–1966	Neutral to basic organic waste, containing Cs-137

a. In 1958, the 216-A-24 Crib replaced the 216-A-8 Crib. In 1966, the waste stream was diverted back from the 216-A-24 Crib to the 216-A-8 Crib. The 216-A-24 Crib was believed to be valved out of service in 1966, but the valve was found to be open in 1979.

b. This contaminated site was discovered in 1979 during routine monitoring. Low volumes of contaminated waste from the adjacent 216-A-24 Crib most likely seeped laterally to this location.

Table 2-4. 200-PW-6 Operable Unit Waste Sites

Waste Site	Primary Period of Operation	Primary Waste Stream
216-Z-10 Injection/Reverse Well	1945 (February to June)	Neutral to basic Low-Salt aqueous wastes, containing plutonium
216-Z-5 Crib*	1945-1947	Neutral to basic Low-Salt aqueous wastes, containing plutonium
241-Z-8 Settling Tank	1955-1962	Neutral to basic Low-Salt aqueous wastes, containing plutonium
216-Z-8 French Drain	1955-1962	Neutral to basic Low-Salt aqueous wastes, containing plutonium

* In 1945, the 216-Z-5 Crib replaced the 216-Z-10 Injection/Reverse Well.

2.2 Physical Setting

The following sections briefly describe the meteorology, topography, and hydrogeologic setting in the vicinity of the 200-PW-1, 200-PW-3, and 200-PW-6 OUs.

2.2.1 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 (3 mi) west of the 200 East Area.

The prevailing surface winds on Hanford's Central Plateau are from the northwest, and occur most frequently during the winter and summer. The HMS reported wind speeds, from 1945 through 2004, at 15.2 m (50 ft) above the ground that are lower during the winter months, averaging 2.7 to 3.1 m/s (6 to 7 mi/h), and faster during the spring and summer, averaging 3.6 to 4.0 m/s (8 to 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 record maximum temperature, 45°C (113°F) occurred at the HMS on July 13, 2002, and August 4, 1961. The record minimum temperature, -31°C (-23°F) occurred on February 1 and 3, 1950. The annual average relative humidity at the HMS is 55 percent. The annual average dew point temperature at the HMS is 1°C (34°F).

Average annual precipitation at the HMS is 17 cm (6.8 in.). Most precipitation occurs during the late autumn and winter, with more than one-half of the annual amount occurring from November through February. Average snowfall ranges from 0.25 cm (0.1 in.) during October, to a maximum of 13.2 cm (5.2 in.) during December, and decreases to 1.3 cm (0.5 in.) during March. Snowfall accounts for about 38 percent of all precipitation from December through February.

Concerns about severe weather usually center on hurricanes, tornadoes, and thunderstorms. Washington does not experience hurricanes; and tornadoes are rare and generally small. The estimated probability of a tornado striking a point on the Hanford Site is 9.6×10^{-6}/yr. The average occurrence of thunderstorms near the HMS is 10 per year according to the Pacific Northwest National Laboratory (PNNL) Hanford NEPA (PNNL-6415, *Hanford Site National Environmental Policy Act [NEPA] Characterization*).

2.2.2 Topography

The 200-PW-1, 200-PW-3, and 200-PW-6 OU waste sites are located in the 200 East and 200 West Area of the Hanford Site. The 200 Area is located on a broad, relatively flat area that constitutes a local topographic high commonly referred to as the 200 Area Plateau. The plateau is a giant flood bar (Cold Creek Bar) that was formed during cataclysmic ice-age floods from glacial Lake Missoula. The flood bar may have started forming during the earliest floods 1 to 2 million years ago. The Cold Creek Bar trends generally east-west, with elevations between 197 and 225 m (647 to 740 ft). The plateau drops off rather steeply to the north and east into a former flood channel that runs east-southeast, with elevation changes of between 15 and 30 m (50 and 100 ft). The plateau gently decreases in elevation to the south into the Cold Creek valley. Most of the 200 West Area and the southern half of the 200 East Area are situated on the Cold Creek Bar, while the northern half of the 200 East Area lies on the edge of a former flood channel. A secondary flood channel running south from the main channel bisects the 200 West Area. More detail on the physical setting of the 200 Area and vicinity is provided in the Implementation Plan, Appendix F (DOE/RL-98-28).

Waste sites in the 200 West Area are situated on a relatively flat area within the secondary flood channel that bisects the 200 West Area. Surface elevations range from approximately 201 to 217 m (660 to 712 ft). Waste site surface elevations in the 200 East Area range from about 189 m (620 ft) in the northern portion to about 220 m (720 ft) in the southern portion. The ground surface in the 200 East Area slopes gently to the northeast.

2.2.3 Geology

The 200-PW-1, 200-PW-3, and 200-PW-6 OU waste sites are located in the Pasco Basin, one of several structural and topographic basins of the Columbia Plateau. Basalts of the Columbia River Basalt Group and a sequence of suprabasalt sediments underlie the waste sites. From oldest to youngest, the major geologic units of interest are the Elephant Mountain Member of the Saddle Mountains Basalt Formation, the Columbia River Basalt Group, the Ringold Formation, the Cold Creek Unit (CCU), the Hanford

formation, and surficial deposits. Figures 2-1 and 2-2 show the stratigraphy of the 200 Area and the major units of interest.

2.2.3.1 Elephant Mountain Member

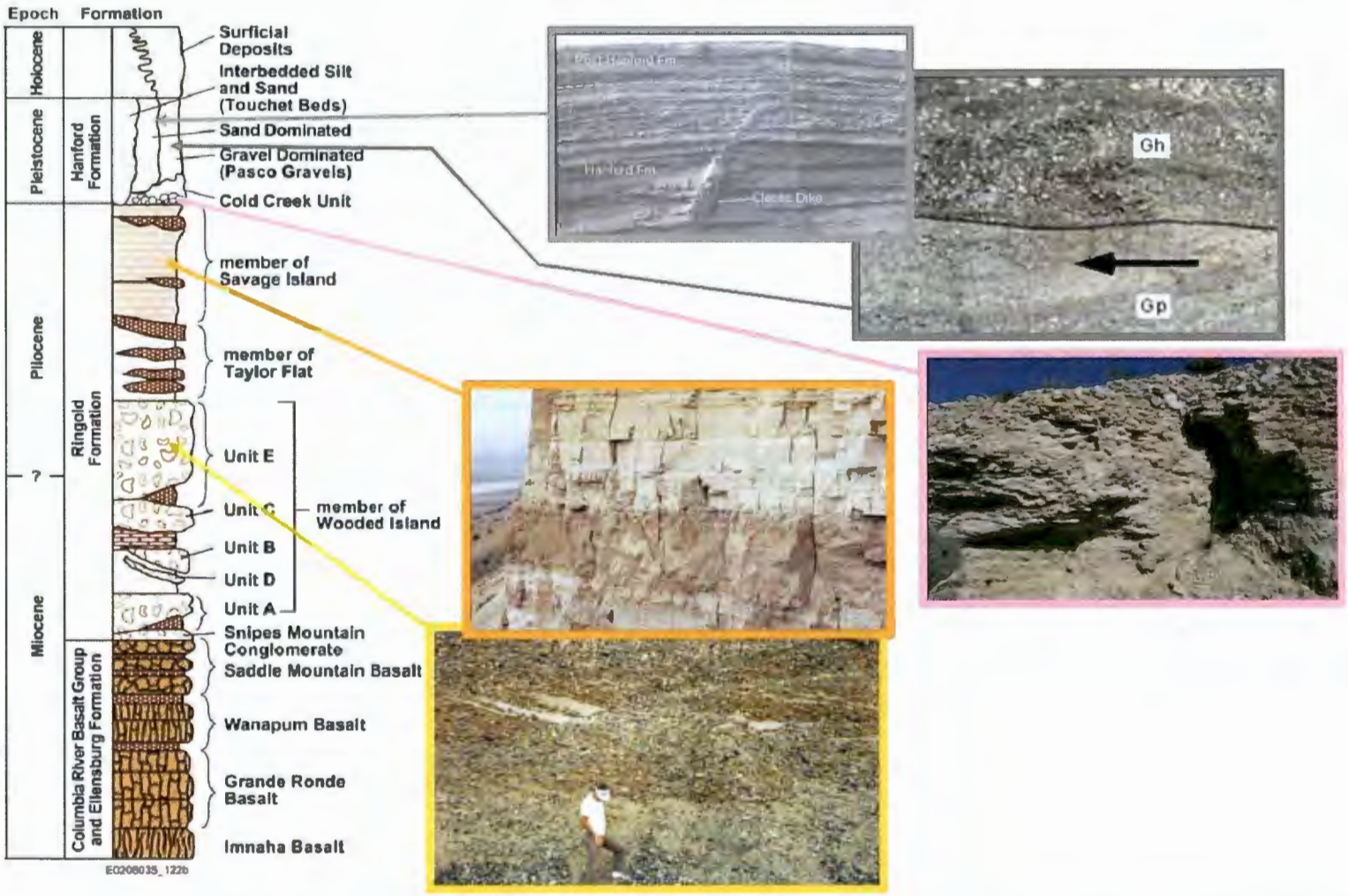
The Elephant Mountain Member of the Saddle Mountains Basalt Formation is the uppermost basalt unit (i.e., bedrock) in the 200 Area (DOE/RL-98-28, Appendix F). Except for a small area north of the 200 East Area boundary where it has been eroded away, the Elephant Mountain Member is laterally continuous throughout the 200 Area. The RI field investigations for the 200-PW-1, 200-PW-3, and 200-PW-6 OUs did not penetrate to the basalt.

2.2.3.2 Ringold Formation

The Ringold Formation consists of an interstratified fluvial-lacustrine sequence of unconsolidated to semiconsolidated clay, silt, sand, and granule-sized gravel to cobbles that were deposited by the ancestral Columbia River (PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*, and PNNL-13858, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington*). These sediments, shown in Figure 2-2, consist of four major units (from oldest to youngest): the fluvial gravel and sand of Unit 9 (basal coarse); the buried soil horizons, overbank, and lake deposits of Unit 8 (lower mud); the fluvial sand and gravel of Unit 5 (upper coarse); and the lacustrine mud of Unit 4 (upper fines). Units 9 and 5 consist of silty-sandy gravel with secondary lenses and interbeds of gravelly sand, sand, and muddy sands to silt and clay. Unit 8 (lower mud) consists mainly of silt and clay. Unit 4 (upper fines) consists of silty overbank deposits and fluvial sand. Units 6 and 7 are not present beneath the 200 West and East Areas; Unit 4 is not present in the 200 East Area, and it is discontinuous in the 200 West Area (PNNL-12261 and PNNL-13858). The two RI boreholes at the 216-Z-9 Trench penetrated into the Ringold Formation Unit 5. The RI borehole at the 216-A-8 Crib penetrated into the Ringold Formation Unit 9. Boreholes drilled as part of the carbon tetrachloride-dispersed plume investigation also penetrated into the Ringold Formation Unit 5.

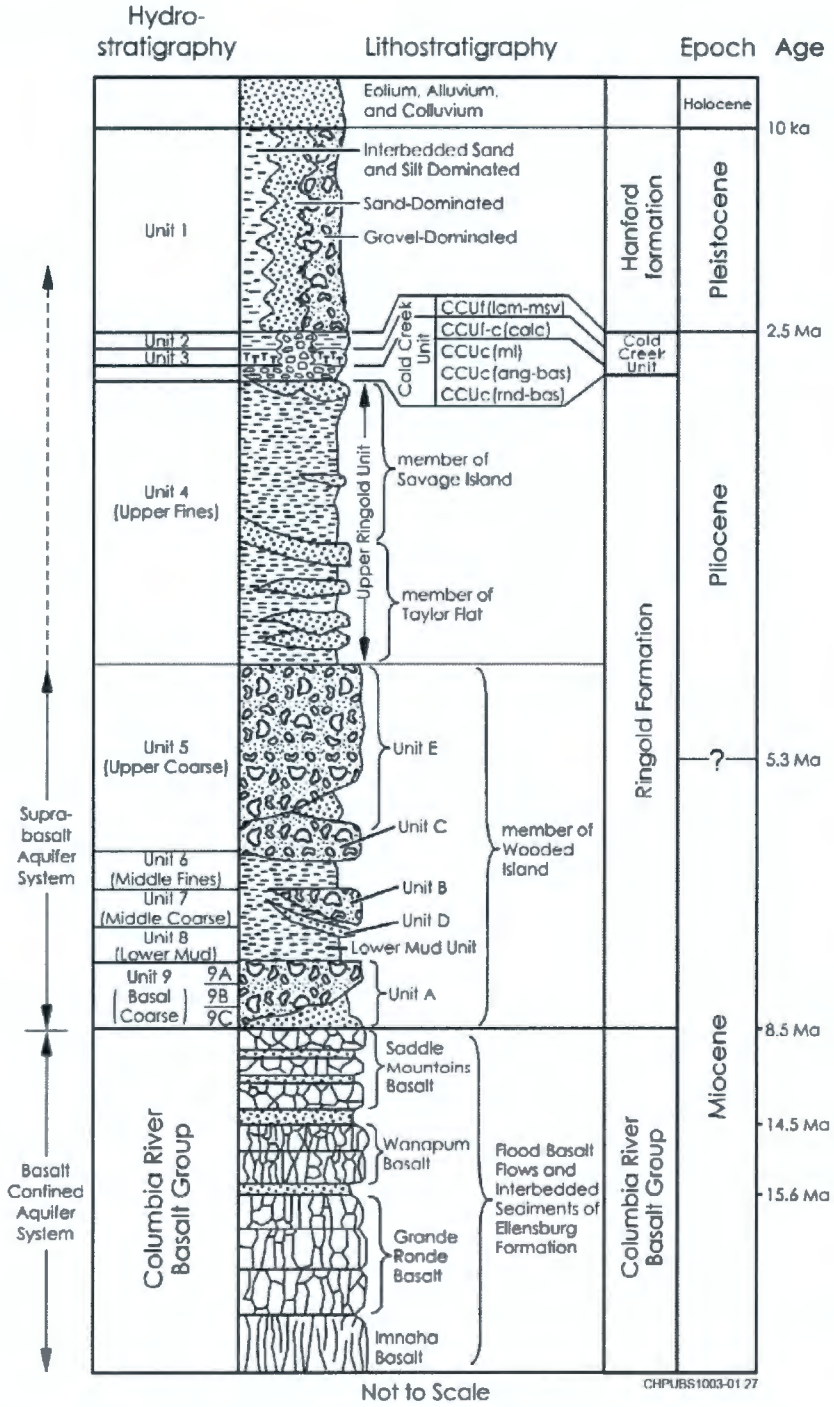
2.2.3.3 Cold Creek Unit

The CCU 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 CCU includes the sediments formerly identified as the Plio-Pleistocene unit, caliche, early Palouse soil, pre-Missoula gravels, and sidestream alluvial facies in previous site reports. The CCU has been divided into five lithofacies: fine-grained, laminated to massive (fluvial overbank and/or eolian deposits, formerly the early Palouse soil); fine- to coarse-grained, calcium-carbonate cemented (calcic paleosol, formerly the caliche); coarse-grained, multilithic (mainstream alluvium, formerly the pre-Missoula gravels); coarse-grained, angular, basaltic (colluvium); and coarse-grained, rounded, basaltic (sidestream alluvium, formerly sidestream alluvial facies; DOE/RL-2002-39). The two RI boreholes at the 216-Z-9 Trench penetrated the CCU. At the 216-Z-9 Trench, the CCU is present from about 33 to 36 m (108 to 118 ft) depth and comprises two distinct layers. The upper silt layer is about 2.5 m (8 ft) thick, and the lower calcic paleosol layer is about 0.5 m (2 ft) thick and is composed of a variable mixture of gravel, sand, and silt with a calcium-carbonate cemented matrix. The RI borehole drilled to investigate the 216-A-8 Crib did not encounter the CCU, because it is not present in the vicinity of the 216-A-8 Crib.



Notes: DOE/RL-2006-51, *Remedial Investigation Report for the Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit: Includes the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units.*
Gh = horizontally bedded
Gp = Foreset-Bedded

Figure 2-1. Major Geologic Units of Interest in the 200 Area



After WHC-MR-0391, *Field Trip Guide to the Hanford Site*; PNL-8971, *Three-Dimensional Conceptual Model for the Hanford Site Unconfined Aquifer System, FY 1993 Status Report*; BHI-00184, *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington*; PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*; and DOE/RL-2002-39, *Standardized Stratigraphic Nomenclature for Post-Ringold-Formation Sediments Within the Central Pasco Basin.*

Figure 2-2. Generalized Stratigraphic Column for the 200 Area

2.2.3.4 Hanford Formation

The Hanford formation is the informal stratigraphic name used to describe the Pleistocene cataclysmic flood deposits in the Pasco Basin (DOE/RL-2002-39). The Hanford formation consists predominantly of

unconsolidated sediments that range from boulders to gravel, 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 facies associations: 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), which have been further subdivided into 11 textural-structural lithofacies (DOE/RL-2002-39). Beneath the waste sites and the adjacent areas, the Hanford formation includes all three facies associations. The gravel-dominated facies are cross-stratified, coarse-grained sands and granule-size gravel to boulders. The gravel is uncemented and matrix-poor. The sand-dominated facies are well-stratified fine- to coarse-grained sand and granule gravel. Silt in these facies is variable and may be interbedded with the sand. Where the sand and silt content is low in the gravel-dominated facies, an open framework texture is common. Clastic dikes are common in the Hanford formation but rare in the Ringold Formation (Implementation Plan, DOE/RL-98-28, and DOE/RL-2002-39). They appear as vertical to subvertical sediment-filled structures, especially within sand- and silt-dominated units (Figure 2-1). The two RI boreholes at the 216-Z-9 Trench and the RI borehole at the 216-A-8 Crib penetrated the Hanford formation. In general, from shallowest to deepest, the Hanford formation units encountered beneath the 200 West Area included an upper fines unit (Hanford formation upper fines), the upper gravel-dominated sequence (H1), a sand-dominated sequence (H2), and a lower gravel-dominated sequence (H3). Not all of these units are laterally continuous beneath the waste sites.

The cataclysmic floodwaters that deposited sediments of the Hanford formation locally reshaped the topography of the Pasco Basin. The floodwaters deposited a thick sand and gravel bar (Cold Creek Bar) that constitutes the higher southern portion of the 200 Area, informally known as the 200 Area Plateau. In the waning stages of the ice-age floods, these floodwaters also eroded a channel north of the 200 Area in the area currently occupied by West Lake and the former Gable Mountain Pond. The pre-Hanford formation erosion and the floodwaters removed all of the Ringold Formation from this area and deposited Hanford formation sediments directly over basalt.

2.2.3.5 Surficial Deposits

Surficial deposits include Holocene eolian sheets of sand that form a thin veneer over the Hanford formation across the site, except in localized areas where the deposits are absent. Surficial deposits consist of very fine- to medium-grained sand to occasionally silty sand. Fill material was placed in and over some waste sites during construction and for contamination control. The fill consists of reworked Hanford formation sediments and/or surficial sand and silt.

2.2.3.6 Hydrostratigraphy

Vadose zone hydrostratigraphic units in the 200-PW-1, 200-PW-3, and 200-PW-6 OUs include the Ringold Formation, the CCU, the Hanford formation, and surficial deposits. The base of the unconfined aquifer typically is the top of the Ringold Formation Unit 8 (lower mud) within the 200 West Area and the top of the basalt (Elephant Mountain Member) in the 200 East Area.

2.2.3.7 Vadose Zone

The vadose zone is the unsaturated interval between the ground surface and the water table. The vadose zone is approximately 104 m (340 ft) thick in the southern section of the 200 East Area and thins to the north to as little as 0.3 m (1 ft) near West Lake. Sediments in the vadose zone are dominated by the Hanford formation, although the CCU and part of the Ringold Formation are 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 predominantly comprises Hanford

formation sediments between this area and Gable Mountain to the north. Basalt also projects above the water table in the northern part of the 200 East Area.

In the 200 West Area, the vadose zone thickness ranges from 40 to 75 m (132 to 246 ft). Sediments in the vadose zone are the Ringold Formation, the CCU, and the Hanford formation. Erosion during cataclysmic flooding removed some of the CCU and the Ringold Formation, especially in the northern part of the 200 West Area.

Historically, and as recently as the early 1990s, perched water has been documented above the CCU at locations in the 200 West Area. While liquid waste facilities were operating, localized areas of saturation or near saturation were created in the soil column. With the reduction of artificial recharge from waste facilities in the 200 Area in 1995, downward flux of liquid in the vadose zone beneath these waste sites has been decreasing.

2.2.3.8 Unconfined Aquifer

The top of the unconfined aquifer in the 200 Area occurs within the Ringold Formation, the CCU, or the Hanford formation, depending on location. The base of the unconfined aquifer is the top of the Ringold Formation Unit 8 (lower mud), or the top of the basalt where Unit 8 is absent at the 200 West Area, and the top of the basalt in the 200 East Area. 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. In the central and southern parts 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 the 200 East Area and vicinity ranges from about 54 m (177 ft) near the former B Pond area to about 104 m (340 ft) near the southern boundary of the 200 East Area. The water table across the 200 East Area is very flat, making it difficult to determine groundwater flow direction based on water level measurements from monitoring wells. The configuration of contaminant groundwater plumes, however, indicates that groundwater flows 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 difficult because of the flat water table. The highly transmissive Hanford formation sediments are the cause of the flat water table in the 200 East Area.

The water table has been declining since surface liquid discharges were terminated in the 200 East Area in the mid-1990s. In the 200 East Area, the elevation of the water table declined by an average of 0.07 m (0.2 ft) from March 2005 to April 2006. 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 below the average rate of decline observed from June 1997 to March 2002 (0.17 m/yr [0.56 ft/yr]) (PNNL-16346).

Groundwater beneath the 200 West Area occurs primarily in the Ringold Formation. Depth to water varies from about 40.2 m (132 ft) to greater than 75 m (246 ft). In the 200 West Area, groundwater in the unconfined aquifer typically flows from west to east. The surface elevation of the water table beneath the 200 West Area currently is declining at an average rate of 0.31 m/yr (1 ft/yr) in those areas not influenced by the 200-ZP-1 Groundwater OU pump-and-treat remediation system (PNNL-16346).

Recharge to the unconfined aquifer in the 200 Area is from artificial sources and, less significantly, from natural precipitation. According to estimates, 1.7 trillion L (450 billion gal) of liquid waste, some containing radionuclides and hazardous chemicals, have been released to the ground at the Hanford Site since 1944. Much of this contamination remains in the vadose zone above the water table, but some of the more mobile contaminants have reached groundwater (DOE/RL-2002-68, *Hanford's Groundwater*

Management Plan: Accelerated Cleanup and Protection). Most sources of artificial recharge were terminated in 1995. The current artificial recharge is limited to liquid discharges from sanitary sewers, two state-approved land disposal structures (one east of the 200 East Area and one north of the 200 West Area), and 140 small volume, uncontaminated miscellaneous liquid discharge streams.

2.3 Natural Resources

Natural resources in the vicinity of the 200-PW-1, 200-PW-3, and 200-PW-6 OUs include vegetation and wildlife resources. A wildfire in 2000, in and around the Hanford Site, did not affect any waste sites considered in this FS.

Biological and ecological information aids in evaluating impacts to the environment from contaminants in the soils, including potential effects of implementing remedial actions and identification of sensitive habitats and species. This section also considers cultural and aesthetic resources and socioeconomics associated with activities in the 200 Area.

2.3.1 Vegetation

PNNL-6415 reports that the undisturbed portions of the 200 Area are characterized by sagebrush/ cheatgrass or sagebrush/Sandberg's bluegrass communities. The dominant plants on the 200 Area Plateau are big sagebrush, rabbitbrush, cheatgrass, and Sandberg's bluegrass. Of the vegetation types found on the Hanford Site adjacent to the 200-PW-1, 200-PW-3, and 200-PW-6 OUs, those with a shrub component (i.e., 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 Area at each of the waste sites in the 200-PW-1, 200-PW-3, and 200-PW-6 OUs.

Before RI field activities began, excavation permits were obtained for the 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-A-8 Crib. As part of the excavation-permit process for site investigation activities, ecological compliance reviews (ECRs) were issued by PNNL for the 216-Z-9 Trench (ECR#2006-200-031, *Biological Review of the Stage 5 VET Probes Project, 200W Area*) on April 13, 2006; the 216-Z-1A Tile Field (ECR#2005-200-045, *Biological Review of the Cone Penetrometer Probes South of 234-5Z Project, 200 W Area*) on May 19, 2005; and the 216-A-8 Crib (ECR#2004-200-048, *Biological Review of the Borehole and Geoprobe Casings Installation at 216-A-8 Project, 200W Area*) on February 26, 2004. The ECR consisted of a biological review to determine the occurrence in the project area of plant species protected under the *Endangered Species Act of 1973* (ESA), candidates for protection; and species listed as threatened, endangered, candidate, sensitive, or monitored by the State of Washington. The ECR survey methods consisted of pedestrian visual reconnaissance at the 216-Z-9 Trench and 216-Z-1A Tile Field and knowledge of priority habitats and species of concern for each respective site documented by the Washington State Department of Fish and Wildlife and the Washington State Department of Natural Resources. Lists of plant species considered endangered, threatened, proposed, or candidate by the U.S. Fish and Wildlife Service (USFWS) are maintained in 50 CFR 17.12,

"Endangered and Threatened Wildlife and Plants," "Endangered and Threatened Plants." The survey results at the 216-Z-9 Trench found that the area was highly disturbed with an essentially barren sand and gravel ground surface. The ECR found no plant species protected under the ESA, no candidates for such protection, and no species listed by Washington State as threatened or endangered near the 216-Z-9 Trench. Ground surface conditions at the 216-Z-8 French Drain and 216-Z-10 Injection/Reverse Well are considered similar to those at the 216-Z-9 Trench. The 241-Z-361 Settling Tank is located inside the PFP and thus is located in a highly disturbed environment and considered similar to that of the 216-Z-9 Trench. The survey results at the 216-Z-1A Tile Field found the area highly disturbed by windblown sand, resulting in the elimination of most forbs and grasses. The area was dominated by gray rabbitbrush (*Ericameria nauseousa*) with little understory. The ECR found no plant species protected under the ESA, no candidates for such protection, and no species listed by Washington State as threatened or endangered near the 216-Z-1A Tile Field. The survey results at the 216-A-8 Crib reported that the site had been revegetated with crested wheatgrass (*Agropyron cristatum*) and maintained free of broadleaf plants with regular herbicide applications. The ECR found no plant species protected under the ESA, no candidates for such protection, and no species listed by Washington State as threatened or endangered near the 216-A-8 Crib.

2.3.2 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 nonburrowing 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-PW-1, 200-PW-3, and 200-PW-6 OUs is the mule deer. Mule deer collect around the 200 Area, 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 occasionally seen on the 200 Area Plateau.

Common upland gamebird species in shrub and grassland habitat include chukar (*Alectoris chukar*), partridge (*Perdix perdix*), 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 (*Centrocercus 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 (*Buteo regalis*), 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 habitats on the Hanford Site. Butterflies, grasshoppers, and darkling beetles are among the most conspicuous of the about 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).

An inventory was performed on three selected waste sites to evaluate occurrences of potential Hanford Site fauna; specifically, the ECRs issued for the 216-Z-9 Trench, the 216-Z-1A Tile Field, and the 216-A-8 Crib also considered wildlife resources. The PNNL biological review in the project area determined the occurrence of wildlife species protected under the ESA, candidates for protection; species listed as threatened, endangered, candidate, sensitive, or monitored by the State of Washington; and species protected under the *Migratory Bird Treaty Act of 1918*. The survey methods consisted of pedestrian visual reconnaissance at the 216-Z-9 Trench and the 216-Z-1A Tile Field and knowledge of priority habitats and species of concern documented for each respective site by the Washington Department of Fish and Wildlife. Lists of wildlife species considered endangered, threatened, proposed, or candidate by the USFWS are maintained in 50 CFR 17.12, and the list of birds protected under the *Migratory Bird Treaty Act of 1918* are maintained in 50 CFR 10.13, "General Provisions," "List of Migratory Birds." The survey results at the 216-Z-9 Trench found no migratory birds observed nesting in the vicinity of the site. The ECR found no wildlife species protected under the ESA, no candidates for such protection, and no species listed by Washington State as threatened or endangered were observed in the vicinity of the 216-Z-9 Trench. Ground surface conditions at the 216-Z-8 French Drain and 216-Z-10 Injection/Reverse Well are similar to those at the 216-Z-9 Trench. The 241-Z-361 Settling Tank is located inside the PFP and is located in a highly disturbed environment, similar to that of the 216-Z-9 Trench. The survey results at the 216-Z-1A Tile Field reported that no migratory birds were observed nesting in the vicinity of the site. The ECR also found no wildlife species protected under the ESA, no candidates for such protection, and no species listed by Washington State as threatened or endangered in the vicinity of the 216-Z-1A Tile Field. The survey results at the 216-A-8 Crib reported there was a possibility of migratory birds nesting at the site. Nevertheless, the ECR found no wildlife species protected under the ESA, no candidates for such protection, and no species listed by Washington State as threatened or endangered in the vicinity of the 216-A-8 Crib.

2.3.3 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, not the Central Plateau.

Several threatened, endangered, and candidate species are found on the Central Plateau. These species are detailed in Table 2-5. Fauna are managed by the Washington Department of Fish and Wildlife, and migratory birds are protected by the *Migratory Bird Treaty Act of 1918*. Species that are associated with specific localities or altitude not within the Central Plateau, or whose habit is riparian or river shore, are omitted with the exceptions of the bald eagle (*Haliaeetus leucocephalus*), the peregrine falcon (*Falco peregrinus*), and the golden eagle (Aquila chrysaetos). It should be noted that the bald and golden eagles are protected by the *Bald and Golden Eagle Protection Act of 1940*. While these species are dependent on the river corridor, they are occasionally observed on the Central Plateau. Additionally, the pygmy rabbit (*Brachylagus idahoensis*), a federal and state endangered species, has not been observed on the Central Plateau but has been seen on the Arid Lands Ecology Reserve and is included in Table 2-5.

Table 2-5. Potential Species of Concern on the Central Plateau

Common Name(s)	Scientific Name(s)	State Listing	Federal Listing
Plants			
Great Basin gilia	*Aliciella leptomeria*	T	None
Geyer's milk-vetch	*Astragalus geyeri*	T	None
Rosy pussypaws/rosy calyptridium	*Cistanthe rosea*	T	None
Desert dodder	*Cuscuta denticulata*	T	None
Loeflingia	*Loeflingia squarrosa var. squarossa*	T	None
Small-flowered evening primrose	*Camissonia minor*	S	None
Dwarf evening-primrose	*Camissonia pygmaea*	S	None
Gray cryptantha	*Cryptantha leucophaea*	S	None
Piper's daisy	*Erigeron piperianus*	S	None
Suksdorf's monkey-flower	*Mimulus suksdorfii*	S	None
Coyote tobacco	*Nicotiana attenuata*	S	None
Birds			
Sage sparrow	*Amphispiza belli*	E	None
Ferruginous hawk	*Buteo regalis*	T	SC
Greater sage grouse	*Centrocercus urophasianus*	T	C
Burrowing owl	*Athene cunicularia*	C	SC
Golden eagle*	*Aquila chrysaetos*	C	None
Loggerhead shrike	*Lanius ludovicianus*	C	SC
Sage thrasher	*Oreoscoptes montanus*	C	None
Bald eagle*	*Haliaeetus leucocephalus*	S	SC
Peregrine falcon	*Falco peregrinus*	S	SC
Mammals			
Pygmy rabbit	*Brachylagus idahoensis*	E	E
Black-tailed jackrabbit	*Lepus californicus*	C	None
White-tailed jackrabbit	*Lepus townsendii*	C	None
Merriam's shrew	*Sorex merriami*	C	None
Townsend's ground squirrel	*Spermophilus townsendii*	C	SC
Washington's ground squirrel	*Spermophilus washingtoni*	C	C

Table 2-5. Potential Species of Concern on the Central Plateau

Common Name(s)	Scientific Name(s)	State Listing	Federal Listing
	Amphibians and Reptiles		
Striped whipsnake	*Masticophis taeniatus*	C	None
Northern sagebrush lizard	*Sceloporus graciosus*	C	SC

* Bald and golden eagles are protected by the *Bald and Golden Eagle Protection Act.*

WDFW, 2009, "Species of Concern in Washington State," Current through June 1, 2009

WNHIS, 2009, "List of Known Occurrences of Rare Plants and Animals in Washington"

WHNP, 2009, "List of Plants Tracked by the Washington National Heritage Program," January 2009

C = Candidate

E = Endangered

S = Sensitive

SC = Species of Concern

T = Threatened

Plant and animal species of concern, their designations, and the places of their occurrence can change over time. At this time, it is not anticipated that remediation of the 200-PW-1/3/6 OU will affect any species of concern, but incorporating the needs of these species into project planning will help to mitigate any potential effects. Especially important is avoiding, where possible, undisturbed shrub-steppe habitat because this is important to many species of concern. The undisturbed shrub steppe in the Central Plateau was designated as Level 3 habitat in DOE/RL-96-32, *Hanford Site Biological Resources Management Plan*, which requires mitigation of any disturbance (for example, through avoidance and minimization) and possibly rectification and compensation. Additional details on protecting Level 3 habitats and species of concern are provided in DOE/RL-96-32. In addition, site-specific environmental surveys, required before ground disturbance can occur, serve as a final check to ensure that ecological resources are adequately protected.

2.3.4 Cultural Resources

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. 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-PW-1, 200-PW-3, and 200-PW-6 OUs (PNNL-6415).

As part of the excavation permit process for RI field activities, NPCE#2006-200-031, *Cultural Resource Review Notices to Proceed* (Rodriguez, 2006), was obtained to determine the potential of the RI activities to have an impact on cultural resources. At the 216-Z-9 Trench, planned RI characterization activities were determined by the DOE Cultural and Historic Resource Program on June 8, 2006, to not have an effect on cultural resources (NPCE#2006-200-031). Review of historic properties by aerial and recent photographs of the 216-Z-9 Trench confirmed ground surface disturbance of the waste site. At the 216-Z-1A Tile Field, planned RI characterization activities were determined by the DOE Cultural and Historic Resource Program on May 16, 2005, not to have an effect on historic properties (HCRC#2005-200-045, *Cultural Resource Review Notices to Proceed* [McFarland, 2005]). The survey consisted of a literature review indicating the 216-Z-1A Tile Field had little potential to contain cultural

resources. 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, were adequately identified, evaluated, and considered in planning for a proposed undertaking (e.g., remediation, renovation, or demolition) (DOE/RL-97-56, *Hanford Site Manhattan Project and Cold War Era Historic District Treatment Plan*). The subject waste sites do not contain any 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). Historic preservation requirements are not applicable for the 216-Z-1A Tile Field, 216-Z-8 French Drain, 216-Z-9 Trench, 216-Z-10 Injection/Reverse Well, 216-A-8 Crib, or 241-Z-361 Settling Tank, upon evaluation and classification as noncontributing/exempt from documentation requirements as historical properties (DOE/RL-97-56).

2.3.5 Aesthetics, Visual Resources, and Noise

With the exception of Rattlesnake Mountain, the land near the Hanford Site generally has little relief. Rattlesnake Mountain, rising to 1,060 m (3,477 ft) above mean sea level, forms the western boundary of the Hanford Site. Gable Mountain and Gable Butte are the highest landforms within the Site. The Columbia River and Rattlesnake Mountain generally are considered scenic.

Studies of the propagation of noise at the Hanford Site have been concerned primarily with occupational noise at work sites. Environmental noise levels have not been extensively evaluated because of the remoteness of most Hanford Site activities and isolation from receptors covered by federal or state statutes. Most industrial facilities on the Hanford Site are located far enough away from the Hanford Site boundary that noise levels at the boundary are not measurable or are barely distinguishable from background noise levels (PNNL-6415).

2.3.6 Socioeconomic

As reported in PNNL-6415, 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.

DOE and its contractors compose the largest single source of employment in the Tri-Cities. During FY 2006, an average of 9,759 employees was employed by DOE Office of River Protection and its prime contractor CH2M HILL Hanford Group, Inc.; DOE-RL and its prime contractors Fluor Hanford, Inc., Washington Closure Hanford, LLC (WCH), and AdvanceMed Hanford; and the DOE Office of Science Pacific Northwest Site Office and PNNL, which is operated by Battelle. FY 2006 year-end employment for all DOE contractors was 9,707, down from 10,135 at the end of FY 2005. In addition to these totals, Bechtel National, Inc. (BNI), which has had the responsibility to design, build, and start up waste treatment facilities for the vitrification of liquid radioactive waste since December 2000, employed 1,647 at the end of FY 2006. BNI employment peaked at 3,867 in July 2004.

The total annual average number of DOE contractor employees has declined by nearly 7,600 since FY 1994 when employment peaked at 19,200 employees, but DOE contractor employment still represents 11 percent of the total jobs in the economy. Total employment in the Richland, Kennewick, and Pasco metropolitan statistical area averaged 106,100 per month during 2006, down from 107,700 in 2005. Based on employee records as of April 2007, more than 90 percent of DOE contractor employees live in Benton and Franklin Counties. Approximately 73 percent reside in Richland, Pasco, or Kennewick. More than 36 percent are Richland residents, 11 percent are Pasco residents, and 25 percent live in Kennewick.

Residents of other areas of Benton and Franklin Counties, including West Richland, Benton City, and Prosser, account for about 17 percent of total DOE contractor employment.

In addition to the Hanford Site, other key employers in the area include:

- Energy Northwest
- ConAgra/Lamb Weston
- Tyson Fresh Meats
- Wal-Mart
- AREVA NP, Inc.
- Boise Cascade Corporation Paper and Corrugated Container Divisions

Tourism and government transfer payments to retirees in the form of pension benefits also are important contributors to the local economy.

Benton County had an estimated population of 160,600 and 64,200 lived in Franklin County during 2006, totaling 224,800, an increase of more than 17 percent from the 2000 Census figure. This growth rate is faster than the State of Washington as a whole, which has grown 8.2 percent since the 2000 Census. According to the 2000 Census, population totals for Benton and Franklin Counties were 142,475 and 49,347, respectively. Both Benton and Franklin Counties also grew at a faster pace than the rest of the state during the 1990s. The population of Benton County increased 42.7 percent, up from 112,560 during 1990, and the population of Franklin County increased 71.3 percent, up from 37,473 during 1990, while the population of the State of Washington rose 21.1 percent.

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.

2.4 Waste Site Description, Characterization, and Contamination

This section provides a description of the 16 waste sites, grouped by OU. Each description includes a discussion of the waste site configuration, a summary of characterization results, and a discussion of contaminant distribution at the site.

Figures 2-3 through 2-18 present contaminant distribution models for each waste site. The current contaminant distributions, which are summarized in these figures, are based on review of all available information for each site (DOE/RL-2006-51, Appendix E). The current contaminant distribution at each site resulted from vadose zone conditions that were present during active liquid waste management, when large volumes (typically millions of liters) of contaminated liquids were being discharged directly to the soil column. Under those conditions, effluent and associated mobile contaminants readily migrated vertically and, in some instances, laterally in the subsurface. However, current subsurface conditions at these waste sites are dramatically different. No liquids have been discharged to the soil for decades, and the only liquid entering the subsurface in the interim has been a very small amount of infiltrating precipitation, measured in millimeters per year. In addition, SVE has been conducted for 15 years at or near all of the sites that have high concentrations of plutonium and americium, and has helped to remove

residual moisture from the vadose zone beneath these sites. As a result, there now is only limited potential for transporting even very mobile contaminants toward groundwater.

Also, as discussed in Section 2.5, the deeper distribution of plutonium and americium observed at High-Salt waste sites was facilitated by the low pH of the effluent at the time of discharge. Buffering of the effluent pH by the alkaline native soils limited the extent of radionuclide contamination. Even during active waste management, when large volumes of acidic liquids were discharged directly to the soil column, only limited amounts of plutonium and americium were able to reach the CCU. Current conditions, where water infiltrating to the subsurface is neutral pH precipitation and measured in millimeters per year, are not expected to support mobilization of the plutonium and americium.

2.4.1 200-PW-1 Waste Sites

The following sections describe the waste sites assigned to the 200-PW-1 OU. Waste sites that received High-Salt wastes are addressed first, and include the 216-Z-9 Trench, the 216-Z-1A Tile Field, and the 216-Z-18 Crib. These are followed by the sites that received Low-Salt waste, including the 216-Z-12 Crib, the 216-Z-1 Crib, the 216-Z-2 Crib, and the 216-Z-3 Crib. A discussion of the 241-Z-361 Settling Tank, which was used to manage Low-Salt wastes, closes out the section.

2.4.1.1 216-Z-9 Trench

The 216-Z-9 Trench is about 213 m (700 ft) east of the 234-5Z Building in the 200 West Area of the Hanford Site. The surface elevation at the site is approximately 202 m (664 ft). Groundwater is approximately 69 m (226 ft) below ground surface (bgs) based on nearby Well 299-W15-46 on May 18, 2008.

The 216-Z-9 Trench consists of a 6.1 m (20 ft) deep open excavation with a 36.5 by 27.4 m (120 by 90 ft) concrete cover. The walls of the trench slope inward and downward to the 18 by 9 m (60 by 30 ft) floor space, which has a slight slope to the south. The underside of the concrete cover was paved with acid-resistant brick/tiles. The cover of the trench is supported by six concrete columns. More than 4 million liters (1,000,000 gals) of plutonium/organic rich process wastes were discharged to the trench between 1955 and 1962.

Plutonium was detected in a well (Well 299-W15-85, 105 ft deep) north of the 216-Z-9 Trench; in 1958, it was concluded that plutonium in wastes discharged to the 216-Z-9 Trench probably had not reached groundwater; therefore, there was no immediate need to replace this waste site (letter dated February 19, 1958 [Linderoth, 1958, "Plutonium Contamination in Shallow Wells Adjacent to 234-5 Building Waste Cribs"]). The letter also acknowledged that there were no groundwater monitoring wells near the site. In March 1958, it was recommended that three wells be drilled north of the 216-Z-9 Trench before deciding whether to replace the 216-Z-9 Trench: two wells (Well 299-W15-94[1] and Well 299-W15-95) drilled to 30 m (100 ft) depth were used to monitor the lateral spread of plutonium and one well (Well 299-W15-6) was used to monitor the groundwater (HW-55196, *Replacement Disposal Facilities for 241-Z Tank Waste Process Technology – Preliminary Design*; HW-55497, *Project Proposal Crib and Test Wells for 234-5 Building Wastes*).

[1] Well 299-W15-94 was deepened to groundwater in 1966 and renamed Well 299-W15-9.

216-Z-9 Trench

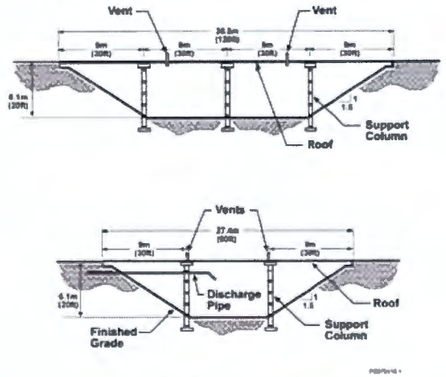
200-PW-1 Operable Unit
Waste Type: Process Waste

PFP Zone

History

The 216-Z-9 Trench is an enclosed, below-grade trench that was used from 1955 to 1962 for disposal of Z Plant RECUPLEX aqueous and organic liquid waste. Carbon tetrachloride was received in the aqueous phase liquid and, mixed with other organics, as a dense, non-aqueous phase liquid (DNAPL). In 1976 and 1977, the upper 0.3 m (1 ft) of the trench floor was mined to reduce the amount of plutonium in the trench; after mining, 38 to 48 kilograms (84 to 106 pounds) of plutonium were estimated to remain in the soils beneath the trench. Soil vapor extraction has been ongoing at the 216-Z-9 Trench since 1993 to remove carbon tetrachloride from the vadose zone.

CONSTRUCTION: The site is a rectangular, enclosed trench with a concrete cover supported by six columns. The trench is 18 by 9 m (60 by 30 ft) at the bottom and 6 m (21 ft) deep. The underside of the concrete cover was lined with acid resistant bricks. Two stainless steel pipes discharged effluent above the trench bottom.



WASTE VOLUME: 4,090,000 L (1,081,000 gal) (RHO-LD-114)

DURATION: 1955 to 1962

DISCHARGED INVENTORY:

Plutonium	38-48 kg (remaining) (RHO-ST-21)
Americium-241	2.5 kg (RHO-LD-114)
Carbon tetrachloride	83,000 to 300,000 L (DOE/RL-91-32)
Tributyl phosphate	27,900 L (WHC-SD-EN-TI-248)
Dibutylbutyl phosphonate	46,500 L (WHC-SD-EN-TI-248)
Lard oil	9,300 L (WHC-SD-EN-TI-248)
Nitrate	1,361,000 kg (HNF-31792)

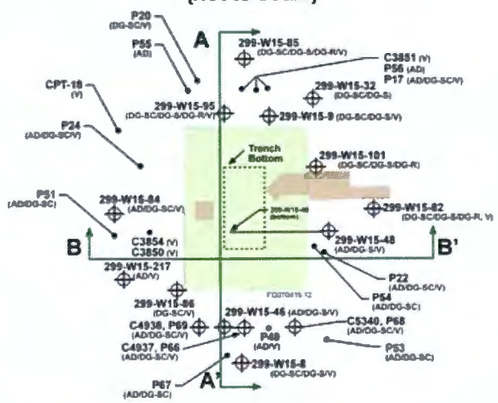
REFERENCES:
WIDS general summary reports
ARH-2915
RHO-ST-21
RHO-LD-114
PNNL-16103
PNNL-11978
DOE/RL-91-32
WHC-SD-EN-TI-248
BHI-00431
SGW-33746
HNF-31792

Basis of Knowledge (Data Types)

- Process History (PH)
- Downhole Geophysics - Spectral (DG-S)
- Downhole Geophysics - Scintillation (DG-SC)
- Downhole Geophysics - Radionuclide Logging System (DG-R)
- Soil Sampling Analytical Data (AD)
- Vapor Sampling Data (V)

Site Plan View

(not to scale)



Characterization Summary

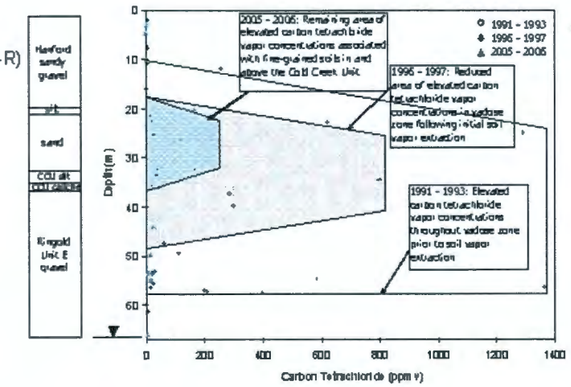
Wells were installed around the 216-Z-9 Trench beginning in the 1950s to monitor contaminant migration. Many of these wells have been geophysically logged. Characterization was conducted in 1961, 1963, and 1973 to evaluate the plutonium and americium in the trench (ARH-2915). Characterization was conducted in 1991 to 1993 to support soil vapor extraction activities. A DNAPL investigation conducted on the northeast corner of the 216-Z-9 Trench in 1995 detected no DNAPL in well 299-W15-32 (BHI-00431). Remedial investigation activities conducted at the trench included sampling from one deep well (299-W15-46) and one slant well (299-W15-48) and a phased carbon tetrachloride investigation. DNAPL was identified in a silt lens 20 m (65 ft) bgs south of the trench.

LEGEND

- Existing Borehole (data type)
- Water Table
- bgs = below ground surface

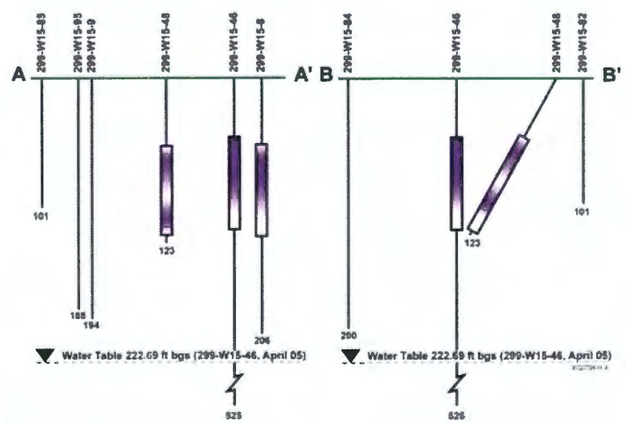
Site Section View Scale. Concentrations of plutonium; no color bar on Site Section View indicates no contamination was identified in available data.

Carbon Tetrachloride Vapor Distribution

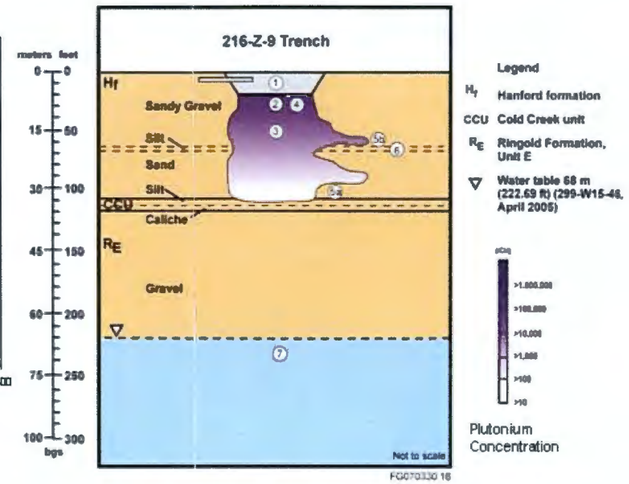


Site Section Views

(not to scale, units in feet bgs)



Contaminant Distribution Model



1. At the 216-Z-9 Trench, more than 4 million liters of plutonium/organic-rich process wastes were discharged between 1955 and 1962.
2. Effluent containing contaminants was discharged at the bottom of the unlined 216-Z-9 Trench. The trench floor slopes slightly to the south.
3. The wetting front and contaminants moved vertically beneath the trench. Lateral spreading of liquids is associated mainly with the Hanford gravel and sand contact, the Cold Creek unit, or fine-grained lenses in the Hanford or Ringold formations. In addition, vapor phase carbon tetrachloride migrated vertically and laterally beneath and around the trench, but has been considerably reduced by soil vapor extraction operations started in 1993 (see vapor distribution chart at left).
4. Constituents with large distribution coefficients, such as americium and plutonium, sorb to soils resulting in higher concentrations near the bottom of the trench. Concentrations generally decrease with depth. However, these contaminants were detected to depths up to 36.9 m (121 ft) bgs beneath the trench, indicating that plutonium and americium mobility was enhanced in the presence of the organic and acidic liquid wastes.
5. Carbon tetrachloride is present throughout the vadose zone beneath the 216-Z-9 Trench. As determined from sample data, carbon tetrachloride exists as vapor (5A), as a DNAPL near the Hanford gravel/sand contact on the south side (5B), and as a dissolved aqueous phase and/or sorbed phase in soil.
6. The highest concentrations of detected carbon tetrachloride are associated with silts in a thin lens at 20 m (65 ft) bgs.
7. Carbon tetrachloride has impacted the groundwater; impacts may have been associated with vapor, aqueous liquid, and/or organic liquid phases. In addition, carbon tetrachloride may have been dissolved in aqueous waste effluent from nearby facilities and subsequently been transported to groundwater. Plutonium and americium have been detected at low concentrations in the groundwater collected from one well near the trench. Older boreholes, and possibly clastic dikes, may have provided preferential pathways through the vadose zone.

200-PW-1FS.216-Z-9.08/28/07

Figure 2-3. Contaminant Distribution Model, 216-Z-9 Trench

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200-PW-1 Operable Unit
Waste Type: Process Waste

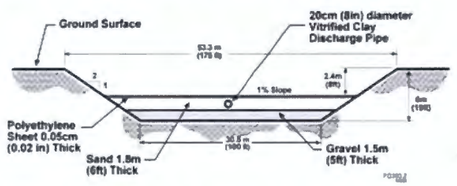
216-Z-1A Tile Field

PFP Zone

History

The 216-Z-1A Tile Field was a liquid waste site that was used to dispose of aqueous and organic liquid waste generated at the Plutonium Finishing Plant. The waste streams included overflow from the 216-Z-1, 216-Z-2, and 216-Z-3 Cribs, which received process and laboratory waste from 1949 to 1959, and 236-Z plutonium recovery waste and 242-Z americium recovery waste discharged directly to the tile field from 1964 to 1969. Carbon tetrachloride was received in the aqueous phase liquid and, mixed with other organics, as a dense, non-aqueous phase liquid (DNAPL) from 1964 to 1969. The site was deactivated in 1969 by plugging facility discharge piping to the tile field when plutonium recovery waste was diverted to the 216-Z-18 Crib. Soil vapor extraction has been ongoing at the site since 1992 to remove carbon tetrachloride from the vadose zone.

CONSTRUCTION: The 216-Z-1A Tile Field consists of a 30 m (100 ft) wide, 79 m (260 ft) long, and 5.8 m (19 ft) deep excavation. The 20-cm (8-in) diameter vitrified clay distribution pipes lie on a 1.5-m (5-ft) thick gravel bed, 4.3 m (14 ft) bgs. The distribution pipes are covered with a 1.8-m (6-ft) thick sand layer. The central distribution pipe is a continuous line without perforations; the seven pairs of lateral pipes are divided into 0.3-m (1-ft) long segments.



WASTE VOLUME: 6,200,000 L (1,600,000 gal) (RHO-LD-114)

DURATION: 1949 to 1969

ESTIMATED DISCHARGED INVENTORY:

Plutonium	57 kg (RHO-LD-114)
Americium-241	1 kg (RHO-ST-17)
Carbon tetrachloride	270,000 kg (WHC-SD-EN-TI-248)
Tributyl phosphate	23,900 L (WHC-SD-EN-TI-248)
Dibutylbutyl phosphonate	27,500 L (WHC-SD-EN-TI-248)
Lard oil	11,000 L (WHC-SD-EN-TI-248)
Nitrate	3,000 kg (DOE/RL-91-58)

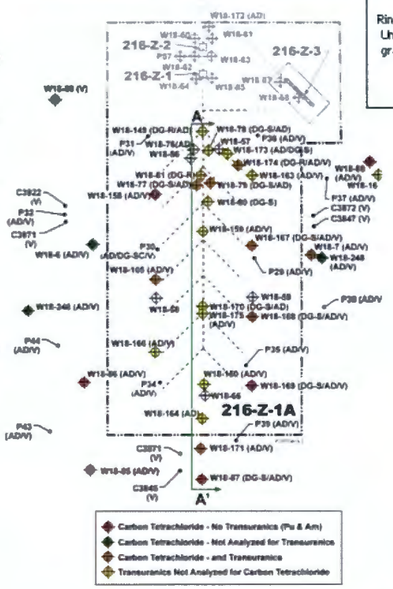
REFERENCES:
WIDS general summary reports
RHO-ST-17
RHO-LD-114
DOE/RL-91-32
WHC-SD-EN-TI-248
DOE/RL-91-58
SGW-33746
SGW-33829

Basis of Knowledge (Data Types)

- Process History (PH)
- Downhole Geophysics - Spectral (DG-S)
- Downhole Geophysics – Scintillation (DG-SC)
- Geologic Logs (GL)
- Soil Sampling Analytical Data (AD)
- Vapor Sampling Data (V)

Site Plan View

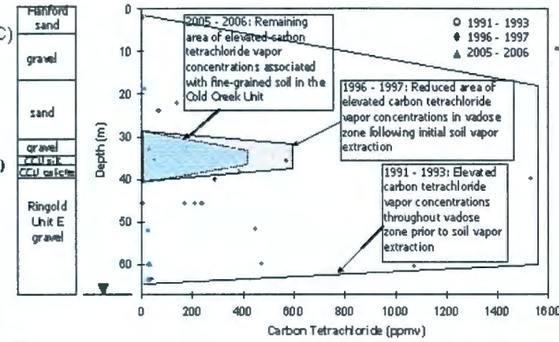
(not to scale; all well numbers prefixed with 299-)



Characterization Summary

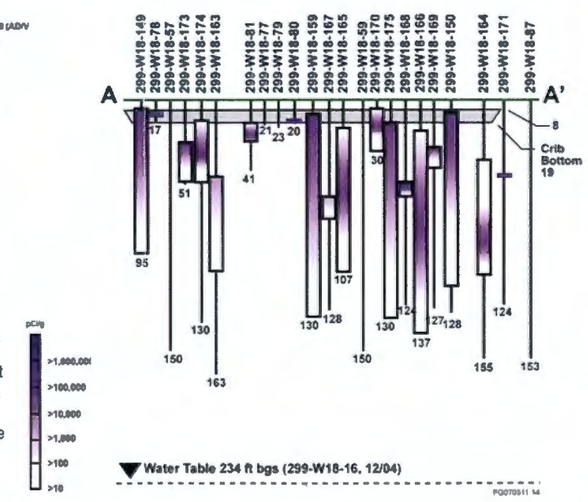
Data collection activities have been ongoing at the 216-Z-1A Tile Field since early operations. The distribution of plutonium and americium was characterized at 16 wells at this site in the 1970s (RHO-ST-17). Also, many of the wells in and around the tile field have been geophysically logged (ARH-ST-156, SGW-33829). Characterization was conducted in 1991-1993 to support soil vapor extraction, which has been ongoing at this site since 1992. As part of the remedial investigation, information from additional characterization boreholes was used to evaluate the distribution of carbon tetrachloride and other organic contaminants.

Carbon Tetrachloride Vapor Distribution



Site Section View

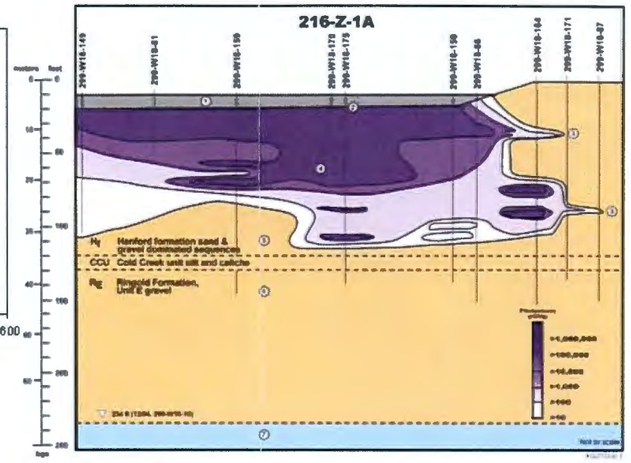
(not to scale; units in feet bgs)



Site Section View Scale. Concentrations of plutonium; no color bar on Site Section View indicates no contamination was identified in available data.

LEGEND
- Existing Borehole (data type)
- Water Table
- bgs = below ground surface

Contaminant Distribution Model



1. Between 1964 and 1969, the 216-Z-1A Tile Field received 5.2 million liters of high-salt, acidic liquid waste containing significant inventories of plutonium and carbon tetrachloride. From 1949 to 1959, the 216-Z-1A Tile Field received 1.0 million liters of slightly basic, aqueous waste.
2. Effluent and contaminants were released to the soil at the bottom of the tile field through a herringbone arrangement of pipes.
3. The wetting front and contaminants moved vertically beneath the tile field. Lateral spreading is mainly attributed to contact with the Cold Creek unit or fine-grained lenses in the Hanford or Ringold formations. Vapor phase carbon tetrachloride exists throughout the vadose zone in the source area.
4. Constituents such as plutonium (Pu) and americium (Am), which are generally immobile in soils, sorb readily to soils, resulting in higher concentrations directly beneath the tile field. The Am and Pu concentrations generally decrease with depth. However, radionuclides were detected to depths up to 37 m, indicating that Pu and Am mobility was enhanced in the presence of carbon tetrachloride, tributyl phosphate and derivatives, and acidic liquid wastes.
5. Carbon tetrachloride initially spread throughout the vadose zone beneath and around the 216-Z-1A Tile Field. However, soil vapor extraction operations started at the site in 1992 have considerably reduced the vadose zone carbon tetrachloride inventory (see vapor distribution chart at left). Dense non-aqueous phase liquid carbon tetrachloride was not identified during the remedial investigation.
6. The highest concentration of carbon tetrachloride is associated with the fine-grained sediments of the Cold Creek unit.
7. The effluent volume discharged to the tile field suggests that groundwater may not have been directly impacted by the wetting front unless a preferential pathway is present. Carbon tetrachloride in the soil vapor phase may have reached groundwater.

200-PW-1FS.216-Z-1A.08/30/07

Figure 2-4. Contaminant Distribution Model, 216-Z-1A Tile Field

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200-PW-1 Operable Unit
Waste Type: Process Waste

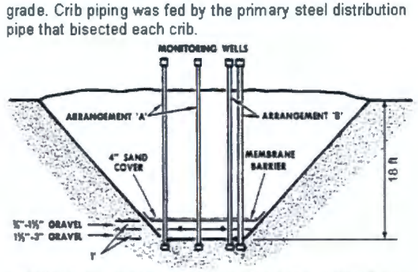
216-Z-18 Crib

PFP Zone

History

The 216-Z-18 Crib was used, as a replacement for the 216-Z-1A Tile Field, to receive high salt, acidic (pH 1 to 2.5) aqueous liquid waste and organic liquid waste from the Plutonium Finishing Plant. The waste streams included plutonium recovery waste from the 236-Z Building and americium recovery waste from the 242-Z Building. Carbon tetrachloride was received in the aqueous phase liquid and, mixed with other organics, as a dense, non-aqueous phase liquid (DNAPL). Crib structures 1 through 4 (shown numbered east to west) received waste; crib structure 5 was not used. The individual crib structures were operated for approximately 1 year each beginning with crib structure 3, followed by crib structures 2, 1, and 4, in that order. The 216-Z-18 Crib was retired in 1973 and deactivated by blanking pipelines in the 236-Z and 242-Z Buildings. Soil vapor extraction has been ongoing at the crib since 1992 to remove carbon tetrachloride from the vadose zone.

CONSTRUCTION: The 95 by 79 m (311 by 259 ft) site consists of 5 separate, parallel crib structures, each 63 m by 3 m (207 ft by 10 ft), and 5.5 m (18 ft) deep. Each crib structure has two 8-cm (3-in) diameter distribution pipes placed on a 0.3-m (1-ft) thick bed of gravel at 5.2 m (17 ft) bgs, buried under an additional 0.3 m (1 ft) of gravel, covered with a membrane and sand, and then backfilled to grade. Crib piping was fed by the primary steel distribution pipe that bisected each crib.



WASTE VOLUME: 3,860,000 L (1,020,000 gal) (RHO-LD-114)

DURATION: 1969 to 1973

ESTIMATED DISCHARGED INVENTORY:

Plutonium	23 kg (RHO-LD-114)
Americium-241	0.4 kg (DOE/RL-91-32)
Carbon tetrachloride	175,000 kg (WCH-SD-EN-TI-248)
Tributyl phosphate	16,400 kg (WCH-SD-EN-TI-248)
Dibutylbutyl phosphonate	19,100 kg (WCH-SD-EN-TI-248)
Nitrate	500,000 kg (DOE/RL-91-58)

REFERENCES:
WIDS general summary reports
RHO-LD-114
SGW-33746
WHC-SD-EN-TI-248
DOE/RL-91-32
DOE/RL-91-58

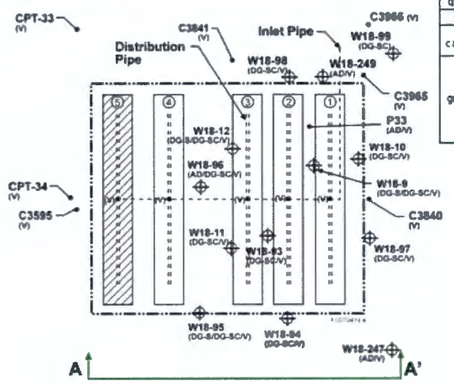
LEGEND
- Existing Borehole (data type)
- Water Table
- bgs = below ground surface

Basis of Knowledge (Data Types)

- Process History (PH)
- Downhole Geophysics - Spectral (DG-S)
- Downhole Geophysics – Scintillation (DG-SC)
- Soil Sampling Analytical Data (AD)
- Vapor Sampling Data (V)

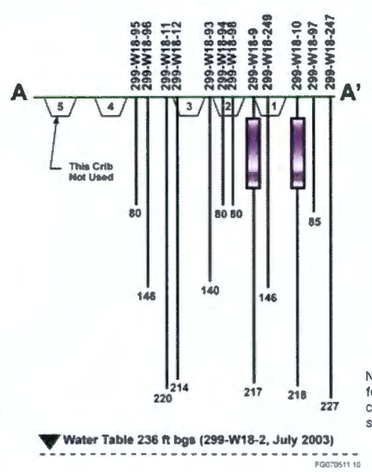
Site Plan View

(not to scale; all W18 well numbers prefixed by 299-)

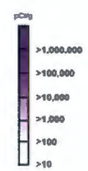


Site Section View

(not to scale, units in feet bgs)

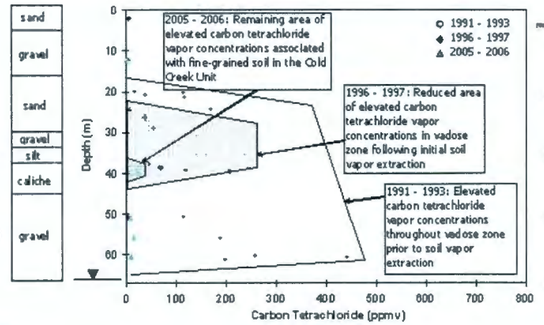


Note: Concentration profile for 299-W18-10 derived from comparison with 299-W18-9 scintillation and logging data.



Site Section View Scale. Concentrations of plutonium; no color bar on Site Section View indicates no contamination was identified in available data.

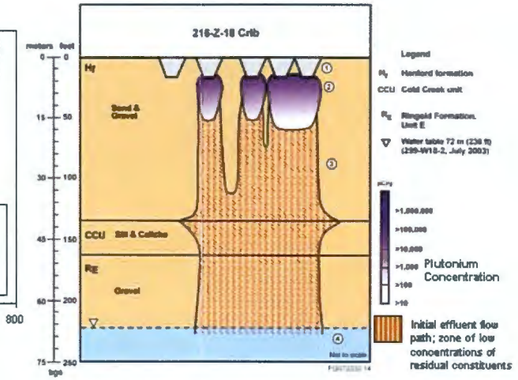
Carbon Tetrachloride Vapor Distribution



Characterization Summary

Characterization activities have been conducted at 216-Z-18 since the 1960s. Scintillation logging of site monitoring wells was conducted in 1968, 1973 and 1976. Wells 299-W18-9 and 299-W18-10 were the only wells that showed contamination above background levels; contamination was identified at about 8 to 17 m (26 to 55 ft) bgs (ARH-ST-156). Characterization was also conducted in 1992 and 1993 in support of soil vapor extraction activities. Spectral gamma logging and neutron moisture logging were conducted in 2006 at wells 299-W18-9, 299-W18-12, and 299-W18-95. Well 299-W18-9 identified plutonium and americium-241 from 7.6 to 18 m (25 to 60 ft) bgs with a maximum concentration of 400,000 pCi/g at 8.2 m (27 ft) bgs. Concentrations decreased with depth to 18 m (60 ft) bgs, where they increased to 250,000 pCi/g. Concentrations decreased to the tool detection limits below about 21 m (70 ft) bgs. Analytical soil data obtained from wells 299-W18-96, 299-W18-247, and 299-W18-249 in 1992 and 1993 did not identify significant organic chemical contamination (e.g., carbon tetrachloride was < 2 ppm). Nitrate was identified in well 299-W18-96 at 4,400 mg/kg at 25.6 m (84 ft) bgs decreasing to < 10 mg/kg at 38.1 m (125 ft) bgs. No significant concentrations of carbon tetrachloride or other volatile organic compounds were identified during soil vapor sampling conducted for the remedial investigation or soil vapor extraction operations in 2005 or 2006.

Contaminant Distribution Model



1. From 1969 to 1973, about 4 million liters of liquid waste were discharged to the 216-Z-18 Crib at a depth of about 5.2 m (17 ft) bgs. Crib operations were controlled so effluent was discharged evenly over the 4 (of 5) crib structures that received waste.
2. Liquid waste and contaminants moved through the gravel bed where the immobile radionuclides (plutonium and americium) sorbed to soils directly below the crib. Site-specific data show crib contamination extending from about 7.6 to 21 m (25 to 70 ft) bgs. Analytical sampling to date did not identify the presence of organics in soil in significant quantities. Any remaining carbon tetrachloride or other organic contaminants are likely associated with, or are directly above, the Cold Creek unit.
3. As the liquid waste continued to migrate downward, more mobile contaminants (e.g., nitrate) moved toward the groundwater. Because of the proximity of the individual crib structures to one another, subsurface intermingling of the waste streams has likely occurred. Fine-grained soils in the vadose zone slowed water movement and allowed mobile contaminants to concentrate and, to a minor extent, move laterally along the interfaces between fine-grained and coarser-grained sediments.
4. Although the overall effluent volume to each crib structure within the site was relatively low and evenly distributed throughout the crib structures, nitrate inventory was reportedly high. Analytical sample results for nitrate and soil moisture demonstrate a potential for past and/or future groundwater impacts from this site. Impacts to groundwater from organic constituents are not expected from this crib.

200-PW-1RIR.216-Z-18.08/30/07

Figure 2-5. Contaminant Distribution Model, 216-Z-18 Crib

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200-PW-1 Operable Unit
Waste Type: Process Waste

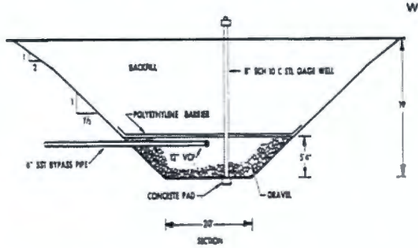
216-Z-12 Crib

PFP Zone

History

The 216-Z-12 Crib is a subsurface liquid waste site that was used from 1959 to 1973 to dispose of PFP liquid process waste, and analytical and development laboratory waste, from the 234-5Z Building via the 241-Z-361 Settling Tank. The waste was low-salt and neutral-basic (pH 8 to 10) when discharged. When the crib was deactivated, the pipeline was blanked in the 241-Z facility. A portion of the crib was vitrified in 1987. The downward progression of the melt reached about 5 m (16 ft) bgs.

CONSTRUCTION: The crib is rectangular, 91 by 6 m (300 by 20 ft) at the bottom, and 5.8 m (19 ft) deep. Waste entered at 4.6 m (15 ft) bgs through a 30-cm (12-in) diameter, perforated, vitrified clay pipe that ran the length of the crib and rested on a 1.5 m (5 ft) bed of gravel. The pipe was covered with a polyethylene barrier and backfilled to grade. In 1968, a 15-cm (6-in) diameter bypass line was installed 9 m (30 ft) west of and parallel to the original distribution line to bypass 30.5 m (100 ft) of the original line that was plugged.



WASTE VOLUME: 281,000,000 L (74,240,000 gal) (RHO-LD-114)

DURATION: 1959 to 1973

ESTIMATED DISCHARGED INVENTORY:

Plutonium	25.1 kg (RHO-LD-114)
Americium-241	Unknown
Nitrate	900,000 kg (DOE/RL-91-58)
Fluoride	300,000 kg (DOE/RL-91-58)
Carbon tetrachloride	Unknown, but limited (RHO-ST-44)

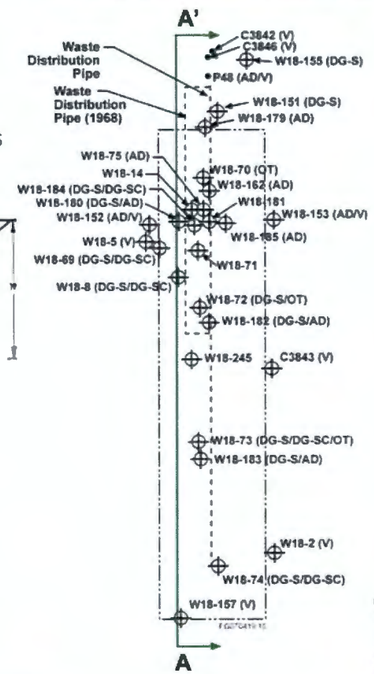
REFERENCES:
WIDS general summary reports
HW-9671
DOE/RL-91-58
RHO-LD-114
RHO-ST-44

Basis of Knowledge (Data Types)

- Process History (PH)
- Downhole Geophysics - Spectral (DG-S)
- Downhole Geophysics – Scintillation (DG-SC)
- Geologic Logs (GL)
- Soil Sampling Analytical Data (AD)
- Other Downhole Alpha Techniques (OT)
- Vapor Sampling Data (V)

Site Plan View

(not to scale; all well numbers prefixed by 299-)

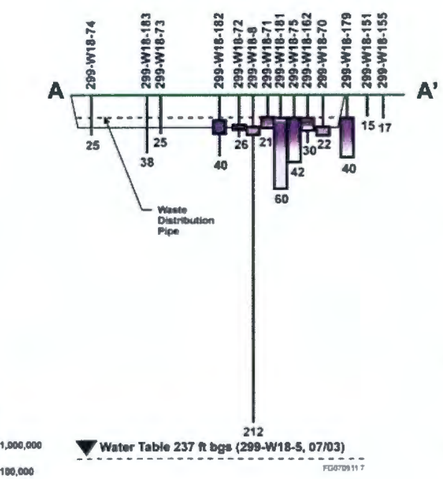


Characterization Summary

Data collection activities have been ongoing at the 216-Z-12 Crib since early operations. RHO-ST-44 summarizes these early data collection activities (surveys and sampling of shallow wells) and documents characterization activities associated with installation and sampling of additional wells starting in 1979 to better define the plutonium and americium distribution. A soil vapor survey in 1991 indicated the presence of carbon tetrachloride near the crib, and soil vapor extraction operations were initiated in 1995. As part of the remedial investigation, additional soil vapor samples were collected to evaluate the concentration of carbon tetrachloride in the vadose zone at this site.

Site Section View

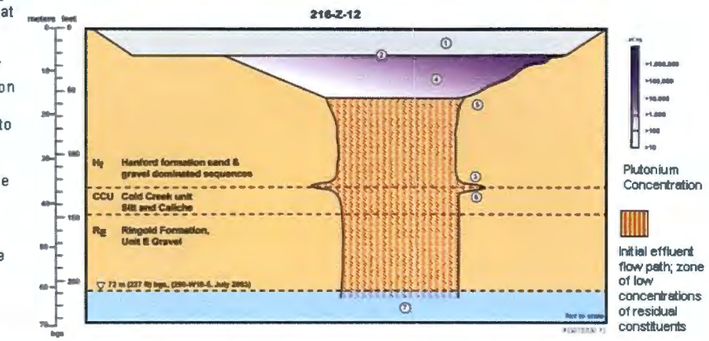
(not to scale, units in feet bgs)



Site Section View Scale. Concentrations of transuranics; no color bar on Site Section View indicates no contamination was identified in available data.

LEGEND
- Existing Borehole (data type)
- Water Table
- bgs = below ground surface

Contaminant Distribution Model



1. 281 million liters of plutonium process waste was discharged to the 216-Z-12 Crib from 1959 to 1973. The wastes were low-salt and neutral to slightly basic.
2. Effluent and contaminants were released to the environment near the bottom of the crib, into the Hanford formation sands.
3. The wetting front and contaminants moved vertically beneath the crib. Lateral spreading is limited and mainly associated with the Hanford formation gravel-sand contact, the Cold Creek unit, or fine-grained lenses in the Hanford or Ringold Formations. Inventory data on organic contaminants (e.g., carbon tetrachloride) are limited; however, soil vapor sampling indicates the presence of low concentrations of vapor phase carbon tetrachloride in the vadose zone in the vicinity of the crib.
4. More immobile constituents, such as americium and plutonium, generally sorb readily to soils, resulting in higher concentrations near the discharge point. Beneath the crib, however, radionuclides were detected to a depth of more than 18 m (60 ft) bgs. The americium and plutonium concentrations generally decrease with depth. The plutonium and americium are distributed in the northern half of the crib, with little evidence of contamination in the southern half.
5. Carbon tetrachloride migrated through the vadose zone beneath and around the 216-Z-12 Crib. Soil vapor extraction activities at the site have considerably reduced the carbon tetrachloride inventory in the vadose zone. The remedial investigation did not identify carbon tetrachloride in the dense, non-aqueous liquid phase at this location.
6. Low levels (up to a few tens of picocuries per gram) of plutonium and americium activity were detected from 30 to 36 m (98 to 118 ft) below the crib, associated with a thick silt layer in the Cold Creek unit
7. Discharged inventory estimates for nitrate would support potential past and/or future groundwater impacts. However, existing data do not address characterization of the deeper vadose zone.

200-PW-1RIR.216-Z-12.09/04/07

Figure 2-6. Contaminant Distribution Model, 216-Z-12 Crib

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216-Z-1 & 2 Cribs

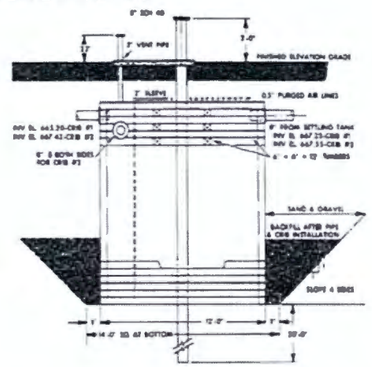
200-PW-1 Operable Unit
Waste Type: Process Waste

PFP Zone

History

The 216-Z-1 Crib and 216-Z-2 Crib are wooden timber structures that were used for disposal of Z-Plant liquid waste. The 216-Z-2 Crib overflowed into the 216-Z-1 Crib, which overflowed into the 216-Z-1A Tile Field. From 1949 to 1952, the cribs received basic (pH 8 to 10) process and laboratory waste from the 234-5Z Building via the 241-Z-361 Settling Tank. The cribs received acidic (pH 1 to 2.5), high-salt aqueous and organic waste directly from the 236-Z and 242-Z Buildings during two brief periods of a few weeks in 1966 and 1967 while the 216-Z-1A Tile Field discharge point was being moved further south along the main distribution pipe. The cribs received uranium wastes directly from the 236-Z Building from 1968 to 1969. The cribs were administratively retired in 1969 and physically isolated when inlet piping was cut and blanked.

CONSTRUCTION: The 216-Z-1 Crib and 216-Z-2 Crib consist of two open-bottom, 3.7 m (12 ft) square wooden timber boxes set in excavations that were 4.3 m (14 ft) square at the bottom, 6.4 m (21 ft) deep, and backfilled to grade. The cribs were connected and fed by a 20 cm (8 in) diameter stainless steel central pipe with an outlet pipe to the 216-Z-1A Tile Field.



WASTE VOLUME: 33,700,000 L (10,271,000 gal) (RHO-LD-114)

DURATION: 1949 to 1969

ESTIMATED DISCHARGED INVENTORY:

Plutonium	7.0 kg (RHO-LD-114)
Americium-241	Unknown
Uranium (total)	80.9 kg (RHO-LD-114)
Nitrate	100,000 kg (DOE/RL-91-58)
Fluoride	30,000 kg (DOE/RL-91-58)

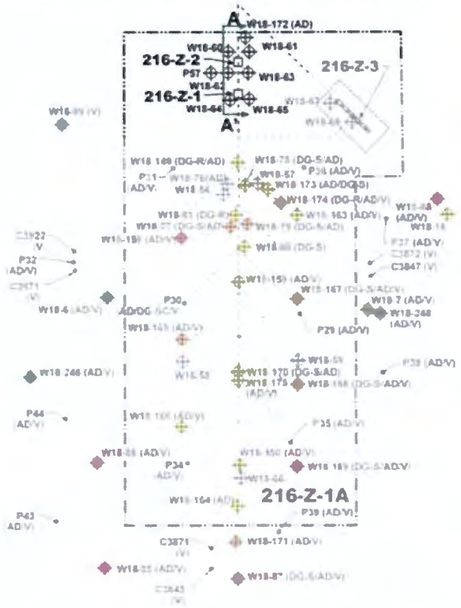
REFERENCES:
WIDS general summary reports
RHO-LD-114
DOE/RL-91-58
Rockwell 1986

Basis of Knowledge (Data Types)

- Process History (PH)
- Downhole Geophysics - Spectral (DG-S)
- Other Downhole Alpha Techniques (OT)
- Soil Sampling Analytical Data (AD)

Site Plan View

(not to scale, all well numbers prefixed by 299-)



LEGEND
- Existing Borehole (data type)
- Water Table
- bgs = below ground surface

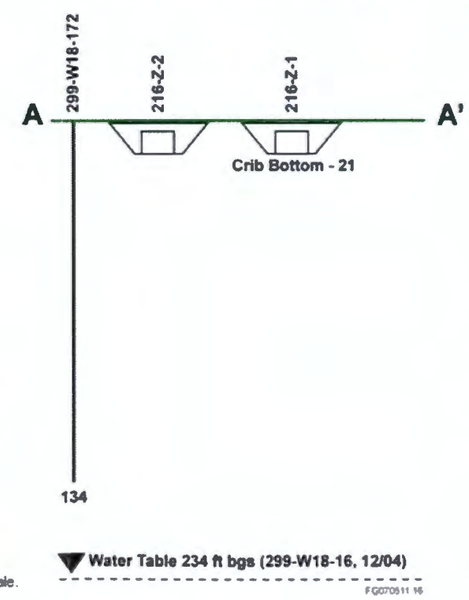
Site Section View Scale. Concentrations of plutonium; no color bar on Site Section View indicates no contaminstion was identified in available data.

Characterization Summary

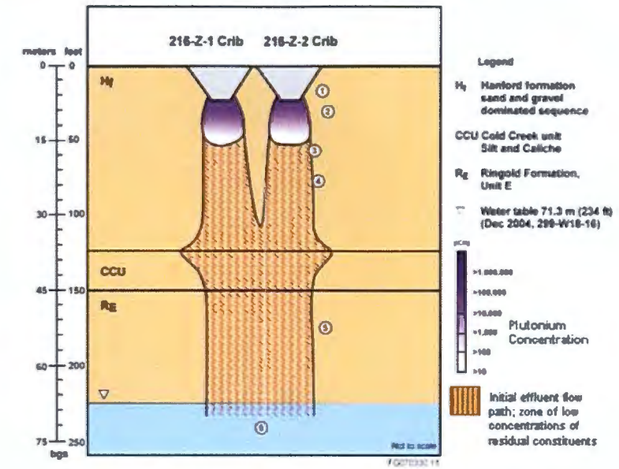
Site-specific sampling data for the 216-Z-1 Crib and 216-Z-2 Crib are limited. A borehole to the north of 216-Z-2 (299-W18-172) was geophysically logged in 2006; no manmade radionuclides were detected. No radionuclide contamination was detected during drilling of a new well (P57) west of the cribs in 2006. In 1986, drop cords, visual inspection, and foil activation methods were used to evaluate alpha contamination in 11 wells at the 216-Z-1 and 216-Z-2 Cribs and the 216-Z-1A Tile Field (CCN 65632-86-095). Wells 299-W18-60, 299-W18-61, and 299-W18-65 near the 216-Z-1 and 216-Z-2 Cribs were found to contain plutonium and americium concentrations estimated as high as 900 nCi/g. The contamination was believed to have resulted from contaminated sediments entering and accumulating in the wells.

Site Section View

(not to scale, units in feet bgs)



Contaminant Distribution Model



1. Approximately 33.7 million liters of liquid waste was discharged to these cribs from 1949 to 1969 at approximately 6.4 m (21 feet) bgs.
2. Liquid waste containing contaminants moved through the cribs where the less mobile contaminants (e.g., plutonium and americium) sorbed to soils near the bottom of the crib structures. A zone of high contamination (i.e., > 1,000,000 pCi/g of plutonium) likely extends a few feet below the crib bottoms, based on data from the 216-Z-3 Crib, which replaced the 216-Z-1 and 216-Z-2 Cribs, and the 216-Z-12 Crib, which replaced the 216-Z-3 Crib.
3. Concentrations are expected to decrease quickly with depth because waste stream contaminants did not significantly impact mobility of the alpha emitters. Significant volumes of organics likely were not discharged to these cribs during the few weeks that they received high salt waste from plutonium recovery operations in the 236-Z Building and 242-Z Building.
4. As the liquid waste continued to migrate downward, more mobile contaminants (e.g., nitrate) continued to be carried downward towards the groundwater. Fine-grained zones in the vadose zone slowed water movement and allowed contaminants to concentrate and move laterally along the interfaces between fine-grained and coarser-grained sediments.
5. Because of the proximity of these waste sites to the 216-Z-3 Crib and the 216-Z-1A Tile Field, subsurface commingling of the waste streams is anticipated. Differentiation of the more mobile contaminants is not likely between the cribs and tile field.
6. The effluent volume and nitrate inventory received at the 216-Z-1 and 216-Z-2 Cribs are sufficient to have likely impacted groundwater. Future groundwater impacts are possible, especially associated with nitrate. Organic impacts are not expected from the 216-Z-1 and 216-Z-2 Cribs.

200-PW-1RIR.216-Z-1&2.08/28/07
CHPUBS1104_2007-27_R0_02.07

Figure 2-7. Contaminant Distribution Model, 216-Z-1&2 Cribs

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200-PW-1 Operable Unit
Waste Type: Process Waste

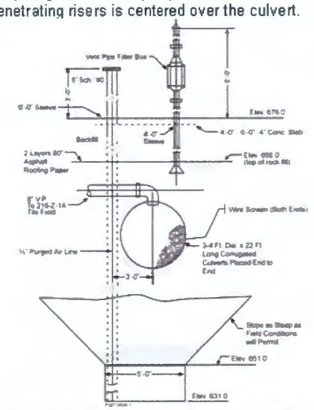
216-Z-3 Crib

PFP Zone

History

The 216-Z-3 Crib is a liquid waste site that was used from 1952 to 1959 as a replacement for the 216-Z-1 Crib and 216-Z-2 Crib for disposal of Z-Plant neutral-basic liquid process and laboratory waste received via the 241-Z-361 Settling Tank. Overflow from the crib went to the 216-Z-1A Tile Field. The site was deactivated by valving out the pipeline to the crib and plugging the overflow line to the 216-Z-1A Tile Field.

CONSTRUCTION: The crib consists of three, 1.2-m (4-ft) diameter, 6.7 m (22 ft) long, perforated corrugated metal culverts laid horizontally, end to end, in the upper portion of a 21-m (70-ft) long, 7.6-m (25-ft) deep excavation. Wire was welded on the culvert ends to prevent gravel intrusion. The culverts were approximately 2.4 m (8 ft) below grade on a 5-m (17-ft) deep bed of gravel that was covered with asphalt roofing paper and backfilled to grade. A 1.2-m (4-ft) wide, 1.8-m (6-ft) long, and 10-cm (4-in) thick concrete slab with penetrating risers is centered over the culvert.



WASTE VOLUME: 178,000,000 L (46,992,000 gal) (RHO-LD-114)

DURATION: 1952 to 1959

ESTIMATED DISCHARGED INVENTORY:

Plutonium	5.7 kg (RHO-LD-114)
Americium-241	Unknown
Nitrate	600,000 kg (DOE/RL-91-58)
Fluoride	160,000 kg (DOE/RL-91-58)

REFERENCES:
WIDS general summary reports
RHO-LD-114
DOE/RL-91-58
ARH-2155

Basis of Knowledge (Data Types)

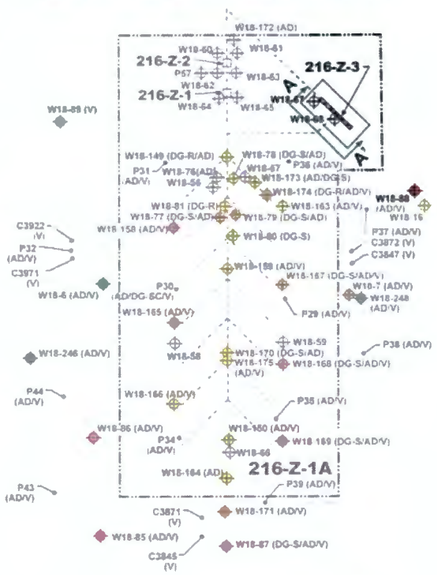
- Process History (PH)
- Downhole Geophysics - Spectral (DG-S)

Characterization Summary

Characterization activities include geophysical logging of 2 boreholes drilled through the crib. The logs show plutonium and americium contamination from about 5.5 to 9 m (18 to 30 ft) bgs at concentrations exceeding 1,000,000 pCi/g for plutonium.

Site Plan View

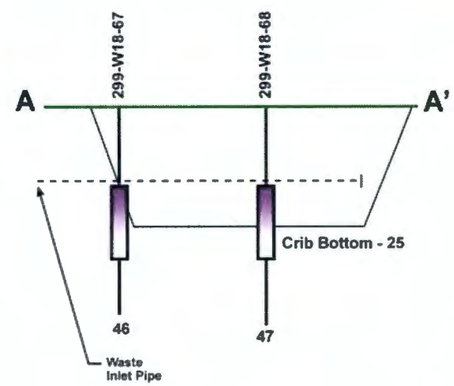
(not to scale; all well numbers prefixed by 299-)



LEGEND
- Existing Borehole (data type)
- Water Table
- bgs = below ground surface

Site Section View

(not to scale; units in feet bgs)

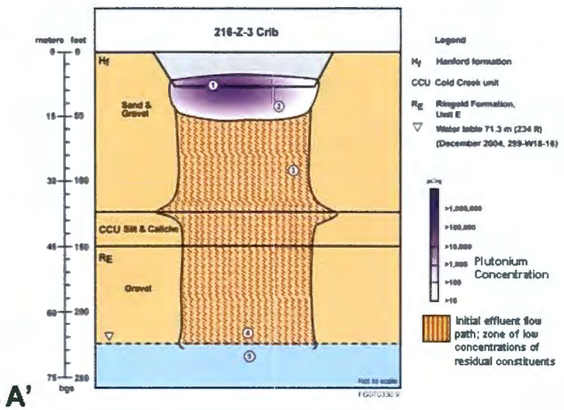


Water Table 234 ft bgs (299-W18-16, 12/04)

FG070511 17

Site Section View Scale. Concentrations of plutonium; no color bar on Site Section View indicates no contamination was identified in available data.

Contaminant Distribution Model



1. Approximately 178 million liters of liquid waste was discharged to the crib from 1952 to 1959 at a depth of approximately 2.4 m (8 ft) bgs. The crib was filled with gravel to the bottom of the excavation, approximately 7.6 m (25 ft) bgs.
2. Liquid waste containing contaminants moved through the gravel bed, and the less mobile contaminants (e.g., plutonium and americium) sorbed to soils near the bottom of the crib structure. A zone of high contamination (i.e., > 1,000,000 pCi/g of plutonium) extends from about 5.5 to 9 m (18 to 30 ft) bgs. Concentrations decreased quickly with depth below 9 m (30 ft). Only a small volume of organics, if any, were likely to have been discharged to this crib in association with the laboratory development waste.
3. As the liquid waste continued to migrate downward, more mobile contaminants (e.g., nitrate) continued to be carried downward towards the groundwater. Fine-grained lenses in the vadose zone slowed water movement and allowed contaminants to concentrate and move laterally along the interfaces between fine-grained and coarser-grained sediments.
4. Because of the proximity of this site to the 216-Z-1 Crib, the 216-Z-2 Crib, and the 216-Z-1A Tile Field, subsurface commingling of the waste streams is anticipated. Differentiation of the more mobile contaminants is not likely between the cribs and tile field.
5. The effluent volume and nitrate inventory received at the 216-Z-3 Crib are sufficient to have likely impacted groundwater. Future groundwater impacts are possible, especially associated with nitrate. Organic impacts are not expected from the 216-Z-3 Crib.

200-PW-1RIR.216-Z-3.08/28/07

Figure 2-8. Contaminant Distribution Model, 216-Z-3 Crib

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200-PW-1 Operable Unit
Waste Type: Process Waste

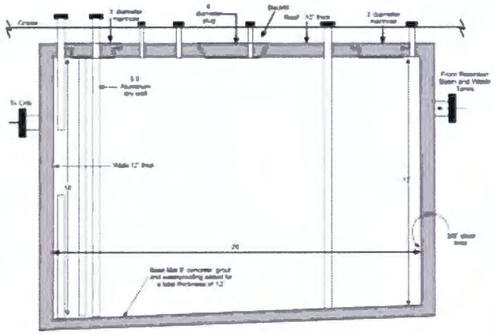
241-Z-361 Settling Tank

PFP Zone

History

The 241-Z-361 settling tank is an underground reinforced concrete structure that operated from 1949 to 1973 as a settling tank for neutralized 234-5Z, 242-Z and 236-Z liquid waste arriving from the 241-Z sump tanks. Settling tank supernatant was routed to numerous cribs, including the 216-Z-1, 216-Z-2, 216-Z-3, and 216-Z-12 cribs. The tank was isolated in 1973 and was partially pumped in May 1975 leaving approximately 800 L (210 gal) of liquid and 75 m³ (82 yd³) of sludge. The tank was evaluated in 1997 as part of a chemical hazard risk assessment. Characterization and analysis of the tank contents, completed in 2001, concluded that the tank contents posed no imminent threat to the environment (HNF-8735).

CONSTRUCTION: The tank interior is 7.9 by 4.0 m (26 by 13 ft) with 0.3-m (1-ft) thick walls and a sloping bottom resulting in an internal height varying between 5.2 and 5.5 m (17 and 18 ft). The top is 0.6 m (2 ft) below grade. There are two manhole covers and frames and several risers visible above grade. Waste entered the tank through two 15 cm (6 in) diameter stainless steel pipes; waste exited through a 20 cm (8 in) diameter stainless steel pipe.



WASTE VOLUME: 800 L of liquid and 75 m³ of sludge are estimated to remain in the tank (HNF-8735)

DURATION: 1949 to 1973

REMAINING INVENTORY:
Plutonium 29 kg (HNF-8735)

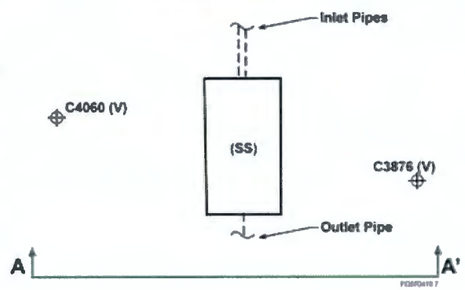
REFERENCES:
WIDS general summary reports
DOE/RL-2003-52
DOE/RL-2001-01
HNF-2867
HNF-8735
HNF-4371
FH-0002791

Basis of Knowledge (Data Types)

- Process History (PH)
- Vapor Sampling Data (V)
- Sludge Sampling Data (SS)

Site Plan View

(not to scale)



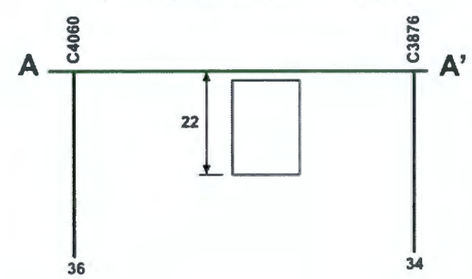
LEGEND
- Existing Borehole (data type)
- Water Table
- bgs = below ground surface

Characterization Summary

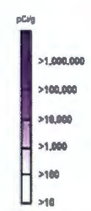
The 241-Z-361 Settling Tank and its contents were characterized from 1999 to 2001 in two phases. Phase I focused on opening the tank, characterizing the headspace vapor, and conducting a video camera survey of the tank interior (HNF-2867). Phase I identified volatile and semivolatile organics (HNF-8735). Phase II focused on characterizing the sludge (HNF-4371). Phase II identified approximately 75 m³ (82 yd³) of sludge with 29 kg of plutonium at concentrations of Pu-239 ranging from 428 ppm to 69 ppm and Pu-240 from 61 ppm to less than detectable. Metals (e.g., cadmium, chromium) and polychlorinated biphenyls (PCB) were detected in the sludge (HNF-8735). Helical piers installed to support tank sampling were surveyed when removed; no radiological contamination was detected (FH-0002791). Comparison of the 1999 camera survey to the 1975 photographs indicates the depth of the contents has not changed, signifying the tank has not leaked.

Site Section View

(not to scale, units in feet bgs)



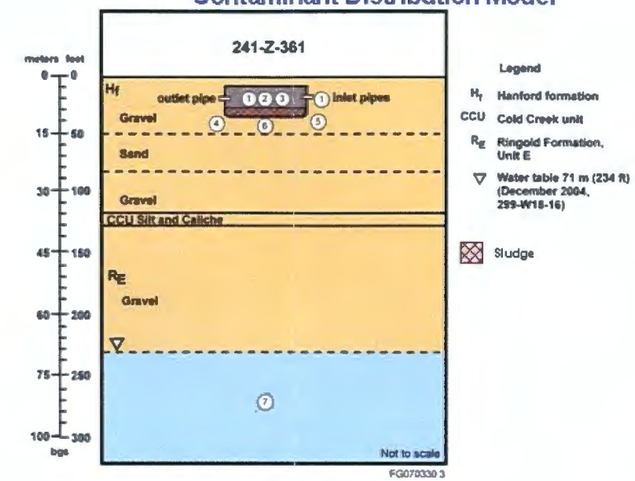
Site Section View Scale. Concentrations of plutonium; no color bar on Site Section View indicates no contamination was identified in available data.



Water Table 234 ft bgs (299-W18-16, 12/04)

FG070511 19

Contaminant Distribution Model



FG070330 3

1. From 1949 to 1973, the settling tank was used to precipitate the heavier constituents from plutonium/organic rich process waste discharged to the tank.
2. After pumping in May 1975, a layer of sludge approximately 2.4 m (8 ft) thick remained with an estimated volume of 75 m³ (82 yd³) and containing approximately 29 kg of plutonium.
3. Characterization of the tank and its contents from 1999 to 2001 concluded that there are no imminent threats posed by the tank or its contents in their present condition and that the conditions are not likely to change in the near future. The sludge was identified as requiring remediation based on plutonium and toxic metals content.
4. Limited opportunistic survey of soils in the vicinity of the 241-Z-361 tank was conducted in 1999. Helical piers were installed and extended beneath the depth of the tank bottom within a meter from the tank. Some piers were removed and surveyed, and no radiological contamination was detected.
5. Potential leaks from this tank seem unlikely, based on comparisons of 1999 videos to 1975 still photographs showing the waste level remained unchanged and on the lack of radiological contamination from removed piers.
6. Although not expected, if tank leakage had occurred, immobile contaminants such as plutonium would be expected to sorb near the point of release. More mobile contaminants were mainly present in the remaining liquid in the tank, not in the sludge; most were removed with the supernatant.
7. Groundwater impact from this site is not expected. Evidence shows the tank likely did not leak and even had leakage occurred, the potential leak volume is much less than the soil column pore volume.

200-PW-1FS.241-Z-361.08/28/07

Figure 2-9. Contaminant Distribution Model, 241-Z-361 Settling Tank

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200-PW-3 Operable Unit
Waste Type: Process Waste

216-A-8 Crib

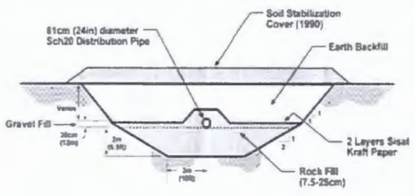
PUREX Zone

History

The 216-A-8 Crib was a liquid waste site used to dispose of vapor condensate and cooling water from operation of ventilation systems associated with the 241-A, 241-AX, 241-AY, and 241-AZ Tank Farms via the 216-A-508 Control Structure. In May 1958, when the crib approached its radionuclide capacity, the condensate was routed to the 216-A-24 Crib. Between 1966 and 1985, the 216-A-8 Crib intermittently received the vapor condensate waste. After 1985, all tank farm condensate waste was routed to the double-shell tank system. This site was surface stabilized in September 1990. The site was permanently isolated in April 1995 by filling the 216-A-508 Control Structure with concrete.

CONSTRUCTION: The 216-A-8 Crib is 6 by 259 m (20 by 850 ft) at the bottom, and ranges from 4.9 to 5.8 m (16 to 19 ft) deep. The crib was fed by a 61-cm (24 in) diameter, perforated distribution pipe located 2.6 to 3.5 m (8.5 to 11 ft) below original grade (1955) along the length of the crib on a 30-cm (12-in) thick bed of gravel. The gravel overlies 2.0 m (6.5 ft) of rock fill. The crib was covered with sisalkraft* paper and backfilled to grade. An overflow pond was excavated to the northeast of the crib. The pond was fed by a narrow ditch that was fed by a 41-cm (16-in) diameter pipe.

*Trademark of Fortifiber Corporation, Los Angeles, CA.



WASTE VOLUME: 1,150,000,000 liters (303,800,000 gal) (ARH-CD-745)

DURATION: 1955 to 1985

ESTIMATED DISCHARGED INVENTORY (RPP-26744, mean values; radionuclides decayed to 01/01/2001):

Cesium-137	2,410 Ci
Tritium	24,561 Ci
Uranium (total)	391 kg
Tributyl phosphate	128,582 kg
Normal paraffin hydrocarbon	55,107 kg
Butanol	1,364 kg

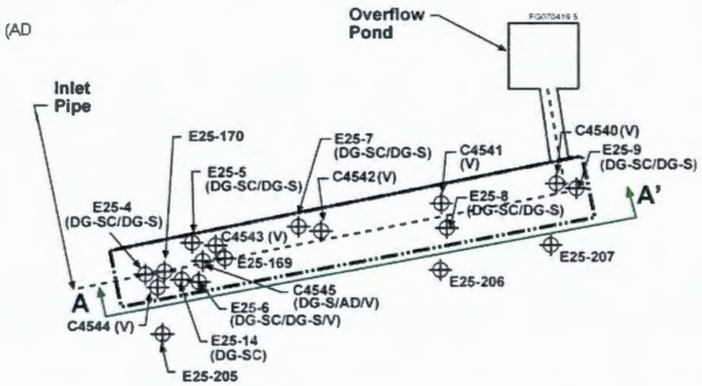
REFERENCES:
WIDS general summary reports
ARH-CD-745
RPP-26744
DOE/RL-2001-01
DOE/RL-92-04
WHC-EP-0287, Volume 3

Basis of Knowledge (Data Types)

- Process History (PH)
- Downhole Geophysics - Spectral (DG-S)
- Downhole Geophysics – Scintillation (DG-SC)
- Downhole Geophysics – Radionuclide Logging System (DG-R)
- Geologic Logs (GL)
- Soil Sampling Analytical Data (AD
- Vapor Sampling Data (V)

Site Plan View

(not to scale; all well numbers prefixed by 299-)



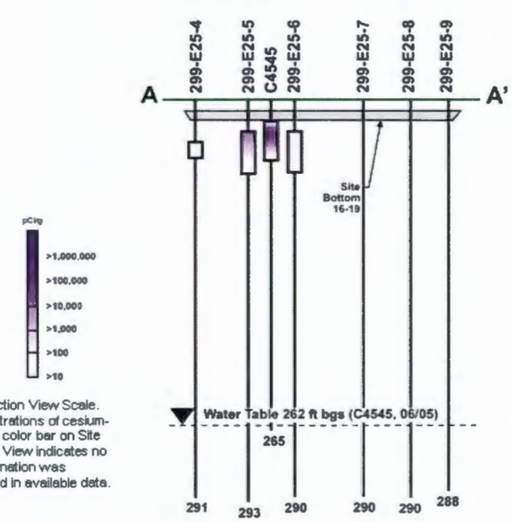
Characterization Summary

Characterization of the 216-A-8 Crib was performed during the remedial investigation. A deep borehole (C4545) was drilled, sampled, and geophysically logged at the head end of the crib (west end). Maximum cesium-137 concentrations were 877,000 pCi/g from 5.8 to 6.6 m (19 to 21.5 ft) bgs from soil sampling and 1.5 million pCi/g at 6 m (20 ft) bgs from geophysical logging. Additionally, 6 existing boreholes were geophysically logged to assess the distribution of gamma-emitting radionuclides. The highest cesium-137 concentration was 30,800 pCi/g in well 299-E25-5 at 7.6 m (25 ft) bgs. Sampling and geophysical data indicate higher contamination near the head end of the crib. An anticipated layer of organic contamination from the preliminary conceptual site model (DOE/RL-2001-01) was not observed, based on the borehole sampling.

LEGEND
- Existing Borehole (data type)
- Water Table
- bgs = below ground surface

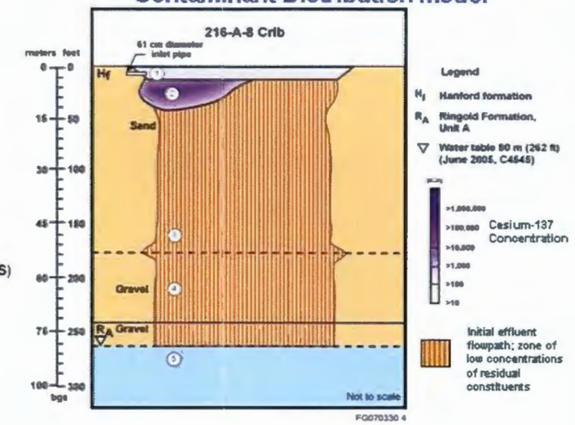
Site Section View

(not to scale, units in feet bgs)



Site Section View Scale. Concentrations of cesium-137; no color bar on Site Section View indicates no contamination was identified in available data.

Contaminant Distribution Model



1. The 216-A-8 Crib received liquid waste created by condensing vapors from self-boiling tanks in the 241-A, 241-AX, 241-AY, and 241-AZ Tank Farms. The crib received 1.15 billion liters from 1955 to 1985.
2. The more immobile radioactive contaminants (e.g., cesium-137, strontium-90) sorbed to soils at the bottom of the crib and concentrations decrease with depth. A zone of elevated cesium-137 concentrations exists between about 3.4 and 7.6 m (11 and 25 ft) bgs; concentrations in this zone range from 10 pCi/g to over 1 million pCi/g. Higher contamination is associated with the head end of the crib. Data from geophysical logging and vapor sampling show no contamination at the distal end of the crib.
3. The effluent and mobile contaminants traveled downward through coarser-grained material but tended to slow and spread at the intersection with finer-grained material. As the effluent traveled downward after discharge, contaminants may have been deposited along the top of these zones.
4. Waste water and mobile contaminants migrated downward through the vadose zone. These contaminants include both radioactive and nonradioactive constituents. A number of the radioactive constituents had short half lives and through time have decayed away. Nonradioactive constituents, especially the organics, have undergone vaporization, decay, and organic/metabolic processes that limit their persistence in the environment. The remedial investigation data indicate limited residual organic contamination in the vadose zone beneath the crib.
5. Groundwater in this area has been impacted by discharge to the crib. Based on the effluent volume and the tritium inventory for the 216-A-8 Crib, any future groundwater impacts are likely to be from tritium; however, future impacts are expected to be minimal due to the large effluent volume discharged, the mobility of tritium, and the short half life of tritium (12.3 years) (i.e., likely only a small inventory of tritium remains in the vadose zone).

200-PW-1FS.216-A-8.08/29/07

Figure 2-10. Contaminant Distribution Model, 216-A-8 Crib

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216-A-24 Crib

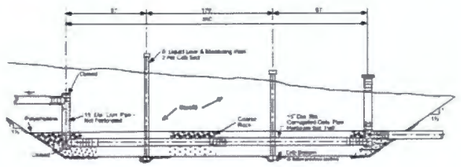
200-PW-3 Operable Unit
Waste Type: Process Waste

200-E Ponds Zone

History

The 216-A-24 Crib was a liquid waste site used for disposal of low salt, neutral/basic radioactive vapor condensate from the 241-A, 241-AX, 241-AY, and 241-AZ tank farms. This crib replaced the 216-A-8 Crib. After crib construction, surface condensers were installed in the tank farms, which greatly reduced the waste volume discharged to the crib. As a result, most of the waste volume was discharged to the first two of the four crib sections. This site is associated with UPR-200-E-56. The crib was believed to have been deactivated in 1966 by closing the valve on the inlet pipe, but the valve was discovered to be open in 1979; the crib could potentially have received waste until then. The site was surface stabilized in 1988.

CONSTRUCTION: The crib was built in four in-line sections, each 107 m (350 ft) long, separated by soil berms installed at increasingly lower elevations, to allow the effluent to cascade from one section to the next. The crib is a total of 427 m (1,400 ft) long and 6 m (20 ft) wide. The crib was constructed with a 38-cm (15-in) diameter perforated steel pipe placed horizontally 3 m (10 ft) below grade and backfilled with a polyethylene barrier between the gravel and the backfill.



WASTE VOLUME: 820,000,000 L (216,480,000 gal) (ARH-CD-745)

DURATION: 1958 to 1966 (and potentially to 1979 due to open valve)

ESTIMATED DISCHARGED INVENTORY (RPP-26744, mean values; radionuclides decayed to 01/01/2001):

Cesium-137	401 Ci
Tritium	8,798 Ci
Uranium (total)	65 kg
Tributyl phosphate	21,420 kg
Normal paraffin hydrocarbon	9,192 kg
Butanol	1,034 kg

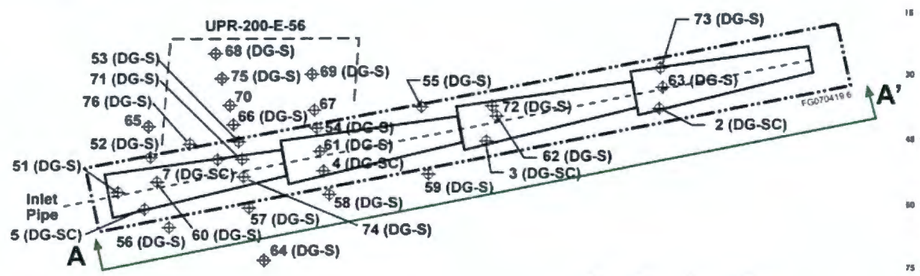
REFERENCES:
WIDS general summary reports
ARH-CD-745
RPP-26744
DOE/RL-2001-01
DOE/RL-92-04

Basis of Knowledge (Data Types)

- Process History (PH)
- Downhole Geophysics - Spectral (DG-S)
- Downhole Geophysics – Scintillation (DG-SC)
- Geologic Logs (GL)

Site Plan View

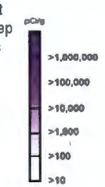
(not to scale, all well numbers prefixed by 299-E26-)



Characterization Summary

The 216-A-24 Crib has been investigated with a number of boreholes located along the discharge pipe, at the head end of each segment, and at the boundary of the crib. Geophysical logs are available for most of the boreholes. Data show that high concentrations of cesium-137 are located beneath the crib, with the highest levels associated with the two head end western segments. Concentrations exceeded 1,000,000 pCi/g at these boreholes. Concentrations decrease with depth to about 16 m (54 ft) bgs, where the cesium-137 is below 10 pCi/g. Logging data indicate the cesium-137 has not spread outside the crib boundaries except at the UPR-200-E-56 unplanned release to the north. Organics and tritium are identified as being discharged to the crib; boreholes drilled in 1981 (299-E26-53) noted a liquid, blue-green sample at 10 m (33 ft) and organic odors from 4.6 to 12 m (15 to 40 ft) bgs. Drilling logs from boreholes in the crib indicate strong organic odors. The effluent volume and inventory indicate some potential for deep contamination and groundwater monitoring indicates breakthrough (e.g., tritium) beneath the first 2 crib segments.

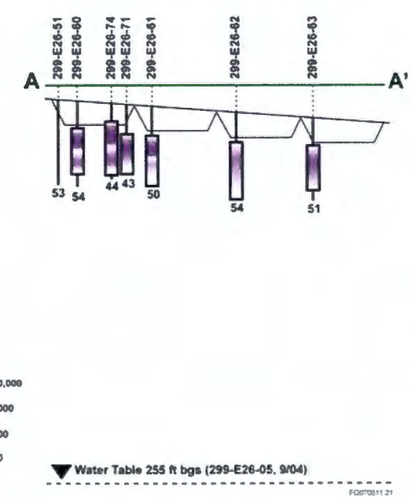
LEGEND
- Existing Borehole (data type)
- Water Table
- bgs = below ground surface



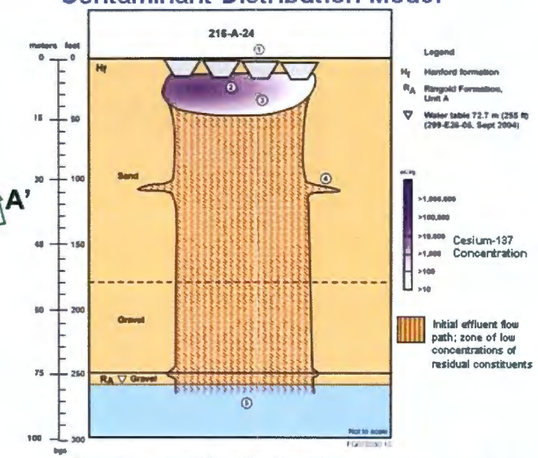
Site Section View Scale. Concentrations of cesium-137; no color bar on Site Section View indicates no contamination was identified in available data.

Site Section View

(not to scale, units in feet bgs)



Contaminant Distribution Model



1. The crib received 820 million liters of low salt, neutral to basic liquid condensate waste from 1958 to 1966; unintentionally open piping may have resulted in additional discharges until 1979. Most of the waste volume was discharged to the first 2 segments of the 4-segment crib.
2. Liquid waste containing contaminants moved through the gravel fill material of the crib, where the more immobile contaminants (e.g., cesium-137) filtered out near the bottom of the crib structure. A zone of high contamination (i.e., > 1,000,000 pCi/g of cesium-137) extends from about 4.6 to 6.7 m (15 to 22 ft) bgs. A second zone (concentrations >10,000 pCi/g) was noted in several boreholes approximately 9 to 12 m (30 to 40 ft) bgs. Concentrations decrease below this depth.
3. Based on evidence from drilling in the 1980's, organics migrated to at least 12 m (40 ft) bgs. Biological and other attenuation processes may have reduced organic contamination through time. While organic constituents still may be located in the vadose zone, data collected at the 216-A-8 Crib, which the 216-A-24 Crib replaced, did not indicate remaining organics in the vadose zone.
4. As the liquid waste continued to migrate downward, more mobile contaminants (e.g., tritium) continued to be carried downward towards the groundwater. Finer-grained zones in the vadose slowed water movement and allowed contaminants to concentrate and move laterally along the interfaces between fine-grained and coarser-grained sediments.
5. Groundwater in this area has been impacted by discharge to the crib. Based on the effluent volume and the tritium inventory for the 216-A-24 Crib, any future groundwater impacts are likely to be from tritium; however, future impacts are expected to be minimal due to the large effluent volume discharged, the mobility of tritium, and the short half life of tritium (12.3 yr) (i.e., likely only a small inventory of tritium remains in the vadose zone).

200-PW-1RIR.216-A-24.09/04/07

Figure 2-11. Contaminant Distribution Model, 216-A-24 Crib

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200-PW-3 Operable Unit
Waste Type: Process Waste

216-A-7 Crib

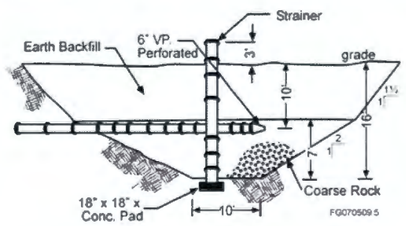
PUREX Zone

History

The 216-A-7 Crib was a liquid waste disposal site that received PUREX sump waste from the 241-A-152 Diversion Box sump at the 241-A Tank Farm from January 1956 to July 1959. After 1959, the sump waste was rerouted to a catch tank that overflowed to the 216-A-7 Crib. In November 1966, the site received the entire tributyl phosphate-Soltrol* organic inventory from the 202A Building. The waste was low salt and neutral to basic. The site was deactivated by blanking the effluent pipeline.

*Trademark of Chevron Phillips Chemical Company LP, The Woodlands, TX.

CONSTRUCTION: The crib is 3 by 3 m (10 ft by 10 ft) at the bottom and 4.9 meters (16 feet) deep. It was fed by a 15-cm (6-in) diameter perforated vitrified clay pipe placed horizontally 3.0 m (10 ft) below grade. A 3.0 m (10 ft) length of 15-cm (6-in) diameter perforated vitrified clay pipe connects perpendicularly to the inlet pipe in a horizontal cross pattern to distribute the liquid. The pipes rest on approximately 2.1 m (7 ft) of coarse rock. The site has been backfilled.



WASTE VOLUME: 326,000 L (86,100 gal) (ARH-CD-745)

DURATION: 1956 to 1966.

ESTIMATED DISCHARGED INVENTORY (RPP-26744, mean values; radionuclides decayed to 01/01/2001):

Cesium-137	2,988 Ci
Uranium (total)	481 kg
Tributyl phosphate	159,548 kg
Normal paraffin hydrocarbon	68,367 kg
Soltrol** (inventory based on tank size)	246,000 L
Nitrate	1,492 kg

**RPP-26744 lists the Soltrol, a proprietary hydrocarbon compound, as normal paraffin hydrocarbon.

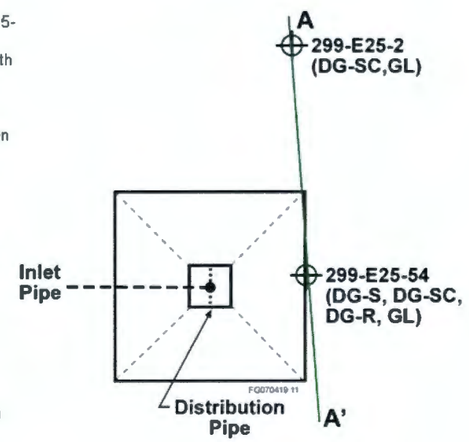
REFERENCES:
WIDS general summary reports
ARH-CD-745
RPP-26744
DOE/RL-92-04
ARH-ST-156

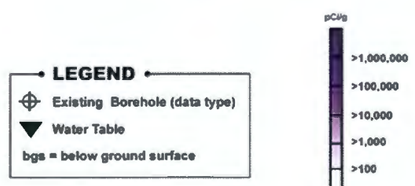
Basis of Knowledge (Data Types)

- Process History (PH)
- Downhole Geophysics - Spectral (DG-S)
- Downhole Geophysics – Scintillation (DG-SC)
- Downhole Geophysics – Radionuclide Logging System (DG-R)
- Geologic Logs (GL)

Site Plan View

(not to scale)





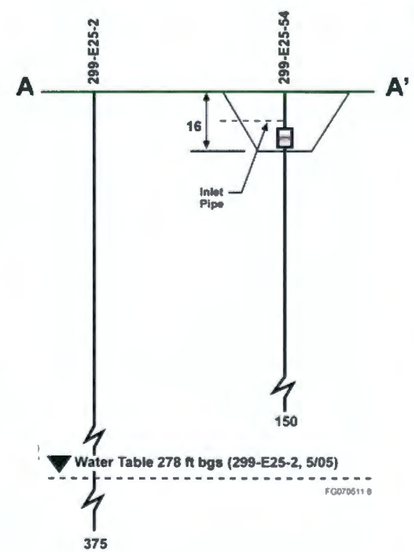
Site Section View Scale. Concentrations of cesium-137; no color bar on Site Section View indicates no contamination was identified in available data.

Characterization Summary

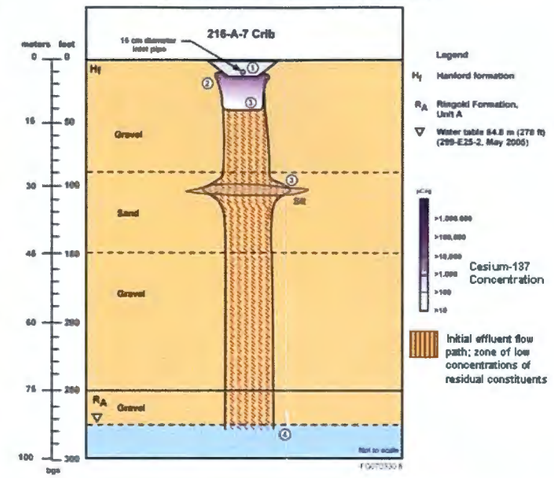
The 216-A-7 Crib operating history and downhole geophysical logs of Wells 299-E25-2 and 299-E25-54 suggest contamination associated with the waste inlet (3 m [10 ft] bgs) and the crib bottom (4.9 m [16 ft] bgs). Cesium-137 was identified in Well 299-E25-54 from 3 to 4.3 m (10 to 14 ft) bgs. The maximum concentration was 600 pCi/g at 3.7 m (12 ft) bgs. Vadose zone contamination was not identified in Well 299-E25-2. Groundwater monitoring in the area is limited to Well 299-E25-2, located 11 m (36 ft) north of the 216-A-7 Crib. The effluent volume and inventory indicate some potential for deeper contamination. Geophysical logging at Well 299-E25-54 showed cobalt-60 and europium-154, more mobile contaminants, between 8.5 and 12.8 m (28 and 42 ft) bgs, and indications of elevated moisture around 35 and 41 m (115 and 135 ft) bgs.

Site Section View

(not to scale, units in feet bgs)



Contaminant Distribution Model



1. The crib received 326 thousand liters of low salt, neutral to basic waste that contained organic chemicals and radionuclides from 1956 to 1966.
2. Cesium-137 typically sorbs to soil immediately below the release point. Cesium-137 concentrations are expected to be highest at 3 m (10 ft) bgs, potentially ranging from the tens to hundreds of thousands of pCi/g or more, based on the estimated inventory discharged and the limited volume of effluent discharged. Cesium-137 concentrations are expected to decrease with depth. Data at the edge of the crib indicate minimal spread of contaminants near the surface. Data collected at the 216-A-8 Crib, a similar site to the 216-A-7 Crib, did not show significant enhanced mobility associated with the organics discharged through the crib. The effects of the tributyl phosphate-Soltrol solution are uncertain, but should be similar to tributyl phosphate-normal paraffin hydrocarbon effects characterized at the 216-A-8 Crib.
3. Organic constituents also are expected primarily near the bottom of the crib but could have migrated downward, and possibly laterally, further than the less mobile cesium-137.
4. Groundwater impacts from the 216-A-7 Crib have not been directly identified; however, Well 299-E25-2 located north of the crib, had elevated concentrations of several constituents (e.g., cesium-137, strontium-90, nitrate) shortly after startup of the crib. These contaminants may also be associated with the 216-A-1 Crib located to the north of both the well and 216-A-7 Crib. Mobile contaminants, such as nitrate or uranium, may have impacted groundwater in the past and may pose a future threat to groundwater if these contaminants remain in the soil column. However, potential impacts to groundwater are not expected to be significant based on the lower effluent volume discharged.

200-PW-1RIR.216-A-7.09/06/07

Figure 2-12. Contaminant Distribution Model, 216-A-7 Crib

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200-PW-3 Operable Unit
Waste Type: Process Waste

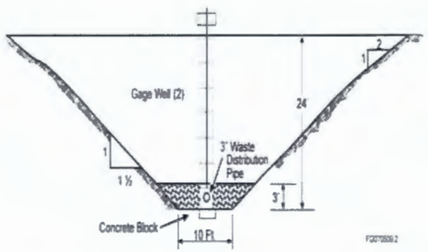
216-A-31 Crib

PUREX Zone

History

The 216-A-31 Crib was a below-grade liquid waste site that was used from 1964 to 1966 to dispose of organic and radioactive liquid waste from 202-A L-Cell, where the final plutonium concentration step of the PUREX process occurred. L-Cell waste was sent to the 216-A-31 Crib via the 241-A-151 Diversion Box after the 216-A-2 Crib was shut down. The site was deactivated in 1966 by blanking the L Cell nozzles to the diversion box.

CONSTRUCTION:. The crib is 21 by 3 m (70 by 10 ft) at the bottom and is 7.3 m (24 ft) deep. A 7.6-cm (3-in) stainless steel perforated distribution pipe was placed horizontally 6.4 m (21 ft) below grade on 0.9 m (3 ft) of gravel and then the crib was backfilled.



WASTE VOLUME: 30,545 L (8,070 gal) (ARH-231)
10,000 L (2,600 gal) (RHO-CD-673)

DURATION: 1964 to 1966

ESTIMATED DISCHARGED INVENTORY (RPP-26744, mean values; radionuclides decayed to 01/01/2001):

Cesium-137	371 Ci
Uranium (total)	60 kg
Tributyl phosphate	19,800 kg
Normal paraffin hydrocarbon	8,491 kg

REFERENCES:
WIDS general summary reports
ARH-231
RHO-CD-673
RPP-26744
ARH-ST-156
DOE/RL-92-04

Basis of Knowledge (Data Types)

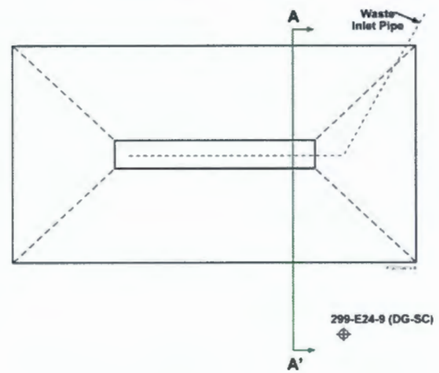
- Process History (PH)
- Downhole Geophysics – Scintillation (DG-SC)

Characterization Summary

No investigation activities have been performed within the boundaries of the 216-A-31 Crib. Well 299-E24-9, located 21 m (69 ft) south of the crib, was geophysically logged in 1963, 1970, and 1975 with a scintillation logging system. No contamination was identified in the vadose zone (ARH-ST-156). The waste from the 216-A-2 Crib was redirected to the 216-A-31 Crib after the 216-A-2 Crib was shut down. The contaminant distribution model is based on an understanding of the 216-A-31 Crib waste stream, the limited contaminant inventory, the small volume discharged at the crib, and on data and information from the 216-A-2 Crib.

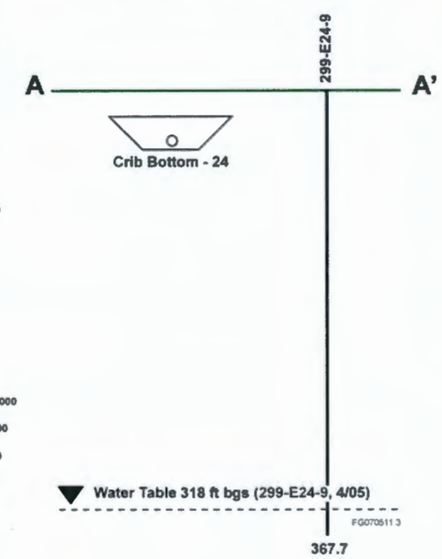
Site Plan View

(not to scale)



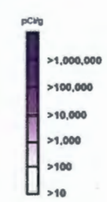
Site Section View

(not to scale; units in feet bgs)



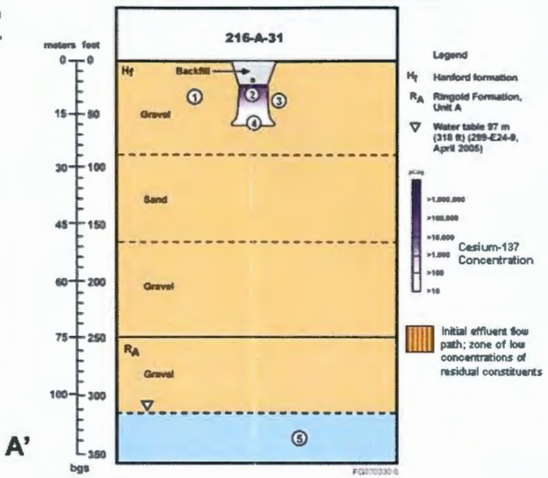
Legend

- ⊕ = Existing Borehole (data type)
- ▼ = Groundwater Surface
- bgs = below ground surface



Site Section View Scale. Concentrations of cesium-137; no color bar on Site Section View indicates no contamination was identified in available data.

Contaminant Distribution Model



1. The 216-A-31 Crib received 10 to 31 thousand liters of organic, low salt, neutral to basic liquid waste from 1964 to 1966. The primary contaminants in the waste were cesium-137 and the organic compounds tributyl phosphate and normal paraffin hydrocarbon.
2. Cesium-137 typically sorbs to soil immediately below the release point. Cesium-137 concentrations are expected to be highest at 7.3 m (24 ft) bgs, potentially ranging from the tens to hundreds of thousands of pCi/g, based on the estimated inventory discharged and the limited volume of effluent discharged. Cesium-137 concentrations are expected to decrease with depth.
3. Organic constituents also are expected primarily near the bottom of the crib but could have traveled downward, and possibly laterally, further than the less mobile cesium-137. Because of the small volume released, waste contaminants are not expected to have migrated laterally beyond the crib boundary or more than a few meters below the crib bottom. A fine-grained layer at about 15.5 m (51 ft) bgs was identified at the nearby 216-A-4 Crib. Contaminants reaching this less permeable layer may have spread laterally but are not expected to have moved deeper.
4. Volatilization and biological degradation decrease organic concentrations over time. Data from the remedial investigation at the similar 216-A-8 Crib did not show significant organic contamination in the vadose zone.
5. Groundwater impacts are not expected due to the low discharge volume.

200-PW-1RIR.216-A-31.08/29/07

Figure 2-13. Contaminant Distribution Model, 216 A-31 Crib

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200-PW-3 Operable Unit
Waste Type: Process Waste

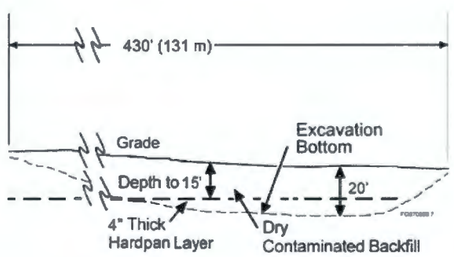
UPR-200-E-56

200-E Ponds Zone

History

The UPR-200-E-56 unplanned release site was initially a borrow pit that was used to provide clean soil to backfill around the new, below-grade 241-AN tanks. The pit was historically 1.5 to 6.1 m (5 to 20 ft) deep; however, no official depth measurement is documented. During radiation monitoring performed in June 1979, the excavation was found to be moist and radioactively contaminated. The source of the moisture and contamination was most likely effluent waste from the adjacent 216-A-24 Crib that had seeped laterally over the surface of a 10-cm (4-in) thick hardpan crust approximately 4.6 m (15 ft) bgs. The pit was refilled with contaminated soil retrieved from the 241-AN tanks location and unplanned releases associated with the 241-C Tank Farm and the 200 East Area (UPR-200-E-91, UPR-200-E-92, and UPR-200-E-93). The site was then covered with 15 to 20 cm (6 to 8 in) of clean soil. In 1985, contaminated soil from the 244-A Lift Station (UPR-200-E-100) was disposed at this site and the site was re-stabilized with 0.6 m (2 ft) of clean soil.

CONSTRUCTION: The pit was a sloping excavation dug 1.5 to 6.1 m (5 to 20 ft) deep (estimated), 131 m (430 ft) long, and an average of 33.5 (110 ft) ft wide (approximately 0.4 hectare [1 acre] overall).



WASTE VOLUME: Unknown

DURATION: 1979 (Occurrence date)

ESTIMATED DISCHARGED INVENTORY: Unknown

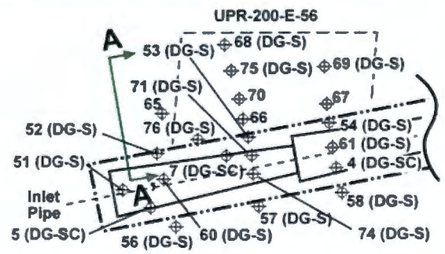
REFERENCES:
WIDS general summary reports
RHO-LD-80-75

Basis of Knowledge (Data Types)

- Process History (PH)
- Downhole Geophysics - Spectral (DG-S)
- Downhole Geophysics – Radionuclide Logging System (DG-R)
- Geologic Logs (GL)

Site Plan View

(not to scale, all well numbers prefixed by 299-E26-)



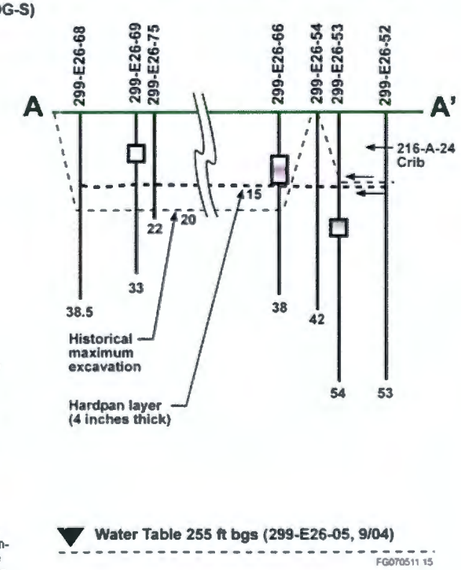
LEGEND
- Existing Borehole (data type)
- Water Table
- bgs = below ground surface

Characterization Summary

Monitoring in 1979 identified moisture and radioactive contamination of 8,000 counts per minute in the excavated borrow pit next to the 216-A-24 Crib. Radionuclide logging at the backfilled site performed in 1994 identified 21.7 pCi/g of cesium-137 at 2.3 m (7.5 ft) bgs in borehole 299-E26-68 and 5.0 pCi/g of cesium-137 at 2.3 m (7.5 ft) bgs in borehole 299-E26-75. Spectral gamma geophysical logging during 2005 identified maximum cesium-137 concentrations of 100 pCi/g at 7.3 m (24 ft) bgs in 299-E26-53, 80 pCi/g at 3.8 m (12.5 ft) bgs in 299-E26-66, and 40 Ci/g at 2.7 m (9 ft) bgs in 299-E26-69, decreasing with depth to the bottom of the excavation (approximately 6 m [20 ft] bgs), where it was generally no longer detected.

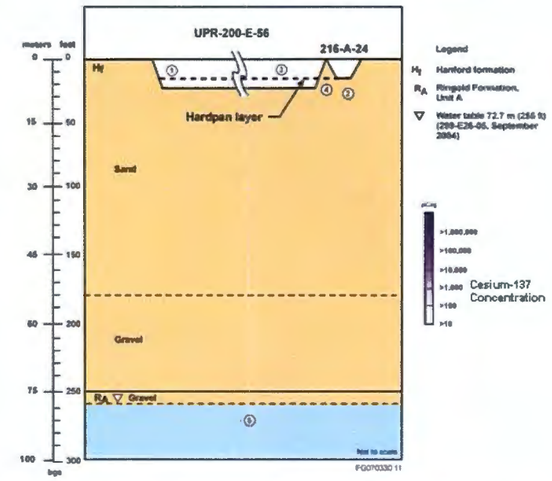
Site Section View

(not to scale, units in feet bgs)



Site Section View Scale. Concentrations of cesium-137; no color bar on Site Section View indicates no contamination was identified in available data.

Contaminant Distribution Model



1. During routine monitoring in 1979, a 1.5 to 6 m (5 to 20 ft) deep borrow pit was found to be moist and to contain radioactive contamination of 8,000 counts per minute. This pit was intended to be a source of clean borrow material, which was used to backfill around the new 241-AN tanks.
2. Low volumes of contaminated effluent waste from the adjacent 216-A-24 Crib most likely seeped laterally to the borrow pit area on the surface of a 10.2-cm (4-in) thick hardpan crust that is approximately 4.6 m (15 ft) bgs.
3. The borrow pit was refilled with dry, contaminated soil retrieved from the 241-AN tanks excavation and other unplanned release areas associated with the 241-C Tank Farm and 200 East Area. The soils added back to the borrow pit are expected to have low-level radioactive contamination that is homogeneously distributed as a result of mixing of soils during transfers and that is immobile because of the lack of moisture.
4. The deepest contamination was found in soil between the excavated pit and the 216-A-24 Crib, just outside the borrow pit excavation boundary and at depths slightly deeper than the historical bottom of the pit This confirms the that the most likely source of the contamination in the excavated pit was lateral waste migration from the 216-A-24 Crib.
5. Contaminants are expected to remain contained within the 6-m (20-ft) deep excavated pit; groundwater impacts from this site are not expected. Excavation backfill material was dry and the unplanned release of effluent was not of sufficient volume to facilitate contaminant migration to groundwater.

200-PW-1RIR.UPR200-E-56.08/29/07

Figure 2-14. Contaminant Distribution Model, UPR-200-E-56 Unplanned Release

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200-PW-6 Operable Unit
Waste Type: Process Waste

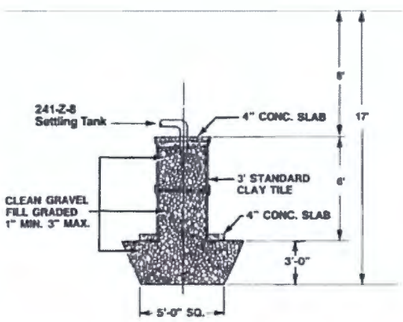
216-Z-8 French Drain

PFP Zone

History

The 216-Z-8 French drain is a liquid waste site that was used from 1955 to 1962 to dispose of overflow liquid waste from the 241-Z-8 Settling Tank. The tank was used as a solids settling tank for effluent waste from back flushes of the RECUPLEX feed filters. Tank waste flowed 11 m (36 ft) east to the French drain via a 10-cm (4-in) steel effluent pipe. Between 1957, when the tank first overflowed, and 1962, an estimated 9,590 L (2,530 gal) overflowed from the 241-Z-8 Settling Tank to the 216-Z-8 French drain. The drain ceased operations in 1962 when discharge piping in the 234-5Z Building was disconnected.

CONSTRUCTION: The 216-Z-8 French drain is constructed of two, 0.9-m (3-ft) long clay tile culverts, stacked vertically underground and filled with gravel. At the base of the culverts is a 10-cm (4-in) thick concrete collar that rests on a 1.5-m (5-ft) square by 0.9-m (3-ft) deep gravel bed that is approximately 5.6 m (17 ft) deep at the bottom.



WASTE VOLUME: 9,590 liters (2,530 gallons) (RHO-LD-114)

DURATION: 1955 to 1962

ESTIMATED DISCHARGED INVENTORY:

Plutonium 48.4 g (RHO-LD-114)

REFERENCES:
WIDS general summary reports
DOE/RL-91-58
RHO-RE-EV-46 P
RHO-LD-114

Basis of Knowledge (Data Types)

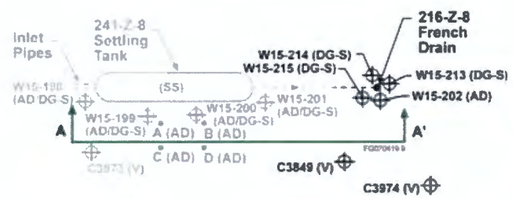
- Process History (PH)
- Downhole Geophysics - Spectral (DG-S)
- Downhole Geophysics – Scintillation (DG-SC)
- Downhole Geophysics – Radionuclide Logging System (DG-R)
- Geologic Logs (GL)
- Soil Sampling Analytical Data (AD)
- Vapor Sampling Data (V)

Characterization Summary

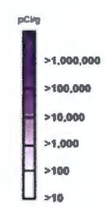
Characterization activities at the 216-Z-8 French drain consist of geophysical logging and soil sampling. A 1984 study focused on evaluating the distribution of transuranic constituents beneath the French drain. Samples were collected and analyzed from well 299-W15-202 (RHO-RE-EV-46 P). Maximum plutonium-239 and americium-241 concentrations were 4,620 and 457 pCi/g, respectively, located near the bottom of the drain structure. Geophysical logging in well 299-W15-213 in 2005 showed plutonium contamination up to 25,000 pCi/g near the bottom of the drain structure.

Site Plan View

(not to scale; all well numbers prefixed with 299-)



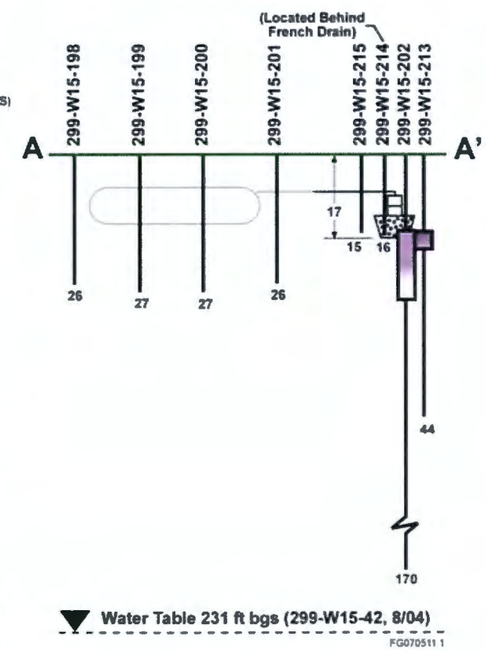
LEGEND
- Existing Borehole (data type)
- Water Table
- bgs = below ground surface



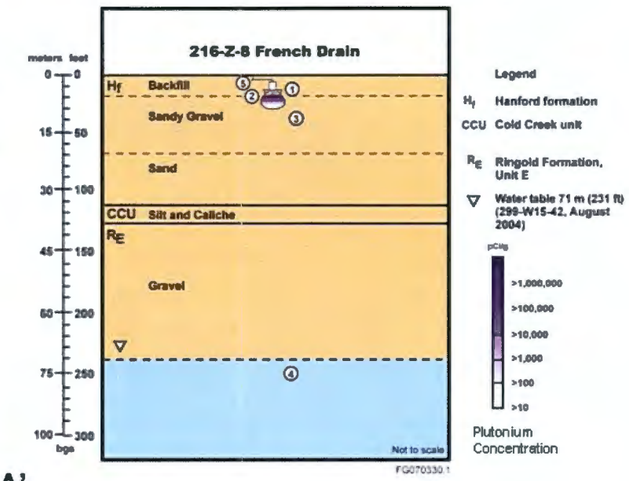
Site Section View Scale. Concentrations of plutonium; no color bar on Site Section View indicates no contamination was identified in available data.

Site Section View

(not to scale; units in feet bgs)



Contaminant Distribution Model



1. Approximately 9,590 L (2,530 gal) of neutral to basic waste overflowed to the 216-Z-8 French drain from the 241-Z-8 Settling Tank between 1955 and 1962. (Note: the first overflow did not occur until 1957.)
2. Soil sampling data and geophysical logging data show an area of plutonium and americium contamination near the bottom of the French drain structure. Because of the affinity of plutonium for the vadose soils, little migration away from the disposal point, either laterally or vertically, was identified.
3. Data show the immobile contaminants plutonium and americium were sorbed onto the sediments within approximately 5 m (16 ft) below the gravel bottom of the drain. Contaminant concentrations decrease with depth and are less than 1 pCi/g near the bottom of this zone. Mobile contaminants were not identified in the inventory.
4. Waste discharged to the French drain likely did not impact groundwater because the discharge volume is very low, the contaminants disposed tend to sorb to soils at the discharge point, sampling data did not identify deeper contamination, and because of the significant depth to groundwater.
5. Leaks from the settling tank, if any, are not expected to impact soils away from the tank and would not have impacted contaminant distribution at the French drain.

200-PW-1FS.216-Z-8.08/28/07

Figure 2-15. Contaminant Distribution Model, 216-Z-8 French Drain

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200-PW-6 Operable Unit
Waste Type: Process Waste

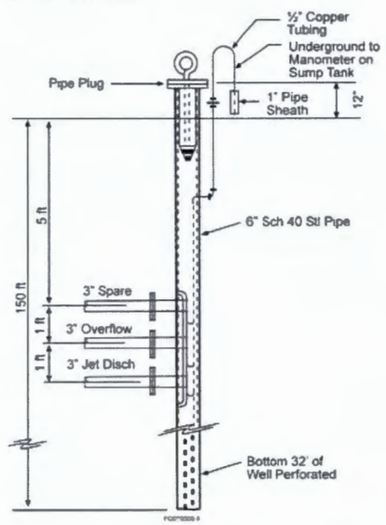
216-Z-10 Injection/Reverse Well

PFP Zone

History

The 216-Z-10 Injection/Reverse Well (well 299-W15-51) is a liquid waste disposal site that was used during 1945 to dispose of process and laboratory waste from the 231-Z building via the 231-W-151 Sump. The transuranic-contaminated process waste was discharged, at a rate of 76 L (20 gal) per minute, directly to the well through a 7.6 cm (3 in) diameter pipe from the 231-Z Building, entered the well about 1.5 m (5 ft) below grade, and was released to the soil through perforations in the well. The reverse well plugged after 4 months of use, after receiving 1,000,000 L (260,000 gal). The discharge line to the reverse well was capped and waste was diverted to the 216-Z-5 Crib.

CONSTRUCTION:



WASTE VOLUME: 1,000,000 L (260,000 gal) (HW-12468)

DURATION: February 1945 to June 1945

ESTIMATED DISCHARGED INVENTORY:
Plutonium 1 to 50 g (HW-12468)

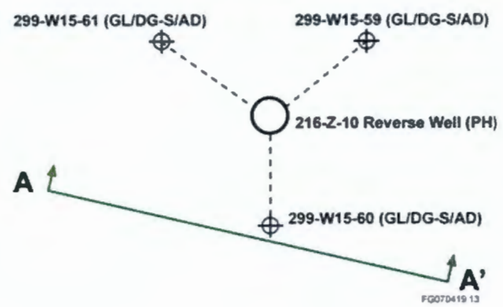
REFERENCES:
WIDS general summary reports
HW-12468
HW-9671
HW-23769
RHO-LD-114

Basis of Knowledge (Data Types)

- Process History (PH)
- Downhole Geophysics - Spectral (DG-S)
- Geologic Logs (GL)
- Soil Sampling Analytical Data (AD)

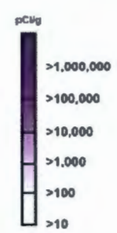
Site Plan View

(not to scale)



LEGEND
- Existing Borehole (data type)
- Perforated Zone
- Water Table

bgs = below ground surface



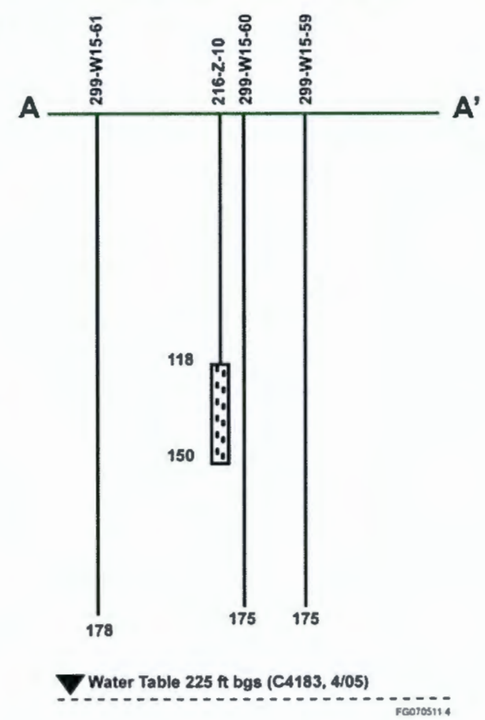
Site Section View Scale. Concentrations of plutonium; no color bar on Site Section View indicates no contamination was identified in available data.

Characterization Summary

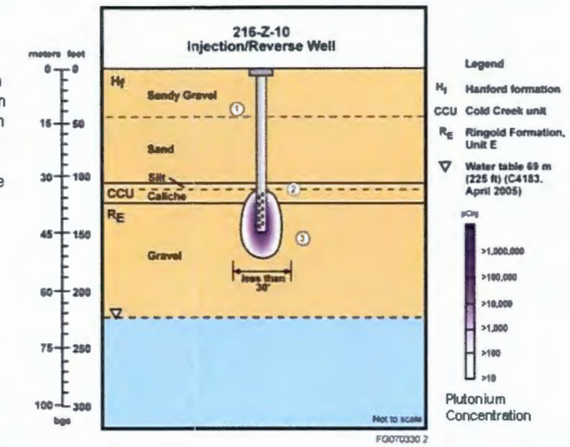
Operating history indicates plutonium (up to approximately 50 g) was the main contaminant released to the injection/reverse well. No organics are expected. Data include geophysical logging and analytical soil samples taken every 1.5 m (5 ft) in depth from three characterization wells surrounding the 216-Z-10 Injection/Reverse Well in an approximate 4.6-m (15-ft) radius and extending about 7.6 m (25 ft) deeper than the 216-Z-10 well. Soil samples did not identify plutonium contamination above a detection limit of approximately 0.15 pCi/g (HW-23769), indicating that waste spread laterally less than 4.6 m (15 ft) (HW-9671).

Site Section View

(not to scale, units in feet bgs)



Contaminant Distribution Model



1. Approximately 1 million liters of liquid waste containing up to approximately 50 g of plutonium and few other contaminants were discharged to the 216-Z-10 Injection/Reverse Well from February to June 1945.
2. Once discharged, the plutonium sorbed to soils around and below the perforations of the well. Only minor lateral spreading is expected because of the low volume of effluent discharged and the short operating period. Data show that migration is confined laterally to less than a 4.6-m (15-ft) radius around the well.
3. Downward migration is expected to be limited to within a few feet of the bottom of the well. Radionuclide impacts to groundwater are not expected. While no direct measurements of plutonium concentrations are available at the reverse well itself, concentrations are expected to be highest in the perforated well section (because the well plugged) and in the soils near the perforations. Concentrations are expected to decrease quickly with depth and with distance from the reverse well, based on the low plutonium inventory discharged, low volume of effluent discharged, and the short length of the perforated casing that distributed the waste over 10 m (32 ft) of soil column.

200-PW-1FS.216-Z-10.08/28/07

Figure 2-16. Contaminant Distribution Model, 216-Z-10 Injection/Reverse Well

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200-PW-6 Operable Unit
Waste Type: Process Waste

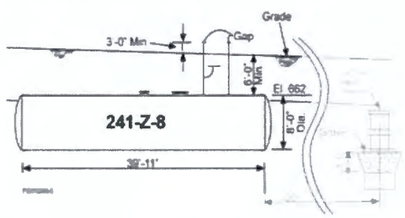
241-Z-8 Settling Tank

PFP Zone

History

The 241-Z-8 settling tank is a horizontal cylindrical tank that operated from 1955 to 1962 as a solids settling tank for effluent waste from back flushes of the RECUPLEX feed filters. Filter backflush solids and silica gel used as a settling agent were flushed to the tank with nitric acid. Overflow from the tank was piped to the 216-Z-8 French drain, located approximately 11 m (36 ft) east of the settling tank. In 1957, the tank reached overflow capacity of 58,500 L (15,435 gal). In 1974, the tank contents were reported as 29,000 L (7,650 gal) of solution, which is well below overflow capacity, and 2,000 L (530 gal) of sludge. This left about 27,580 L (7,285 gal) of waste unaccounted for, creating a concern that waste may have leaked from the tank. However, investigation of surrounding soils found no soil contamination and the unaccounted for waste likely resulted from erroneous measurement of tank contents (RHO-RE-EV-46 P). The tank was pumped in 1974, leaving approximately 18 cm (7 in) of sludge amounting to 1,890 L (500 gallons). The sludge was sampled and shown to contain 0.02 grams of plutonium per liter.

CONSTRUCTION: The tank is 12.2 m (40 ft) long and 2.4 m (8 ft) in diameter. It is constructed of 0.8 cm (5/16 in) thick steel or wrought iron plate and is located 1.8 m (6 ft) below grade. The tank was fed by two 3.8 cm (1.5 in) diameter stainless steel pipes that enter the tank 15 cm (6 in) below the top of the tank.



WASTE VOLUME: 58,500 L tank; up to 1,890 L are estimated to remain in the tank (RHO-RE-EV-46 P)

DURATION: 1955 to 1962

REMAINING INVENTORY:
Plutonium 38 g (WHC-SD-DD-TI-057)
1.5 kg (RHO-RE-EV-46 P)

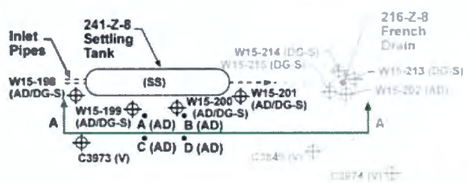
REFERENCES:
WIDS general summary reports
HW-9671
RHO-RE-EV-46 P
WHC-SD-DD-TI-057

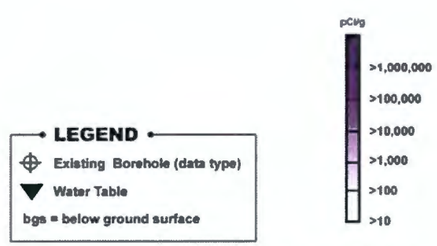
Basis of Knowledge (Data Types)

- Process History (PH)
- Downhole Geophysics - Spectral (DG-S)
- Downhole Geophysics – Radionuclide Logging System (DG-R)
- Soil Sampling Analytical Data (AD)
- Vapor Sampling Data (V)
- Sludge Sampling Data (SS)

Site Plan View

(not to scale; all well numbers prefixed by 299-)





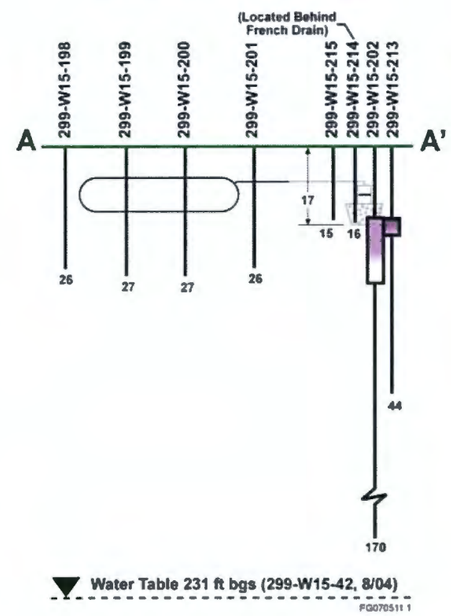
Site Section View Scale. Concentrations of plutonium; no color bar on Site Section View indicates no contamination was identified in available data.

Characterization Summary

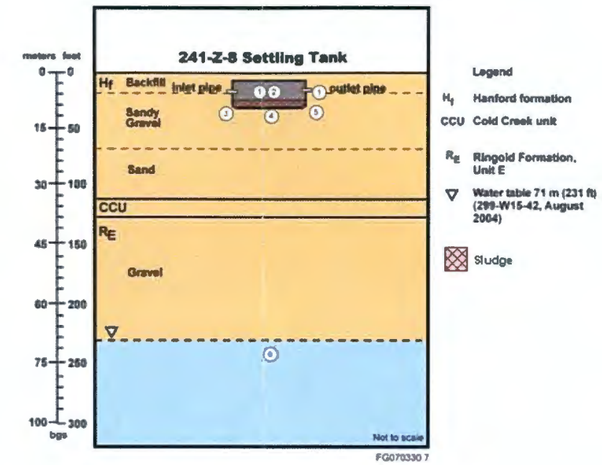
The 241-Z-8 Settling Tank was characterized in 1984 (RHO-RE-EV-46 P) by installation of four wells south of the tank to a depth of 7.6 m (25 ft) bgs (wells 299-W15-198, 299-W15-199, 299-W15-200, 299-W15-201). Two sediment samples were collected from each well at 4.6 and 6.1 m (15 and 20 ft) bgs. In addition, four core samples were collected south of the tank from 0 to 30 cm (0 to 12 in) bgs (core locations A, B, C, D). The maximum plutonium concentration detected was 44 pCi/g in the sample from 0 to 15 cm (0 to 6 in) bgs at core location D. The data do not show that this tank leaked. The tank could contain up to 1.5 kg of plutonium. The four wells south of the tank were geophysically logged in 2005 using a spectral gamma system. No contamination was noted in the logs.

Site Section View

(not to scale; units in feet bgs)



Contaminant Distribution Model



1. The 241-Z-8 Settling Tank received low-level, dilute, neutral plutonium waste from back flushes of the RECUPLEX feed filters from 1955 to 1962. The overflow supernatant liquid was discharged to the soil column through the 216-Z-8 French drain.
2. In 1974, the tank was pumped of liquids leaving approximately 1,890 liters (500 gallons) or 18 centimeters (7 inches) of sludge in the tank containing from 38 grams of plutonium (WIDS) to as much as 1.5 kilograms of plutonium (RHO-RE-EV-46 P).
3. Geophysical logging and soil sample analytical data obtained near the tank identified minimal contamination in the tank vicinity.
4. At the time the tank was pumped approximately 27,500 liters (7,285 gallons) of waste were not accounted for, identifying a potential that the waste was lost through tank leakage. However, data from borehole core samples and geophysical logging do not show that this tank has leaked.
5. If tank leakage had occurred, non-mobile contaminants, such as plutonium, would be expected to exist near the point of release, as observed at the 216-Z-8 French drain, and mobile contaminants, such as nitrate, would have migrated downward with the moisture front. However, because no leaks were identified through sampling activities, contaminant migration from the tank site is not expected.
6. Even if leaks had occurred, the potentially small waste volume and significant depth to groundwater would make impacts to groundwater unlikely.

200-PW-1FS.241-Z-8.08/30/07

Figure 2-17. Contaminant Distribution Model, 241-Z-8 Settling Tank

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200-PW-6 Operable Unit
Waste Type: Process Waste

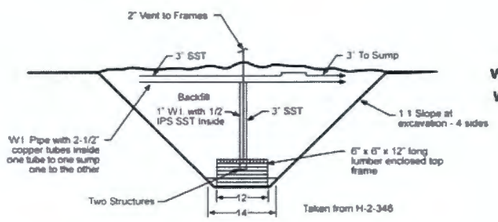
216-Z-5 Crib

PFP Zone

History

The 216-Z-5 Crib was a liquid waste disposal site that was used from 1945 to 1947 to dispose of 231-Z Building plutonium-contaminated process waste from the 231-W-151 Vault. The site ceased operations when sludge blocked the system, and waste was diverted to the 216-Z-7 Crib. The crib was deactivated by capping the inlet line from the vault. The site was stabilized in 1990.

CONSTRUCTION: The crib consists of two, in-line, interconnected 3.8-m (12-ft) square, 1.2-m (4-ft) deep wooden sump boxes that are open at the bottom and fed by the same transfer pipe. Each box was placed at the bottom of a 5.5-m (18-ft) deep rectangular excavation that was 4.3-m (14-ft) square at the bottom and then backfilled to grade. The two crib structures are about 21 m (70 ft) apart.



WASTE VOLUME: 31,000,000 L (8,184,000 gal) (RHO-LD-114)

DURATION: 1945 to 1947

ESTIMATED DISCHARGED INVENTORY:

Plutonium	340 g (RHO-LD-114)
Nitrate	100,000 kg (DOE/RL-91-58)

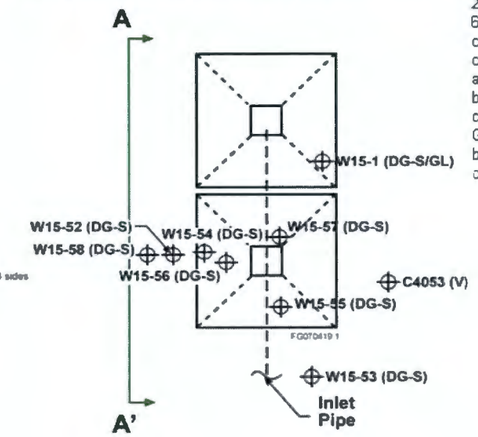
REFERENCES:
WIDS general summary reports
HW-12468
HW-9671
HW-23769
RHO-LD-114
DOE/RL-91-58

Basis of Knowledge (Data Types)

- Process History (PH)
- Downhole Geophysics - Spectral (DG-S)
- Downhole Geophysics – Scintillation (DG-SC)
- Geologic Logs (GL)
- Vapor Sampling Data (V)

Site Plan View

(not to scale; all W15 well numbers prefixed by 299-)

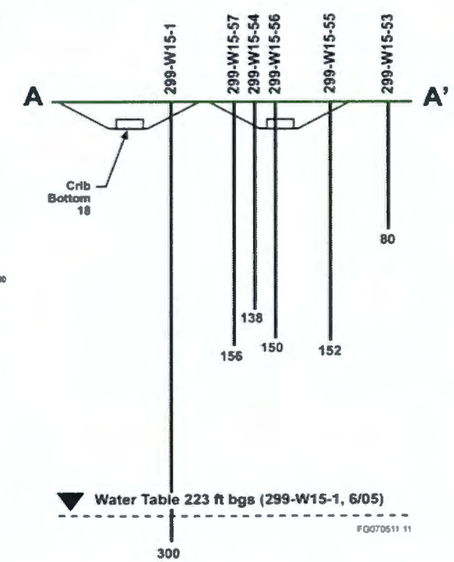


Characterization Summary

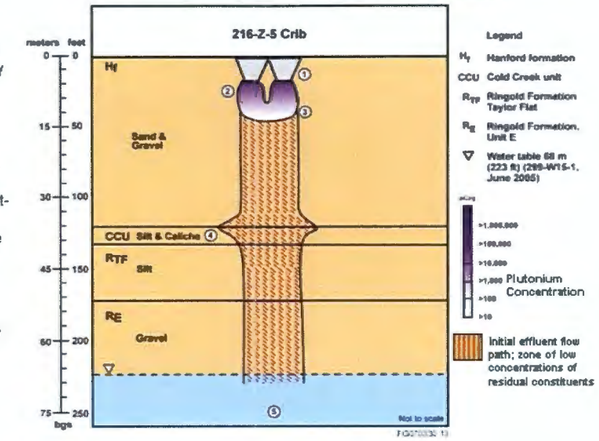
Eight wells were drilled around the first crib structure in 1947 to determine the plutonium distribution in soils around the 216-Z-5 Crib. None of the wells penetrated the bottom of the crib structures. Data indicate that only 0.5 g of the plutonium inventory could be accounted for and that the remainder of the plutonium discharged to this crib likely remains directly beneath the crib bottom (HW-9671). Sample results confirmed that the plutonium had not migrated far beneath the crib bottom. More recent geophysical logging of 6 of these wells in 2005 support the initial results of the 1947 effort. Cobalt-60 and europium-154 (which do not represent current contaminants of potential concern but do indicate where contaminants moved in the soil column) were detected at very low levels in the geophysical logs up to 150 ft bgs. This could indicate the passage of effluent containing more mobile contaminants (e.g., nitrate). Geologic changes at 18 m (60 ft) and 34 m (110 ft) may be zones of elevated concentrations of mobile contaminants.

Site Section View

(not to scale; units in feet bgs)



Contaminant Distribution Model



1. 31 million liters of liquid waste were discharged to the 216-Z-5 Crib from 1945 to 1947.
2. Liquid waste was released at the crib bottom, where immobile contaminants (e.g., plutonium) sorbed to soils. A zone of high contamination likely extends from 5.5 m (18 ft) up to 9 m (30 ft) bgs, based on data from similar sites. Concentrations are expected to decrease quickly with depth.
3. As the moisture front moved downward, more mobile contaminants (e.g., nitrate) were carried along toward groundwater. The effluent volume and nitrate inventory likely are sufficient to have impacted groundwater during operations.
4. Fine-grained zones in the vadose zone slowed water movement and allowed contaminants to concentrate and move laterally along the interfaces between fine-grained and coarser-grained sediments, such as the interface between the Hanford formation and the Cold Creek unit.
5. The effluent volume and nitrate inventory for the 216-Z-5 Crib likely are sufficient to have impacted groundwater. Future groundwater impacts from this crib may be possible, particularly associated with nitrate. However, because the waste inventory is relatively low, significant future impacts are not expected.

LEGEND
- Existing Borehole (data type)
- Water Table
- bgs = below ground surface

Site Section View Scale. Concentrations of plutonium; no color bar on Site Section View indicates no contamination was identified in available data.

200-PW-1RIR:216-Z-5.08/28/07

Figure 2-18. Contaminant Distribution Model, 216-Z-5 Crib

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When the 216-Z-9 Trench was retired in 1962, it had received approximately 50 to 150 kg (110 to 330 lb) of plutonium. Mining took place at the 216-Z-9 Trench in 1976 and 1977 to remove plutonium. The upper 0.3 m (1 ft) of soil was removed from the floor of the trench. The mining operation removed an estimated 58 kg (128 lb) of plutonium. Based on data acquired during the mining operation, an estimated 38 to 48 kg (84 to 106 lb) of plutonium remains in the 216-Z-9 Trench (RHO-ST-21, *Report on Plutonium Mining Activities at 216-Z-9 Enclosed Trench*). The 6.4 m (21 ft) deep open space beneath the concrete cover over the 216-Z-9 Trench remains void of soil and contains only the mining equipment (DOE/RL-91-58, *Z Plant Source Aggregate Area Management Study Report*; RHO-ST-21; ARH-2915, *Nuclear Reactivity Evaluations of 216-Z-9 Enclosed Trench*). The concrete cover has an uncertain lifespan, which is one of the reasons that remedial action is needed at this site.

The RI Report (DOE/RL-2006-51) provides details of the past investigations and the RI results, including soil, soil vapor, borehole geophysical logging, and other investigations. The significant RI findings for the 216-Z-9 Trench are provided in the following summary. As part of the RI, two wells were installed (299-W-15-46 in 2005 and 299-W-15-48 in 2006), and 49 cone penetrometers were installed in 2005 to characterize the site (Figure 2-19).

For most of the radionuclides detected above background levels in soil samples (Np-237, plutonium-238 [Pu-238], Ra-226, Ra-228, Sr-90, Tc-99, Th-232, U-234, and U-235), all of the highest concentrations were at a depth of 14 m (46 ft) bgs or deeper (i.e., deeper than initially postulated in the preliminary contaminant distribution model). The maximum concentrations of Pu-239/240 and americium-241 (Am-241), the primary radionuclides at the site, were near the base of the trench, at 18 to 19 m (59 to 62 ft) bgs and at 31 to 33 m (102 to 108 ft) bgs. Radioactive contamination was identified in several boreholes using geophysical logging methods. Contamination (Am-241, Pa-233, Pu-239, and Pu-241) was detected to a maximum depth of 59.4 m (195 ft) bgs. Radioactive contamination in soil samples (predominantly Am-241 and Pu-239/240) was detected to a maximum depth of 37.2 m (122 ft) bgs. The highest concentrations of plutonium and americium are located at the trench floor and generally decrease with depth below the floor.

Soil vapor samples collected from boreholes drilled in the vicinity of the trench revealed carbon tetrachloride at concentrations up to 28,500 ppmv in 1993. This is approximately 23 percent of the maximum possible carbon tetrachloride soil vapor concentration, indicating carbon tetrachloride saturation in the vadose zone.

Soil samples from boreholes near the 216-Z-9 Trench revealed carbon tetrachloride dense, nonaqueous phase liquid (DNAPL) in soil of up to 380,000 µg/kg in Well 299-W15-46 from 19.4 to 20.1 m (63.5 to 66 ft bgs). At adjacent push location Borehole C5336 (P66), the maximum carbon tetrachloride detected in soil was 390,000 µg/kg in the same silt lens (Figure 2-19). These represent the first detections of DNAPL at any location in the subsurface of the 200 West Area since the beginning of the carbon tetrachloride contamination investigation in the early 1990s.

An SVE system has been operated near the 216-Z-9 Trench as an expedited response action. Between March 1993 and September 2008, approximately 54,608 kg (120,390 lb) of carbon tetrachloride was removed at this location by the SVE system (SGW-40456).

In general, the highest concentrations of COPCs detected in the vadose zone soils have been in fine-grained layers (i.e., silts and the CCU). A higher percentage of the carbon tetrachloride inventory than previously estimated likely was lost to the atmosphere through evaporation during waste management activities. A higher percentage of the carbon tetrachloride inventory than previously estimated is present in the unconfined aquifer. Based on evaluation of new geophysical logging, Am-241 previously was misidentified in spectral gamma logs as Cs-137.

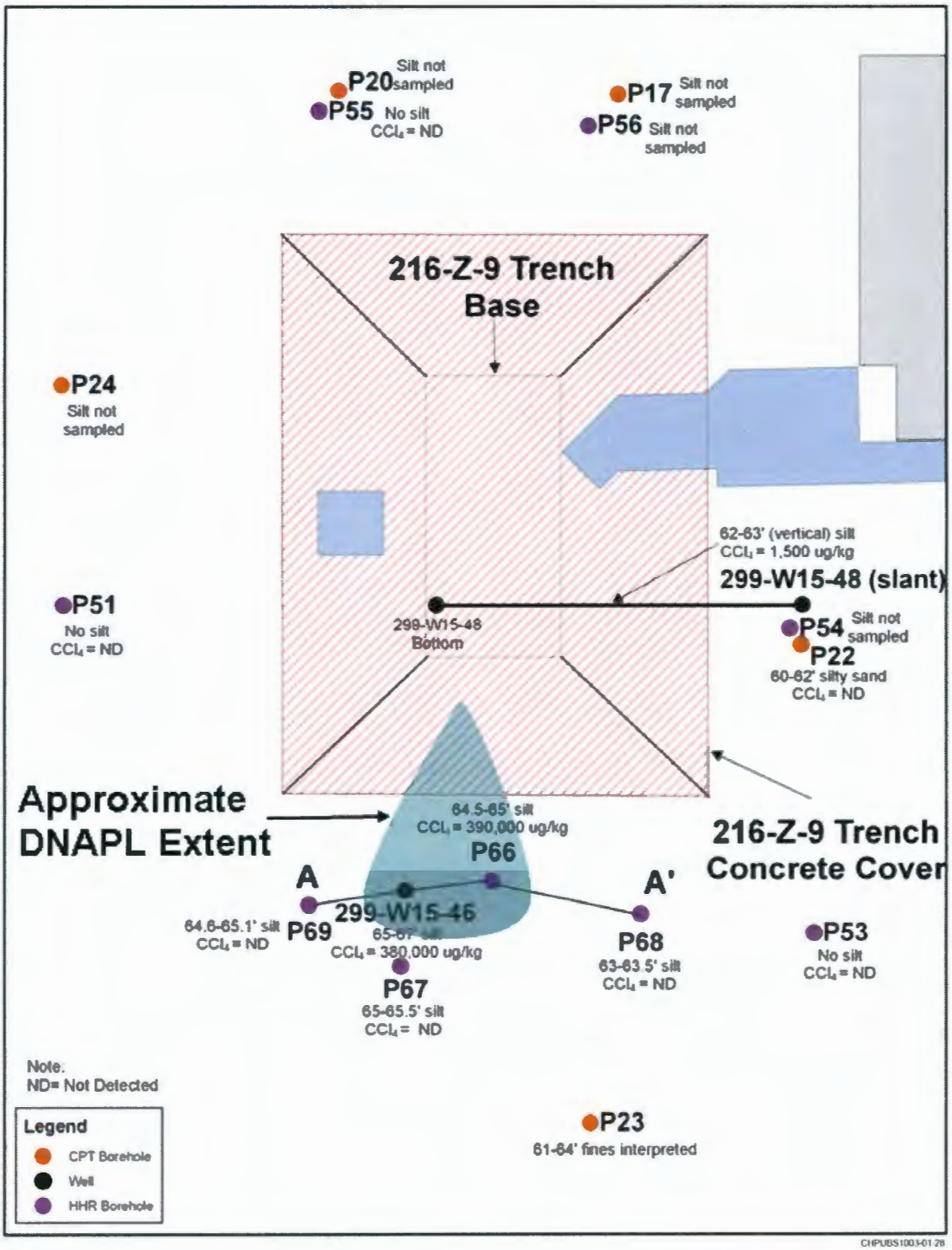

Figure 2-19. Approximate Extent of Carbon Tetrachloride Dense Nonaqueous Phase Liquid in Silt Lens at 19.8 m (65 ft) Below Ground Surface Adjacent to the 216-Z-9 Trench

At the 216-Z-9 Trench, the discharged effluent volume was greater than soil column pore volume, which indicates the volume of effluent released was sufficient to reach the unconfined aquifer during operation of this waste site. However, based on currently available site data including soil moisture content measurements, the 216-Z-9 Trench is not considered to be a significant current source of groundwater contamination.

Table 2-6 provides a summary of the maximum concentrations of radionuclide COPCs in soil samples at the 216-Z-9 Trench. Table 2-7 provides a summary of the maximum concentrations of nonradionuclide COPCs in soil samples at the 216-Z-9 Trench.

Table 2-6. Maximum Concentrations of Radionuclide COPCs in Soil Samples at the 216-Z-9 Trench

Radionuclide Contaminant of Potential Concern	Maximum Concentration (pCi/g)	Depth Interval (ft bgs)[a]		Location[b]
		Top	Bottom	
Americium-241	43,478,261	22	22.3	216-Z-9 Trench Floor (1973)
Neptunium-237	28.9	109.5	112	299-W15-46 Well
Plutonium-238	3,680	70	72	299-W15-48 Well
Plutonium-239/240	404,347,826	22	22.3	216-Z-9 Trench Floor (1973)
Radium-226	2.16	131.5	133	299-W15-48 Well
Radium-228	2.79	109.5	112	299-W15-46 Well
Strontium-89,90	13.4	63.5	66	299-W15-46 Well
Technetium-99	272	70	72	299-W15-48 Well
Thorium-232	1.89	135	140	299-W15-48 Well
Uranium-234	11.8	48.5	50	299-W15-46 Well
Uranium-235	0.13	119.5	122	299-W15-46 Well

Source:

Remedial Investigation Report for Plutonium/Organic-Rich Process Condensate/ Process Waste Group OU: Includes 200-PW-1, 200-PW-3, and 200-PW-6 OUs; Appendix E – Data Summary Tables for Waste Sites (DOE/RL-2006-51)

a. Most of the soil samples collected from the base of the 216-Z-9 Trench in 1973 were analyzed only for Pu-239 and Am-241.

b. Well 299-W15-48 was drilled at a 32 degree (from vertical) angle underneath the 216-Z-9 Trench. The 299-W15-48 depth intervals provided in this table represent the downhole depths (i.e., not converted to vertical depths).

Table 2-7. Maximum Concentrations of Nonradionuclide COPCs in Soil Samples at the 216-Z-9 Trench

Nonradionuclide Contaminant of Potential Concern	Maximum Concentration (mg/kg)	Depth Interval (ft bgs)		Location[a]
		Top	Bottom	
1,1-Dichloroethane	0.0011	115	117.5	299-W15-46 Well
Acetone	2.9	131.5	133	299-W15-48 Well
Ammonium ion	192	109.5	112	299-W15-46 Well
Aroclor 1248	1.6	63.5	66	299-W15-46 Well
Arsenic	11	47.5	50	299-W15-46 Well
Benzene	0.0037	70	72	299-W15-48 Well
Bismuth	156	135	140	299-W15-48 Well
Cadmium	118	122.5	124.5	299-W15-48 Well
Carbon Tetrachloride (CCl_4)	390	64	66	C5336 Borehole[b]
Chlorobenzene	0.00098	115	117.5	299-W15-46 Well
Chloroform	4.9	63.5	66	299-W15-46 Well
Chromium	162	119.5	122	299-W15-46 Well
Copper	26.3	119.5	122	299-W15-46 Well
Ethylbenzene	0.0008	73	75	299-W15-48 Well
Fluoride	51.4	118.5	120.5	299-W15-48 Well
Hexavalent Chromium	0.75	63.5	66	299-W15-46 Well
Hydraulic Fluids (Grease)	2,440	70	72	299-W15-48 Well
Normal Paraffins (greases and cutting oils)	2,440	70	72	299-W15-48 Well
Lead	620	115	117.5	299-W15-46 Well
Mercury	1.02	174	176.5	299-W15-46 Well
Methyl Ethyl Ketone	1.7	122.5	124.5	299-W15-48 Well
Methyl Isobutyl Ketone	0.0012	117	119.5	299-W15-46 Well
Methylene Chloride	0.14	100	102	299-W15-48 Well
Nickel	72.9	119.5	122	299-W15-46 Well
Nitrate	6,990	100	102	299-W15-48 Well
Nitrite	12.1	47.5	50	299-W15-46 Well
Oil and Grease	2,400	63.5	66	299-W15-46 Well
Phosphate	3.9	135	140	299-W15-48 Well
Selenium	3.76	119.5	122	299-W15-46 Well
Silver	2.88	174	176.5	299-W15-46 Well
Sulfate	456	63.5	66	299-W15-46 Well
Tetrachloroethene	17	63.6	66	299-W15-46 Well
Toluene	0.0038	131.5	133	299-W15-48 Well

Table 2-7. Maximum Concentrations of Nonradionuclide COPCs in Soil Samples at the 216-Z-9 Trench

Nonradionuclide Contaminant of Potential Concern	Maximum Concentration (mg/kg)	Depth Interval (ft bgs)		Location[a]
		Top	Bottom	
TBP	3,000	70	72	299-W15-48 Well
Trichloroethene	0.0013	73	75	299-W15-48 Well
Xylene	0.003	73	75	299-W15-48 Well

Source: *Remedial Investigation Report for Plutonium/Organic-Rich Process Condensate/ Process Waste Group OU: Includes 200-PW-1, 200-PW-3, and 200-PW-6 OUs; Appendix E – Data Summary Tables for Waste Sites (DOE/RL-2006-51).*

a. Well 299-W15-48 was drilled at a 32 degree (from vertical) angle underneath the 216-Z-9 Trench. The 299-W15-48 depth intervals provided in this table represent the downhole depths (i.e., not converted to vertical depths).

b. Borehole C5336 is adjacent to 299-W-15-48

As reported in DOE/RL-2006-24, *Remedial Investigation Report for the 200-ZP-1 Groundwater Operable Unit*, no radioactive plumes (or contaminants) above maximum contaminant levels (MCLs) have been identified in the groundwater area of the 216-Z-9 Trench. Because the 216-Z-9 Trench received large inventories of carbon tetrachloride and nitrate, it is considered to have been a major contributor in the past of groundwater contamination in the 200 West Area for these two compounds.

Soil samples were collected in 2005 from Borehole C3426 (completed as Well 299-W15-46) for laboratory analyses of soil moisture content. Measured soil moisture contents in samples from the Hanford formation ranged from 4.2 to 4.4 percent. Measured moisture contents in the CCU ranged from 19.1 to 23.6 percent, and moisture content in the Ringold Formation ranged from 2.8 to 6 percent. These values of soil moisture content for the granular soils of the Hanford formation and Ringold Formation, and for the more porous silt unit of the CCU, indicate the vadose zone soils beneath the trench are unsaturated. Considering the current unsaturated vadose zone conditions, as well as the operation of the SVE system in the vicinity of the 216-Z-9 Trench since 1993, it is not likely that the remaining COPCs in the vadose zone are a significant current source of groundwater contamination. Figure 2-3 presents the contaminant distribution model for the 216-Z-9 Trench.

2.4.1.2 216-Z-1A Tile Field

The 216-Z-1A Tile Field is located in the 200 West Area about 153 m (500 ft) south of the 234-5Z Building and immediately south of the 216-Z-1&2 Cribs and is adjacent to the 216-Z-3 Crib. The surface elevation at the site is approximately 205 m (673 ft). Groundwater is approximately 69.6 m (228.3 ft) bgs based on nearby Well 299-W18-16 on June 3, 2008.

The tile field piping is 20 cm (8 in.) diameter vitrified clay pipe placed on a 1.5 m (5 ft) deep gravel bed. The distributor pipe consists of a 79 m (260 ft) long north-south trunk or main pipeline with seven pairs of 21 m (70 ft) laterals spaced at 11 m (35 ft) intervals in a symmetrical herringbone pattern. The main pipeline is a continuous line without perforations. The laterals are divided into 0.3 m (11 in.) long segments. The piping system was overlaid with 15 cm (6 in.) of cobbles and 1.5 m (5 ft) of sand and gravel.

The tile field was used in this configuration from 1949 to 1959. The waste stream discharged to the adjacent 216-Z-1&2 Cribs (1949 to 1952) and the 216-Z-3 Crib (1952 to 1959), overflowed to the tile field, and consisted of neutral to basic (pH 8 to 10) process waste and analytical and development laboratory waste from the Z Plant via the 241-Z-361 Settling Tank. The total volume of waste estimated to have overflowed to the 216-Z-1A Tile Field from 1949 to 1959 was approximately 1 million L (264,172 gal).

The 216-Z-1A Tile Field initially was taken out of service in March 1959 after low concentrations of plutonium were detected in 1958 in the soil at the bottom of a well 46 m (150 ft) deep, and 15 m (50 ft) above the water table, near the 216-Z-3 Crib (Well 299-W18-57, 18 m (60 ft) southwest of 216-Z-3) (HW-78967, *Process Waste Disposal Facility – Plutonium Reclamation Operations – Z Plant*; HW-55196, 2/19/58 letter from Linderoth to Mobley) (Section 2.4.1.6). No groundwater wells had been installed near the crib or tile field that could be used to confirm breakthrough or lack of breakthrough. There was concern that the soil column retention capacity had been or soon would be exhausted and that plutonium might reach groundwater (HW-55196, 2/19/58 letter from Linderoth to Mobley).
The 216-Z-1A Tile Field was receiving overflow from the 216-Z-3 Crib during this time, and was taken out of service when the 216-Z-3 Crib was replaced.

In 1964, the 216-Z-1A Tile Field was reactivated to receive plutonium reclamation operation waste liquids directly (i.e., the effluent pipelines from the PRF bypassed the 216-Z-1&2 and 216-Z-3 Cribs). The 216-Z-1A Tile Field was recommended for use, replacing the 216-Z-9 Trench, because (1) analysis of soil from the wells within the tile field did not reveal any plutonium; (2) infiltration tests indicated more than sufficient soil percolation rates; and (3) the 216-Z-1A bottom surface area was almost three times larger than the 216-Z-9 floor area (HW-78967; HW-79068, *Design Scope Process Waste Disposal Facility Plutonium Reclamation Operations – Z Plant*). Two groundwater wells (Wells 299-W18-6 and 299-W18-7) were drilled on the west and east sides, respectively, of the tile field to monitor groundwater. From 1964 to 1969, the 216-Z-1A Tile Field was operated as a specific retention facility (RHO-ST-17, *Distribution of Plutonium and Americium Beneath the 216-Z-1A Crib: A Status Report*; ARH-1278, *Plutonium-Americium Soil Penetration at 234-5 Building Crib Sites*). The tile field was taken out of service in 1969 when it had received the prescribed liquid waste volume (ARH-2155, *Radioactive Liquid Waste Disposal Facilities 200 West Area*).

Before the 216-Z-1A Tile Field was reactivated in 1964, a sheet of 0.05 cm (0.02 in.) thick polyethylene and a 30 cm (1 ft) thick layer of sand and gravel were added, and the liquid waste discharge piping was routed directly to the central distributor pipe in the tile field. Between 1964 and 1969, a 5 cm (2 in.) diameter stainless steel (SST) pipe was progressively inserted inside the central distributor pipe to divide the tile field into three operational sections: 216-Z-1AA, 216-Z-1AB, and 216-Z-1AC (RHO-LD-114, *Existing Data on the 216-Z Liquid Waste Sites*).

From 1964 to 1969, the 216-Z-1A Tile Field received approximately 5.2 million L (1.37 Mgal) of liquid waste from 234-5Z (PFP), the 236-Z PRF, the 242-Z Waste Treatment and Americium Recovery Facility, and miscellaneous laboratory waste. Material discharged to the tile field reportedly included 57 kg (126 lb) of plutonium, 1 kg (2.2 lb) of Am-241, 270,000 kg (594,000 lb) of carbon tetrachloride, and 3,000 kg (6,600 lb) of nitrate (Figure 2-4). The carbon tetrachloride was discharged to the 216-Z-1A Tile Field in combination with other organics, as a small entrained fraction of process aqueous wastes, and as DNAPL.

The RI report (DOE/RL-2006-51) provides details of the past investigations and RI results, including soil, soil vapor, borehole geophysical logging, and other investigations. The following significant RI findings are summarized for the 216-Z-1A Tile Field:

- The highest concentrations of radionuclides (Pu-239/240 and Am-241) in sediments are located immediately beneath the tile field, below the distribution pipe.
- The maximum vertical extent of radiological contamination (predominantly Am-241, Pa-233, and Pu-239) detected in soil by borehole geophysical logging, is 37 m (121 ft).
- The maximum vertical extent of radioactive contamination detected above background levels in soil samples (Am-241, Np-237, Pu-239/240, and Pa-233) from the tile field area was 46.8 m (153.5 ft).
- Soil samples from the tile field area revealed a maximum carbon tetrachloride concentration of 6,561 mg/kg in the CCU in 1993.

An SVE system has been operated near the tile field. Between April 1991 and September 2008, approximately 24,772 kg (54,613 lb) of carbon tetrachloride was removed by the SVE system from the combined 216-Z-1A/216-Z-18/216-Z-12 Well Field (SGW-40456).

The 216-Z-1A Tile Field has not been considered to be a past source of groundwater contamination, because the effluent volume discharged at this site was much less than the soil column pore volume. However, based on the dispersed carbon tetrachloride vadose zone plume data presented in the RI, there are significant concentrations of carbon tetrachloride in the vadose zone adjacent to this site, so it is possible that this site was a past source of groundwater contamination, but it is not a significant current source.

The refinements to the 216-Z-9 Trench contaminant distribution model regarding the presence of discontinuous silt layers and the previous misidentification of Am-241 as Cs-137 apply to the 216-Z-1A Tile Field contaminant distribution model as well.

Table 2-8 provides a summary of the maximum concentrations of radionuclide COPCs in soil samples at the 216-Z-1A Tile Field.

Table 2-8. Maximum Concentrations of Radionuclide COPCs in Soil Samples at the 216-Z-1A Tile Field

Radionuclide Contaminant of Potential Concern	Maximum Concentration (pCi/g)	Location	Depth Interval (ft bgs)	
			Top	Bottom
Americium-241	2,590,000	299-W18-149 Well	11.2	11.2
Neptunium-237	40	299-W18-174 Well	48.0	48.0
Plutonium-239/240	38,200,000	299-W18-149 Well	11.2	11.2
Protactinium-233	36.7	299-W18-174 Well	14.6	14.6

Source:

Remedial Investigation Report for Plutonium/Organic-Rich Process Condensate/ Process Waste Group OU: Includes 200-PW-1, 200-PW-3, and 200-PW-6 OUs; Appendix E – Data Summary Tables for Waste Sites (DOE/RL-2006-51).

Table 2-9 provides a summary of the maximum concentrations of nonradionuclide COPCs in soil samples at the 216-Z-1A Tile Field.

Table 2-9. Maximum Concentrations of Nonradionuclide COPCs in Soil Samples at the 216-Z-1A Tile Field

Nonradionuclide Contaminant of Potential Concern	Maximum Concentration (mg/kg)	Depth Interval (ft bgs)		Location
		Top	Bottom	
Chromium (III)	19	118.5	118.5	299-W18-174 Well
Copper	24	56.0	56.0	299-W18-174 Well
Lead	11	124.9	125.4	299-W18-174 Well
Fluoride	16	124.9 and 128.9	124.9 and 128.9	299-W18-174 Well
Nitrate	250	56.0	56.0	299-W18-174 Well
Phosphate	1	56.0	56.0	299-W18-174 Well
Chloroform	0.135	131.0	131.0	299-W18-174 Well
Carbon Tetrachloride (CCl_4)	6,561	127.1	127.1	299-W18-174 Well
Methyl ethyl ketone	0.180	56.0	56.0	299-W18-174 Well
Methyl isobutyl ketone	0.156	74.5	74.5	299-W18-174 Well
Tetrachloroethylene	0.050	128.9	128.9	299-W18-174 Well
Toluene	0.040	71.5	71.5	299-W18-174 Well
Trichloroethylene	0.068	128.9	128.9	299-W18-174 Well

Source:

Remedial Investigation Report for Plutonium/Organic-Rich Process Condensate/ Process Waste Group OU: Includes 200-PW-1, 200-PW-3, and 200-PW-6 OUs; Appendix E – Data Summary Tables for Waste Sites (DOE/RL-2006-51).

The total effluent volume (6.2 million L [1.6 Mgal]) discharged to the 216-Z-1A Tile Field over its period of operation is about 12 percent of the estimated soil pore volume. As reported in DOE/RL-2006-24, no radioactive plumes (or contaminants) above MCLs have been identified in groundwater in the area of the 216-Z-1A Tile Field. The lack of radiological groundwater contamination is consistent with the contaminant profiles in RHO-ST-17 and more recent geophysical logs. As indicated in RHO-ST-17, the maximum vertical extent of radiological contamination in the vadose zone is approximately 30 m (100 ft) bgs. However, geophysical logging suggests that Pa-233 extends to 37 m (121 ft) bgs.

Based on the dispersed carbon tetrachloride vadose zone plume data presented in the RI Report (DOE/RL-2006-51), there are significant concentrations of carbon tetrachloride in the vadose zone adjacent to this site, so it is possible this site was a past source of groundwater contamination. However, considering the current unsaturated vadose zone conditions, as well as the operation of the SVE system in the vicinity of the 216-Z-1A Tile Field since 1991, it is not likely the remaining COPCs in the vadose zone are a significant current source of groundwater contamination. Figure 2-4 presents the contaminant distribution model for the 216-Z-1A Tile Field.

2.4.1.3 216-Z-18 Crib

The 216-Z-18 Crib is located in the 200 West Area, southwest of the 216-Z-1A Tile Field and southeast of the 216-Z-12 Crib. The surface elevation at the site is approximately 208.9 m (685.3 ft). Groundwater is approximately 72.8 m (239 ft) bgs based on nearby Well 299-W15-152 on March 18, 2008.

The 216-Z-18 Crib is a belowgrade inactive liquid waste management unit. The 95 by 79 m (311 by 259 ft) site consists of five separate, parallel, north-south running trenches (Figure 2-5), each 63 m by 3 m (207 ft by 10 ft), and approximately 5.5 m (18 ft) deep. Each crib structure has two 8 cm (3 in.) diameter distribution pipes placed on a 0.3 m (1 ft) thick bed of gravel at 5.2 m (17 ft) bgs, buried under an additional 0.3 m (1 ft) of gravel, covered with a membrane and sand, and backfilled to grade. Waste distributor piping in each trench was fed by the primary steel distribution pipe that bisected each trench. The crib was designed and operated as a specific retention facility.

The 216-Z-18 Crib was used as a replacement for the 216-Z-1A Tile Field, to receive High-Salt, acidic (pH 1 to 2.5) aqueous liquid waste and organic liquid waste from the PFP. The waste streams included plutonium recovery waste from the 236-Z PRF and americium recovery waste from the 242-Z Waste Treatment and Americium Recovery Facility. Carbon tetrachloride was received in the aqueous phase liquid and mixed with other organics as a DNAPL. The individual trenches, shown in Figure 2-5, were operated for approximately 1 year each. Trenches were active sequentially, as follows: Trench 3 (1969 to 1970), Trench 2 (1970 to 1971), Trench 1 (1971 to 1972), and Trench 4 (1972 to 1973). Trench 5 was never used.

The 216-Z-18 Crib was taken out of service in May 1973 when discharge of contaminated waste streams to the ground from PFP was discontinued as a matter of policy (DOE/RL-91-32, *Expedited Response Action Proposal (EE/CA & EA) for 200 West Area Carbon Tetrachloride Plume*, Appendix A). It was deactivated by blanking pipelines in the 236-Z and 242-Z Buildings. Groundwater Wells 299-W18-9, 299-W18-10, 299-W18-11, and 299-W18-12 were installed in 1968 to 1969 during construction of the crib.

The 216-Z-18 Crib received a total of 3,860,000 L (1,020,000 gal) of effluent, constituting approximately 26 percent of the estimated soil pore volume at the site. Material discharged to the crib reportedly included 23 kg (51 lb) of plutonium, 175,000 kg (386,000 lb) of carbon tetrachloride and 500,000 kg (1,102,000 lb) of nitrate (Figure 2-5). The carbon tetrachloride was discharged to the 216-Z-18 Crib in combination with other organics, as a small entrained fraction of process aqueous wastes, and as DNAPL.

SVE has been in operation at the 216-Z-18 Crib since 1992 as an interim action to remove carbon tetrachloride from the vadose zone soils. Between 1991 (when the SVE system pilot test was conducted at the 216-Z-1A Tile Field) and September 2008, the SVE system has removed approximately 24,772 kg (54,613 lb) of carbon tetrachloride from the combined 216-Z-1A/ 216-Z-18/216-Z-12 Well Field (SGW-40456).

Characterization activities have been conducted at the 216-Z-18 Crib since the 1960s. Scintillation logging of site monitoring wells was conducted in 1968, 1973, and 1976. Wells 299-W18-9 and 299-W18-10 (Figure 2-5) were the only wells that showed contamination above background levels; radiological contamination was identified at about 8 to 17 m (26 to 55 ft) bgs (ARH-ST-156, *Evaluation of Scintillation Probe Profiles from 200 Area Crib Monitoring Wells*). Spectral gamma logging and neutron moisture logging were conducted in 2006 at Wells 299-W18-9, 299-W18-12, and 299-W18-95. Pu-239 and Am-241 were identified in Well 299-W18-9 between 7.3 and 20.7 m (24 and 68 ft) bgs, with both showing a maximum of approximately 400,000 pCi/g at about 7.3 m (24 ft) bgs. Am-241 concentrations decreased with depth to 17.4 m (57 ft) bgs, where they increased to 250,000 pCi/g.

Concentrations decreased to the tool detection limits below about 20.7 m (68 ft) bgs. The Pu-240 maximum was estimated at 24,000, based on an assumption of weapons-grade plutonium ratios. Although the passive neutron log corresponds well with interpreted concentrations of alpha emitters, the response appears subdued in comparison to response at the 216-Z-1A Tile Field. This suggests the plutonium and americium at the 216-Z-18 Crib may be in a nitrate or oxide form, as opposed to the fluoride compounds believed to exist at the 216-Z-1A Tile Field (DOE-EM/GJ1273-2006, *299-W18-09 (A7526) Log Data Report*). Review of the gamma scintillation logs suggests radionuclide migration to the top of the CCU and possibly deeper has occurred in the northeastern portion of the 216-Z-18 Crib (DOE/RL-91-58, Section A.1.4.1.2). However, as reported in DOE/RL-2006-24, no radioactive plumes (or contaminants) above MCLs have been identified in the area of the 216-Z-18 Tile Field. The lack of radiological groundwater contamination is consistent with the most recent geophysical logging results.

Soil sampling was conducted in 1992 and 1993 during construction of new Wells 299-W18-247 and 299-W18-249, and the deepening of existing Well 299-W18-96. The highest carbon tetrachloride concentration encountered was 1,957 µg/kg in Well 299-W18-249 found at a depth of 44.6 m (146.2 ft). The maximum carbon tetrachloride concentrations in the other two wells were 861 µg/kg in Well 299-W18-96 (43.8 m [143.8 ft]) and 717 µg/kg in Well 299-W18-247 (41.3 m [135.4 ft]) (DOE/RL-2006-51, Section 3.2.4.8). Although the highest carbon tetrachloride concentrations in all three wells were found at the CCU, it should be noted that sampling within the crib (Well 299-W18-96) did not address soils from 0 to 25.8 m (0 to 84.5 ft) bgs. Nitrate was identified in Well 299-W18-96 at 4,400 mg/kg at 25.6 m (84 ft) bgs decreasing to <10 mg/kg at 38.1 m (125 ft) bgs. No significant concentrations of carbon tetrachloride or other volatile organic compounds (VOCs) were identified during soil vapor sampling conducted for the RI or for SVE operations in 2005, 2006, and 2007. Shallow (<25 m [82 ft] bgs) soils beneath the crib have not been sampled and analyzed. The high nitrate concentration in the shallowest soil sample from within the crib (4,400 mg/kg at 25.8 m [84.5 ft] bgs in 299-W18-96) indicates the potential for significant residual nitrate contamination at the 216-Z-18 Crib. Based on the presence of carbon tetrachloride and nitrate at the CCU (1992 and1993 sampling events), it is possible this site was a past source of groundwater contamination. Operation of the SVE system in the vicinity of the 216-Z-18 Crib since 1993 has likely reduced residual carbon tetrachloride mass, making future impacts associated with natural recharge less likely.

In summary, Pu-239 and Am-241 are most concentrated at the base of the crib, but show evidence of past mobility, with lesser (but notable) concentrations detected at depths of 17.4 and 20.7 m (57 and 68 ft) bgs in more recent logging events. Carbon tetrachloride is evident in soils beneath the crib (in the single borehole sampled within the crib perimeter), extending to the CCU. These results are consistent with contaminant distributions at the nearby High-Salt waste site, the 216-Z-1A Tile Field, which was replaced by the 216-Z-18 Crib. Figure 2-5 presents the contaminant distribution model for the 216-Z-18 Crib.

2.4.1.4 216-Z-12 Crib

The 216-Z-12 Crib is located in the 200 West Area, southwest of the 234-5Z Building and northwest of the 216-Z-18 Crib. The surface elevation at the site is approximately 208.3 m (683.6 ft). Groundwater is approximately 72.3 m (237.2 ft) bgs based on nearby Well 299-W15-152 on March 18, 2008.

The 216-Z-12 Crib is rectangular, 91 by 6 m (300 by 20 ft) at the bottom, and 5.8 m (19 ft) deep. Waste entered at 4.6 m (15 ft) bgs through a 30 cm (12 in.) diameter, perforated, vitrified clay pipe that ran the length of the crib and rested on a 1.5 m (5 ft) bed of gravel. The pipe was covered with a polyethylene barrier and backfilled to grade. In 1968, a 15 cm (6 in.) diameter steel bypass line was installed 9 m (30 ft) west of and parallel to the original distribution line to bypass 30.5 m (100 ft) of the original line that was plugged.

The 216-Z-12 Crib is a subsurface liquid waste site that was used from 1959 to 1973, as a replacement for the 216-Z-3 Crib, to dispose of PFP liquid process waste and analytical and development laboratory waste from the 234-5Z Building via the 241-Z-361 Settling Tank. The waste was Low-Salt and neutral to basic (pH 8 to 10) when discharged. In total, the 216-Z-12 Crib received approximately 281,000,000 L (74,240,000 gal) of waste (RHO-LD-114). Material discharged to the crib reportedly included 25.1 kg (55 lb) of plutonium and 900,000 kg (1,980,000 lb) of nitrate (Figure 2-6). The site likely received a small volume of organics (e.g., an organic phase such as carbon tetrachloride). Discharge of a separate americium waste stream to the 216-Z-12 Crib is considered unlikely.

The 216-Z-12 Crib was taken out of service in May 1973 when discharge of contaminated waste streams to the ground from PFP was discontinued as a matter of policy (DOE/RL-91-32, Appendix A). It was deactivated by blanking the waste feed piping in the 241-Z sump facility. Groundwater Wells 299-W18-1, 299-W18-2, 299-W18-3, 299-W18-4, and 299-W18-5 were installed in 1958 and 1959 during construction of the crib.

A portion of the crib was vitrified as part of an in situ vitrification (ISV) test project conducted in June 1987. After 295 hours of operation at 460 MW/h per hour of electrical current, the soil became molten. This resulted in a 408 metric tons (450 ton) block of vitrified soil, extending down 5 m (16 ft) bgs. According to the NEPA documentation for the test project, the vitrified zone is located about 46 m (150 ft) south of the north end of the crib, approximately centered on borehole 299-W18-243 (Hunter, 1987, "NEPA Information for the In Situ Vitrification [ISV] Large Scale Radioactive Test [LSRT]").

A soil vapor survey in 1991 indicated the presence of carbon tetrachloride near the 216-Z-12 Crib, and SVE has been in operation in the vicinity of the 216-Z-12 Crib since 1995 as an interim action to remove carbon tetrachloride from the vadose zone soils. Between 1991 (when the SVE system pilot test was conducted at the 216-Z-1A Tile Field) and September 2007, the SVE system has removed approximately 24,772 kg (54,613 lb) of carbon tetrachloride from the combined 216-Z-1A/216-Z-18/216-Z-12 Well Field (SGW-40456).

Soil sampling was conducted at the 216-Z-12 Crib in 1980 to evaluate the distribution of plutonium and americium. Table 2-10 lists the maximum Pu-239/240 and Am-241 concentrations for each borehole sampled. The data indicate that (1) the highest concentrations of plutonium and americium are in the sediments immediately below the crib bottom; (2) concentrations decrease rapidly with depth from the crib bottom; and (3) the distributions of plutonium and americium activity are similar (RHO-ST-44, *216-Z-12 Transuranic Crib Characterization: Operational History and Distribution of Plutonium and Americium*). No significant concentrations of plutonium or americium were found at depth.

The 216-Z-12 Crib was investigated as part of the 200-PW-1 RI (DOE/RL-2006-51). Depth discrete soil vapor samples were collected using a cone penetrometer for subsurface access. The highest carbon tetrachloride soil vapor concentration measured was 18 ppmv from location P48 at a depth of 22 m (72.11 ft) (Figure 2-6). The contaminant distribution model for the 216-Z-12 Crib is presented in Figure 2-6.

Table 2-10. Maximum Pu-239/240 and Am-241 Activities Detected in Soil Samples at the 216-Z-12 Crib

		Pu-239/240		Am-241	
Well	Well Depth (ft)	Maximum Activity (pCi/g)	Depth (ft bgs)	Maximum Activity (pCi/g)	Depth (ft bgs)
299-W18-152	118	23	112.5	4	25.0
299-W18-153	110	125	21.0	32	21.0
299-W18-154	20	252,000	18.0	196	18.0
299-W18-157	110	0.39	75.0	1	100.0
299-W18-162	30	4,970,000	19.4	965,000	19.4
299-W18-179	40	1,040,000	17.0	432,000	17.0
299-W18-180	40	14	27.0	3	27.0
299-W18-181	135	4,880,000	20.5	952,000	19.3
299-W18-182	40	2,080,000	20.2	1,660,000	20.2
299-W18-183	40	8	25.0	1	25.0
299-W18-184	30	182,000	22.5	122,000	22.5
299-W18-185	40	3,080,000	19.7	874,000	20.3

Source:

Remedial Investigation Report for Plutonium/Organic-Rich Process Condensate/ Process Waste Group OU: Includes 200-PW-1, 200-PW-3, and 200-PW-6 OUs; Appendix E – Data Summary Tables for Waste Sites (DOE/RL-2006-51).

2.4.1.5 216-Z-1&2 Cribs

The 216-Z-1&2 Cribs are located in the 200 West Area, south of the 234-5Z Building, immediately north of the 216-Z-1A Tile Field, and west of the 216-Z-3 Crib. The 216-Z-1&2 Cribs are separate cribs but operated as one unit. The flow from 216-Z-2 Crib overflowed into 216-Z-1 Crib as part of normal operations. The surface elevation at the site is approximately 207.2 m (679.8 ft). Groundwater is approximately 71.7 m (235.1 ft) bgs, based on nearby Well 299-W18-16 on June 3, 2008.

The 216-Z-1&2 Cribs are open-bottom, 3.7 m (12 ft) square, 4.3 m (14 ft) tall wooden boxes constructed in an excavation that was 4.3 m (14 ft) square at the bottom and 6.4 m (21 ft) deep. To control the intrusion of sand into the structure, open joints in the sides and top were caulked and the upper half of the structure was lagged with 1.9 cm (0.75 in.) plywood. The two cribs, approximately 5.5 m (18 ft) apart, were connected and fed by a 20 cm (8 in.) diameter SST central pipe with an outlet pipe to the 216-Z-1A Tile Field. The 216-Z-2 Crib overflowed into the 216-Z-1 Crib, which overflowed into the 216-Z-1A Tile Field. Two risers are visible from the surface of each crib. One is a filtered vent; the other is the stick up for a test well (now decommissioned). The 20 cm (8 in.) steel test wells were centered within each crib, installed as part of the original construction. Each extended 6.1 m (20 ft) beyond the base of the timber structure to a total depth of 12.5 m (41 ft) bgs.

The 216-Z-1&2 Cribs operated from 1949 to 1969. From 1949 to 1952, the two cribs received PFP Low-Salt waste consisting of neutral to basic (pH 8 to 10) process waste and analytical and development laboratory waste from the 234-5Z Building via the 241-Z-361 Settling Tank. The 216-Z-1&2 Cribs were taken out of service in 1952 because the effluent flow rate to the cribs exceeded the infiltration capacity of the cribs, which then overflowed into the 216-Z-1A Tile Field (ARH-2155). HW-78967 simply states the cribs became plugged. This Low-Salt waste stream was discharged to the 216-Z-3 Crib, which replaced the 216-Z-1&2 Cribs, from 1952 to 1959 and to the 216-Z-12 Crib, which replaced the 216-Z-3 Crib, from 1959 to 1973.

The cribs were used for two brief periods in 1966 and 1967 during work on the central distributor pipe in the 216-Z-1A Tile Field; these periods of service were only intended to be for the duration of the 216-Z-1A pipeline maintenance (ARH-2155). During these two periods, the cribs received very small quantities of High-Salt waste directly from the PRF in the 236-Z PRF and the 242-Z Waste Treatment and Americium Recovery Facility. Significant volumes of organics likely were not discharged to these cribs during these short periods of time.

From 1968 to 1969, the cribs received uranium wastes directly from the 236-Z Building. Final use of the cribs to receive uranium waste was concluded in 1969 when the discharge of uranium waste was discontinued (ARH-2155). No groundwater wells were installed to monitor the 216-Z-1&2Cribs (HW-55196). The cribs were administratively retired in 1969 and physically isolated when the inlet piping was cut and blanked.

In total, the two cribs received approximately 33,700,000 L (10,271,000 gal) of effluent (RHO-LD-114): 33,500,000 L between 1949 and 1952 (Low-Salt wastes), 104,000 L between 1966 and 1967 (High-Salt wastes), and 98,000 L between 1968 and 1969 (Low-Salt wastes). The effluent volume is roughly 13 times the estimated soil pore volume between the base of the cribs and the current water table. An estimate of the discharged inventory includes 7 kg (15 lb) of plutonium and 100,000 kg (220,000 lb) of nitrate (Figure 2-7).

No data were identified regarding the concentration or distribution of nonradiological contaminants in soils at these two cribs. The quantity of nitrate and the volume of effluent received suggest the site probably contributed in the past to nitrate contamination in the unconfined aquifer.

Site-specific radiological characterization data for the 216-Z-1&2 Cribs are limited. In 1986, drop cords, visual inspection, and foil activation methods were used to evaluate alpha contamination in 11 wells at the 216-Z-1&2 Cribs, and the 216-Z-1A Tile Field (Rockwell, 1986, "Alpha Contamination in the Z-1/Z-1A Crib Complex"). Wells 299-W18-60 and 299-W18-61 near the 216-Z-2 Crib, and Well 299-W18-65 near the 216-Z-1 Crib, were found to contain plutonium and americium concentrations estimated as high as 900,000 pCi/g. The contamination was found in the bottom of the wells and was believed to have resulted from contaminated sediments entering (due to well corrosion) and accumulating in the wells. A well to the north of the 216-Z-2 Crib (Well 299-W18-172) was geophysically logged in 2006; no manmade radionuclides were detected. No radionuclide contamination was detected during drilling of Well 299-W18-253 (P57) west of the two cribs in 2006 (DOE/RL-2006-51).

In general, the distribution of plutonium and americium in the soils beneath the 216-Z-1&2 Cribs are expected to reflect limited radionuclide mobility, similar to that seen at the more extensively characterized Low-Salt waste site, the 216-Z-12 Crib. Based on evaluation of available information, the majority of the plutonium and americium contaminant mass is expected to be less than 9.4 m (31 ft) bgs, with the highest activities (i.e., >1,000,000 pCi/g) found very near the base of the cribs. Some uncertainty regarding the plutonium and americium distribution beneath the 216-Z-1&2 Cribs, compared to the distribution beneath the 216-Z-12 Crib, would be associated with differences between the design and

history of use of the waste sites. Residual nitrate is expected to be present from the base of the crib to the water table, but the highest residual concentrations are expected to be well above the CCU. Figure 2-7 presents the contaminant distribution model for the 216-Z-1&2 Cribs.

2.4.1.6 216-Z-3 Crib

The 216-Z-3 Crib is located in the 200 West Area, south of the 234-5Z Building, immediately northeast of the 216-Z-1A Tile Field and adjacent to the 216-Z-1&2 Cribs. The surface elevation at the site is approximately 207.2 m (679.8 ft). Groundwater is approximately 71.7 m (235.1 ft) bgs based on nearby Well 299-W18-16 on June 3, 2008.

The waste distribution system at the 216-Z-3 Crib consists of three corrugated metal culvert sections (6.7 m [22 ft] long, 1.2 m [4 ft] in diameter) laid horizontally, end-to-end, within a gravel-filled excavation. Each culvert section was perforated with 2.5 cm (1 in.) diameter holes. The culvert sections were placed end-to-end, but it is not clear whether they were physically attached. Wire mesh was welded to both ends of the culvert to limit gravel intrusion. The base of the culverts is about 4.5 m (15 ft) belowgrade.

The excavation for the 216-Z-3 Crib was 7.6 m (25 ft) deep and, at its base, 1.5 m (5 ft) wide and 21.3 m (70 ft) long. The side walls were "as steep as field conditions permit" (H-2-12292, *216-Z-3 Crib Waste Effluent Disposal Facilities Plot Plan & Crib Details*). At the base of the excavation, a clam bucket was used to dig two additional holes to a total depth of 13.7 m (45 ft) bgs to allow installation of two 20 cm (8 in.) diameter test wells (now decommissioned). On placement of the test well casings, the two holes were backfilled with sand up to the base of the excavation. (Note: These well excavations were likely preferential pathways for infiltrating effluent.) Gravel was used to fill the excavation to within 2.4 m (8 ft) of the ground surface. The culvert sections and associated waste feed and overflow lines (20 cm [8 in.] vitrified clay pipe) were incorporated within the gravel. The base of the culverts is 4.5 m (15 ft) below grade, roughly 2.1 m (7 ft) below the top of the gravel. The gravel was covered with two layers of asphalt roofing paper and the trench was backfilled to grade with clean fill. Well 299-W18-67 is in the western half of the crib and Well 299-W18-68 is in the eastern half of the crib. Both wells have been decommissioned. A 1.2 m (4 ft) wide, 1.8 m (6 ft) long, and 10 cm (4 in.) thick concrete slab with penetrating risers is centered over the culvert.

The 216-Z-3 Crib received PFP liquid effluent from 1952 to 1959. The effluent, a Low-Salt waste stream, was neutral to basic (pH 8 to 10) and included process waste as well as analytical and development laboratory wastes. Effluent was routed through a chemical sewer line from 234-5Z to the 241-Z-361 Settling Tank, and distributed through pipeline 200-W-210-PL to the western end of the 216-Z-3 Crib. Overflow from the crib went to the 216-Z-1A Tile Field.

The 216-Z-3 Crib was taken out of service in March 1959 after low concentrations of plutonium were detected in 1958 in the soil at the bottom of a well 46 m (150 ft) deep, and 15 m (50 ft) above the water table, near the crib (Well 299-W18-57, 18 m (60 ft) southwest of 216-Z-3) (HW-78967; HW-55196; Linderoth, 1958; HW-55497). No groundwater wells had been installed near the crib that could be used to confirm breakthrough or lack of breakthrough. There was concern that the soil column retention capacity had been or soon would be exhausted and that plutonium might reach groundwater (HW-55196, 2/19/58 letter from Linderoth to Mobley). Replacement of the 216-Z-3 Crib was required "at the earliest practical date to control plutonium contamination of ground water within the Hanford limit of one-tenth of the maximum permissible concentration for drinking water" (HW-55497). The 216-Z-3 Crib was taken out of service when the replacement crib, the 216-Z-12 Crib, was placed into service.

The 216-Z-3 Crib received approximately 178,000,000 L (46,992,000 gal) of Low-Salt waste, which is more than 80 times the estimated soil pore volume between the crib base and the current water table surface. The pore volume within the crib excavation (below the elevation of the overflow line) is roughly 270,762 L (71,528 gal). On average, between 1955 and 1958, the volume of effluent discharged to the 216-Z-3 Crib on a daily basis was approximately 33 percent of the crib pore volume (assumes 30 percent porosity). An estimate of the discharged inventory includes 5.7 kg (12.6 lb) of plutonium and 600,000 kg (1,320,000 lb) of nitrate (Figure 2-8).

No soil analytical data were identified to support assessment of the concentration or distribution of radionuclide or nonradionuclide contaminants in the soils at the 216-Z-3 Crib. Physical characterization data are limited to radiological logging results from the two test wells; these results are summarized in Table 2-11.

Table 2-11. Spectral Gamma Logging Results for the 216-Z-3 Crib

Well	Radionuclide	Depths of Detection (ft bgs)	Maximum Concentration (pCi/g)	Depth of Maximum (ft bgs)
299-W18-67[a]	Am-241	16.9-26.4	230,000	18.9
299-W18-67[a]	Pu-241	16.9-26.4	3,300,000	18.9
299-W18-67[a]	Pu-239	15.4-27.4	1,700,000	18.9
299-W18-67[a]	Pu-240	N/A	400,000	N/A
299-W18-68[b]	Am-241	17.1-27.6	90,000	19.1[c]
299-W18-68[b]	Pu-241	16.1-27.6	473,000	27.1
299-W18-68[b]	Pu-239	15.6-28.1	480,000	27.1
299-W18-68[b]	Pu-240	N/A	100,000	N/A

a. HGLP-LDR-048, *299-W18-67 (A7550) Log Data Report.*

b. HGLP-LDR-051, *299-W18-68 (A7551) Log Data Report.*

c. Repeat log data suggest the maximum concentration may be at 8.3 m (27.1 ft) bgs.

N/A = Not available; no data provided in the log data report.

Radionuclides Pu-239/240 and Am-241 were detected from the base of the culvert sections (approximately 4.6 m [15 ft] bgs) to roughly 8.4 m [27.4 ft] bgs), where logging data suggest the presence of fine-grained sediments. The crib floor is 7.6 m (25 ft) bgs. The logged wells are within excavations that extended 6.1 m (20 ft) below the base of the crib floor. The highest concentrations of Pu-239/240 and Am-241 in the western well, Well 299-W18-67, were found at approximately 5.8 m (18.9 ft) bgs. The passive neutron log indicated increased alpha activity between 4.6 and 6.7 m (15 and 22 ft) bgs, with the peak at 5.8 m (19 ft) bgs. In Well 299-W18-68, in the eastern part of the crib, the maximum Am-241 concentration was found at 5.8 m (19.1 ft) bgs, but the maximum Pu-239 concentration was found at 8.3 m (27.1 ft) bgs. At Well 299-W18-68, the highest responses on the passive neutron log, indicative of alpha activity, were from 4.9 to 6.4 m (16 to 21 ft) bgs, with a secondary peak 7.3 to 8.5 m (24 to 28 ft) bgs. Based on the logging results, all significant plutonium and americium contaminant mass is believed to be located between 4.6 and 5.8 m (15 and 29 ft) bgs, with the majority located between 4.9 and 6.4 m (16 and 21 ft) bgs. This is somewhat different from the distribution seen at the best characterized Low-Salt waste site, the 216-Z-12 Crib, in that much of the plutonium and americium contaminant mass is found at depths shallower than the crib floor. This contaminant distribution suggests even less plutonium and americium mobility than seen at the 216-Z-12 Crib.

Based on the estimated effluent inventory, nitrate was identified as a COPC. Because the effluent volume was more than sufficient to reach groundwater, the site is considered a past source of nitrate contamination in the unconfined aquifer. Residual nitrate is assumed to exist between the crib base and the current water table surface, with the highest concentrations expected to be above the CCU. Figure 2-8 presents the contaminant distribution model for the 216-Z-3 Crib.

2.4.1.7 241-Z-361 *Settling* Tank

The 241-Z-361 Settling Tank is located approximately 35 m (115 ft) north of the 216-Z-1A Tile Field in the 200 West Area, within the boundary of the PFP Complex. The surface elevation at the site is approximately 207.2 m (679.8 ft). Groundwater is approximately 72.2 m (236.9 ft) bgs based on nearby Well 299-W18-16 on June 3, 2008.

The surface elevation and hydrogeologic conditions at the 241-Z-361 Settling Tank site are the same as those for the adjacent 216-Z-1A Tile Field.

The 241-Z-361 Settling Tank is an underground, reinforced-concrete structure 8.5 m (28 ft) long and 4.5 m (15 ft) wide, with a 1 cm (3/8 in.) thick steel liner. The tank has inside dimensions of 7.9 by 4.0 m (26 by 13 ft) with 0.3 m (1 ft) thick walls. The bottom slopes, resulting in an internal height variation between 5.2 and 5.5 m (17 and 18 ft). The top is 0.6 m (2 ft) belowgrade. Two 15 cm (6 in.) diameter SST inlet pipes from the 241-Z Facility enter the settling tank from the north. A single 20 cm (8 in.) diameter SST pipe exits the tank from the south. Several risers are visible abovegrade.

The tank served as the primary solids settling tank for Low-Salt liquid waste from the 234-5Z, 236-Z, and 242-Z Buildings from 1949 to 1973. Supernatant effluent in the tank was discharged to the 216-Z-1&2, 216-Z-3, and 216-Z-12 Cribs. Prior to discharge to the tank, the effluent was neutralized in the 241-Z sump tanks by adding fly ash, and later sodium hydroxide, to raise the pH to the 8 to 10 range. Liquid samples collected in March 1975, however, had a pH as low as 4. Before this characterization, it was assumed the pH was greater than 2, which renders the plutonium mostly insoluble (HNF-8735, *241-Z-361 Tank Characterization Report*).

The 241-Z-361 Settling Tank was taken out of service in May 1973 when discharge of contaminated waste streams to the ground from PFP was discontinued as a matter of policy (HNF-1989, *Tank 241-Z-361 Process and Characterization History*; DOE/RL-91-32, Appendix A). No groundwater wells had been installed near the tank.

Details of the tank investigations and characterization activities are provided in the RI Report (DOE/RL-2006-51). The significant RI findings for the 241-Z-361 Settling Tank are summarized as follows:

- The settling tank currently contains approximately 75 m^3 of sludge. The sludge is contaminated with radionuclides (primarily Pu-239), metals, organics, and polychlorinated biphenyls (PCBs).
- Helical piers installed to support tank sampling were surveyed when removed. No radiological contamination was detected.
- The lack of detected radiological contamination on the piers installed beneath the depth of the tank bottom, and the apparent stability in the tank sludge level since 1975, suggests that there has been no leak of tank contents to the soil column.
- All available information indicates the 241-Z-361 Settling Tank has not leaked, so this site is not considered to be a past or current source of groundwater contamination.

An updated estimate of the current tank inventory (SGW-35955, *Inventory Estimates for Sludge Currently in Tank 241-Z-361*) was developed in 2007 using the extensive data set reported in HNF-8735. Plutonium inventory estimates developed during this recent inventory estimate are consistent with inventory estimates developed previously from multiple analytical data sources (Figure 2-9).

Figure 2-9 presents the contaminant distribution model for the 241-Z-361 Settling Tank.

2.4.2 200-PW-3 Waste Sites

The following sections describe the waste sites assigned to the 200-PW-3 OU, in the 200 East Area, and are presented in the following order: 216-A-8 Crib, 216-A-24 Crib, 216-A-7 Crib, 216-A-31 Crib, and UPR-200-E-56.

2.4.2.1 216-A-8 *Crib*

The 216-A-8 Crib is located approximately 177 m (580 ft) east of the A Tank Farm in the 200 East Area, at a surface elevation of approximately 198 m (650 ft). Groundwater beneath the 216-A-8 Crib was about 80 m (261.7 ft) bgs at Borehole C4545 in June 2005.

The bottom dimensions of the crib are 259 by 6 m (850 by 20 ft). The long axis of the crib trends to the east-northeast. A 61 cm (24 in.) diameter, schedule 20, perforated distribution line extends the length of the crib and rests on a 2 m (6.5 ft) thick layer of rock capped by a 30 cm (12 in.) thick layer of gravel. The gravel fill is mounded over the distribution line. Two layers of Sisalkraft® building paper cover the gravel and prevent overlying native sand backfill from filling the void space. The crib floor was excavated to a uniform elevation of 195 m (639.5 ft). The depth of the excavation varied from 4.9 to 5.8 m (16 to 19 ft.) below the 1955 ground surface. The site was surface stabilized in September 1990 by the addition of 0.6 m (2 ft) of clean fill (DOE/RL-92-04, *PUREX Source Aggregate Area Management Study Report*). Water entered the crib through the 216-A-508 Diversion Box, located due west of the crib. The crib was permanently isolated in April 1995 by filling the 216-A-508 Diversion Box with concrete.

The 216-A-8 Crib was initially taken out of service in May 1958 when the discharged volume was approaching the inventory limit calculated for Sr-90 (ARH-1562, *200 East and North Areas Radioactive Liquid Waste Disposal Sites*; RHO-HS-EV-18, *Serviceability of Cribs Affected by PUREX Startup*). In January 1966, the 216-A-8 Crib was reactivated when a re-evaluation indicated it had not reached its waste capacity (RHO-HS-EV-18). In 1983, the 216-A-8 Crib was determined to meet all serviceability criteria (with the exception of eliminating the source of the surface contamination) for use during PUREX startup in 1984 (RHO-HS-EV-18). The lifetime of the 216-A-8 Crib, from a radiological standpoint, was determined to be greater than 10 years under the predicted disposal conditions (RHO-HS-EV-18). The crib last received waste in 1985. TPA Milestone M-17-28 required all discharge to the crib be ceased by September 1991. Groundwater Wells 299-E25-4 through 299-E25-9 were installed in 1956 after construction of the crib.

Over its operational life, the 216-A-8 Crib received an estimated 1.15 billion L (303.8 Mgal) of process effluent, which is estimated to be greater than 30 times the pore volume beneath the site (DOE/RL-92-04; DOE/RL-96-81, *Waste Site Grouping for 200 Areas Soil Investigations*). The estimated discharged inventory for the 216-A-8 Crib included 390.8 kg (861 lb) of uranium; 2,410 Ci of Cs-137; 128,600 kg (283,500 lb) of TBP; 55,110 kg (121,500 lb) of NPH; and 24,561 Ci of tritium (Figure 2-10). However, the RI activities detected no organics (DOE/RL-2006-51).

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The RI Report (DOE/RL-2006-51) provides details of the RI results, including soil, soil vapor, and borehole geophysical logging. The significant RI findings for the 216-A-8 Crib are summarized as follows:

- The highest radioactive contamination (Cs-137) associated with the crib and detected during the RI was within 8 m (25 ft) of the ground surface.
- The maximum depth of radioactive contamination (Cs-137) detected near the crib, by geophysical logging techniques, was 76.5 m (251 ft) bgs. However, the source of the contamination at this depth is not known.
- Radioactive COPCs were detected above background levels in soil samples (C-14, Cs-137, Eu-155, Pu-239/240, Tc-99, Sr-90, and H-3) beneath the 216-A-8 Crib to total depth (80 m [264.5 ft] bgs).

At the 216-A-8 Crib, the discharged effluent volume was greater than the soil column pore volume, which indicates the volume of effluent released was sufficient to reach the unconfined aquifer during operation of this waste site. However, based on currently available site data, including soil moisture content measurements, the 216-A-8 Crib is not considered a significant current source of groundwater contamination.

Table 2-12 provides a summary of the maximum concentrations of radionuclide COPCs in soil samples at the 216-A-8 Crib.

Table 2-12. Maximum Concentrations of Radionuclide COPCs in Soil Samples at the 216-A-8 Crib

Radionuclide Contaminant of Potential Concern	Maximum Concentration (pCi/g)	Depth Interval (ft bgs)		Location
		Top	Bottom	
Carbon-14	89.7	27.5	30	C4545 Borehole
Cesium-137	877,000	19	21.5	C4545 Borehole
Europium-155	0.055	49	51.5	C4545 Borehole
Plutonium-239/240	55.7	19	21.5	C4545 Borehole
Technetium-99	79.6	19	21.5	C4545 Borehole
Total Radioactive Strontium	4,380	19	21.5	C4545 Borehole
Tritium	8.5	234	236.5	C4545 Borehole

Source:

Remedial Investigation Report for Plutonium/Organic-Rich Process Condensate/ Process Waste Group OU: Includes 200-PW-1, 200-PW-3, and 200-PW-6 OUs; Appendix E – Data Summary Tables for Waste Sites (DOE/RL-2006-51).

Table 2-13 provides a summary of the maximum concentrations of nonradionuclide COPCs in soil samples at the 216-A-8 Crib.

Table 2-13. Maximum Concentrations of Nonradionuclide COPCs in Soil Samples at the 216-A-8 Crib

Nonradionuclide Contaminants of Potential Concern	Maximum Concentration (mg/kg)	Depth Interval (ft bgs)		Location
		Top	Bottom	
Cadmium	0.240	104	106.5	C4545 Borehole
Chromium (III)	41.8	178	180.5	C4545 Borehole
Chromium (VI)	0.278	27.5	30	C4545 Borehole
Selenium	1.8	19	21.5	C4545 Borehole
Acetone	0.019*	19	21.5	C4545 Borehole
Acetonitrile	0.012*	25	27.5	C4545 Borehole
Ethyl acetate	0.023	25	27.5	C4545 Borehole
Decane	0.5*	104	106.5	C4545 Borehole
Nonadecane	1.6*	104	106.5	C4545 Borehole
Di-n-butylphthalate	0.69	178	180.5	C4545 Borehole
Aroclor 1254	0.039	234	236.5	C4545 Borehole

Source:

Remedial Investigation Report for Plutonium/Organic-Rich Process Condensate/ Process Waste Group OU: Includes 200-PW-1, 200-PW-3, and 200-PW-6 OUs; Appendix E – Data Summary Tables for Waste Sites (DOE/RL-2006-51).

*Laboratory estimated value

The large waste stream volumes discharged to the 216-A-8 Crib are known to have impacted groundwater, but it has not been determined whether the contaminant transport occurred uniformly through the soil column or if poor seals in nearby monitoring wells provided a preferential migration pathway. Short-lived beta emitters were detected in groundwater at the crib within 13 months of the start of operations, but longer-lived beta and gamma emitters that were predicted to arrive in January 1958 apparently did not.

Soil samples were collected in 2005 from Borehole C4545 for laboratory analysis of soil moisture content. Soil moisture content ranged from 2.3 to 9.4 percent in the vadose zone beneath the crib. These values of soil moisture content for the granular soils of the Hanford formation and Ringold Formation beneath the crib indicate the vadose zone beneath the crib is unsaturated. Therefore, the remaining COPCs in the vadose zone are unlikely to be a significant current source of groundwater contamination.

The 216-A-8 Crib overlies a known groundwater contamination plume of I-129 and is within a few hundred meters of known plumes of tritium and chromium. PNNL-16346 does not report any current impacts to groundwater from the 216-A-8 Crib.

Figure 2-10 presents the contaminant distribution model for the 216-A-8 Crib.

2.4.2.2 216-A-24 *Crib*

The 216-A-24 Crib is located in the 200 East Area, approximately 140 m (460 ft) east of the 241-AN Tank Farm, and north of the 216-A-8 Crib. Surface elevation at the site is approximately 198 m (650 ft). Groundwater is approximately 76 m (249 ft) bgs based on nearby Well 299-E26-4 on March 20, 2008.

The 216-A-24 Crib is composed of four inline sections, each 107 m (350 ft) long, and each 1.8 m (6 ft) lower than the previous section and separated from the next by a soil berm. At its base, the crib is 427 m (1,400 ft) long and 6 m (20 ft) wide. Waste was distributed to the crib through a 38 cm (15 in.) diameter corrugated galvanized pipe that is perforated on the bottom half. In each section, the waste distribution line is placed horizontally in the middle of a 1.3 m (4.3 ft) bed of gravel, which is overlain by a polyethylene barrier and enough clean backfill to bring the excavation back to grade. The overlying ground surface dips to the east, such that the distribution line is approximately 1.5 m (5 ft) closer to the surface at the end of the section than it is at the beginning. The base of the waste distribution pipe ranges between 2.7 and 4.3 m (9 and 14 ft) belowgrade, depending on its location within the section. Eight 20 cm (8 in.) diameter wells on concrete pads are located on this crib. The wells extend from the bottom of the crib to 0.9 m (3 ft) abovegrade. In addition, four 38 cm (15 in.) corrugated risers with filter box assemblies extend from the distributor pipe to grade.

The 216-A-24 Crib was constructed to replace the 216-A-8 Crib liquid waste site. It received Low-Salt, neutral to basic radioactive vapor condensate from the 241-A, 241-AX, 241-AY, and 241-AZ Tank Farms. After the crib was constructed, surface condensers were installed in the tank farms, which greatly reduced the waste volume discharged to the crib. As a result, most of the waste volume was discharged to the first two of the four crib sections. Over its operational life, the 216-A-24 Crib received an estimated 820 million L (216.5 Mgal) of process effluent. The estimated discharged inventory for the 216-A-24 Crib included 65 kg (143 lb) of uranium, 401 Ci of Cs-137, 21,420 kg (47,200 lb) of TBP, 9,192 kg (20,300 lb) of NPH, and 8,798 Ci of tritium (Figure 2-11).

The 216-A-24 Crib was taken out of service in December 1965 when it had reached its waste capacity (ARH-1562, RHO-HS-EV-18). (In 1979, the valve to the 216-A-24 Crib was found to be open, allowing the waste site to have continued to receive effluent until then.) Groundwater Wells 299-E26-2 through 299-E26-5 were installed in 1958 after construction of the crib. The site was surface stabilized in 1988.

The volume of effluent discharged to the site was more than 14 times the soil pore volume between the bottom of the crib and the current water table surface, based on the footprint of all four sections. On the basis of the five wells monitoring the 216-A-24 Crib, measurable movement of radionuclides disposed to the ground was detected in all wells during crib operations. After waste disposal to the crib was terminated, radiation intensity increased in the lower portion of the sediment column in Well 299-E26-7. These data indicate breakthrough to the groundwater could have occurred from the first and second sections of the crib (ARH-ST-156).

No soil analytical results were identified to support evaluation of contaminant mass and distribution at the 216-A-24 Crib. The site evaluation was conducted using geophysical logging results from 28 boreholes in and around the crib, and general information about the fate and transport of similar types of waste discharged to the 216-A-8 Crib.

Eighteen boreholes are located within the crib boundary; five of which penetrate the crib floor. Scintillation probe profiles from these wells reflect the waste discharge history. Wells 299-E26-4, 299-E26-5, and 299-E26-6 monitor the first and second sections of the crib. These sections received most of the volume and total beta activity discharged during 1958 and 1959. The profiles from these wells show high radiation intensity from these discharges. After December 1959, the volume and the amount of radioactive effluent sent to the crib were greatly reduced. The condensate was later rerouted to the third and fourth crib sections. Wells E26-2 and E26-3 monitor these sections of the crib and, in 1976, scintillation profiles showed radiation intensity at background levels.

More recent geophysical logging revealed only six of the 18 boreholes intersect soils with Cs-137 concentrations exceeding 125 pCi/g, as shown in Table 2-14. In general, logging results indicated only Section 1, Section 2, and Section 4 have residual radiological contamination at levels warranting consideration, and Section 1 contains the bulk of the residual Cs-137. All six of the boreholes in Table 2-14 show some level of Cs-137 contamination from ground surface to depths of at least 15.2 m (50 ft), with the highest concentrations being found somewhere between 4.6 and 7.0 m (15 and 23 ft) bgs. All six also showed notably elevated concentrations somewhere in the interval between 9.1 and 15.2 m (30 and 50 ft) bgs, although these concentrations were orders of magnitude lower than the borehole maximums. Logging data indicate the Cs-137 has not spread laterally outside the crib boundaries except as documented at the UPR-200-E-56 site to the north, where relatively minor activity levels (Cs-137 <100 pCi/g) have been detected (Section 2.4.2.5).

Table 2-14. Logging Results for Wells of Interest at the 216-A-24 Crib

Location	Maximum Cs-137 Concentration (pCi/g)	Depth of Maximum Concentration (ft bgs)
299-E26-60 Well, head end of Section 1	700,000	17.1
299-E26-74 Well, eastern half of Section 1	1,000,000	16.0
299-E26-71 Well, 11 m (35 ft) north of 299-E26-74 Well	217,000	18.9
299-E26-61 Well, head end of Section 2	180,000	20.2
299-E26-62 Well, head end of Section 3	340	19
299-E26-63 Well, head end of Section 4	16,000	19.2

Source:

Remedial Investigation Report for Plutonium/Organic-Rich Process Condensate/ Process Waste Group OU: Includes 200-PW-1, 200-PW-3, and 200-PW-6 OUs; Appendix E – Data Summary Tables for Waste Sites (DOE/RL-2006-51).

Organics also are identified as having been discharged to the 216-A-24 Crib (Figure 2-11). Borehole 299-E26-53, drilled in 1981, encountered organic odors from 4.6 to 12 m (15 to 40 ft) bgs, and produced a liquid, blue-green sample from 10 m (33 ft) bgs. Drilling logs from other boreholes in the crib indicate strong organic odors. The effluent volume and inventory suggest some potential for deep contamination. However, the 216-A-8 Crib received similar types of waste, and very large effluent volumes, yet soil sampling identified no evidence of residual organics (Section 2.4.2.1).

Based on geophysical logging results and drilling log comments, contamination at the 216-A-24 Crib warranting the most consideration appears to be within Section 1 and Section 2 of the crib. Table 2-14 lists the maximum Cs-137 concentrations for each of the crib's four sections.

In Section 1, the highest Cs-137 concentrations are found in soils from 4.3 to 6.4 m (14 to 21 ft) bgs, with the maximum being approximately 1,000,000 pCi/g at 4.9 m (16 ft) bgs in Well 299-E26-74 in the eastern half of the section. Section 1 is also where historical drilling activities encountered evidence of organic contamination between 4.6 and 12.2 m (15 and 40 ft) bgs. Organics may still be present in this interval, although soil analyses for the 216-A-8 Crib appear to suggest that the organics may degrade readily.

In Section 2, the highest Cs-137 concentrations were found between 5.2 and 7.0 m (17 and 23 ft) bgs and between 11.6 and 14 m (38 and 46 ft) bgs, with the maximum being approximately 180,000 pCi/g at 6.2 m (20.2 ft) bgs in Well 299-E26-61 at the head end of the section.

In Section 3, the maximum Cs-137 concentration detected was 340 pCi/g, found at 5.8 m (19 ft) bgs in Well 299-E26-62 at the head end of the section.

In Section 4, the highest Cs-137 concentrations were found between 5.2 and 6.7 m (17 and 22 ft) bgs, with the maximum being approximately 16,000 pCi/g 5.9 m (19.2 ft) bgs in Well 299-E26-63 at the head end of the section.

Figure 2-11 presents the contaminant distribution model for the 216-A-24 Crib.

2.4.2.3 216-A-7 Crib

The 216-A-7 Crib is located in the 200 East Area, approximately 40 m (130 ft) east of the 241-A Tank Farm and 23 m (75 ft) southwest of the 216-A-1 Crib. The surface elevation at the 216-A-7 Crib is approximately 206.4 m (677 ft). Groundwater is approximately 84.4 m (276.9 ft) bgs, based on water level measurements at nearby Well 299-E25-2 on July 7, 2008.

The 216-A-7 Crib was constructed in a 4.9 m (16 ft) deep excavation with a 3 by 3 m (10 by 10 ft) base. Perforated 15 cm (6 in.) vitrified clay pipe was used to distribute discharged liquids within the crib. The base of this piping is about 3.7 m (12 ft) below the current ground surface. Approximately 2.1 m (7 ft) of coarse rock (≥ 7.6 cm [3 in.] diameter) lie between the pipe and the native soils at the base of the excavation, which is about 5.8 m (19 ft) below the current ground surface.

The 216-A-7 Crib received aqueous liquid discharges in 1956 and 1957 and was replaced by the 241-A-302B Catch Tank in 1959. In November 1966, the crib received a one-time discharge of the organic inventory used for a 6-month process test at PUREX. The crib was deactivated in 1966, and isolated by blanking the effluent pipeline. In total, the site received approximately 326,000 L (86,100 gal) of effluent, of which 246,000 L (65,000 gal) was received in 1966. Groundwater Well 299-E25-2 was installed in 1955 and used for monitoring groundwater at the 216-A-7 Crib. In July 1959, Sr-90 and Cs-137 were not detected in this well (HW-61137, *Waste Disposal Monitoring Activities Summary, July, 1959*).

The 216-A-1 and 216-A-7 Cribs shared a common radiological surface contamination area. In 1992, contaminated surface soil in the vicinity of these two cribs was scraped and consolidated on top of the 216-A-1 and 216-A-7 Cribs. The entire area was then stabilized (covered) with 46 to 61 cm (18 to 24 in.) of uncontaminated backfill, increasing the surface elevation by about 1 m (3 ft).

A 46 m (150 ft) deep dry well (299-E25-54 [A6043]) was installed at the site in 1955 to allow monitoring of radionuclides in the subsurface. It is located within the surface footprint of the crib, but approximately 4.5 m (15 ft) east of the crib base. The most recent logging event (HGLP-LDR-024, *299-E25-54 (A6043) Log Data Report*), conducted in October 2006, identified two manmade radionuclides (Cs-137 and U-238) with activity levels exceeding 1 pCi/g, as summarized in Table 2-15. Cs-137 was detected continuously from 1.9 to 3.1 m (6.3 to 10.4 ft) bgs. The highest activity levels were detected between 2.2 and 2.5 m (7.3 and 8.3 ft) bgs, with a maximum of approximately 600 pCi/g at 2.5 m (8.4 ft) bgs. Uranium-238 was detected at 8 m (28 ft), 10 m (34 ft), and continuously from 11 m (38 ft) to 1 m (42 ft) bgs, with a maximum concentration of about 18 pCi/g at 11 m (39 ft).

Although the 216-A-7 and 216-A-8 Cribs received similar waste types that were discharged at similar depths in very similar geology, the differences in site size and in waste discharge history may have resulted in differences in contaminant concentrations in the subsurface and in the depth of contaminant

migration. Relative to the 216-A-8 Crib, the 216-A-7 Crib had a much smaller volume of more concentrated effluent, infiltrating over a smaller surface area, in a shorter period of time, into drier soils, with no subsequent discharges. Thus, based on comparison with the data for the 216-A-8 Crib, one would expect to find higher concentrations of NPH and Cs-137 in the soils beneath the 216-A-7 Crib. Because the 216-A-7 Crib soils were not saturated to begin with, it is possible that a larger percentage of the inventory may be retained at a shallower depth (i.e., less than 4.6 m [15 ft] belowgrade).

Table 2-15. Borehole Logging Results for Well 299-E25-54 at the 216-A-7 Crib

Well	Radionuclide	Depths of Detection (ft bgs)	Maximum Concentration (pCi/g)	Depth of Maximum (ft bgs)
299-E25-54	Cs-137	6.3–10.4	600	7.3 – 8.3
299-E25-54	U-238	28, 34 and 38–42	18	39

Source: HGLP-LDR-024, *299-E25-54 (A6043) Log Data Report.*

Figure 2-12 presents the contaminant distribution model for the 216-A-7 Crib.

2.4.2.4 216-A-31 Crib

The 216-A-31 Crib is located in the 200 East Area, roughly 125 m (410 ft) south of PUREX and 19 m (61 ft) south of the 216-A-2 Crib. The surface elevation at the 216-A-31 Crib is roughly 217 m (712 ft). Groundwater is approximately 95 m (312 ft) bgs, based on water level measurements at nearby Well 299-E24-16 in March 2008.

The 216-A-31 Crib is 21 by 3 m (70 by 10 ft) at the bottom and 7.3 m (24 ft) deep. A 7.6 cm (3 in.) diameter SST perforated distribution pipe was placed horizontally 6.4 m (21 ft) belowgrade in the upper portion of a 0.9 m (3 ft) thick bed of gravel. The gravel was covered with polyethylene sheeting and 5 cm (2 in.) of sand, and the crib was backfilled to grade.

The 216-A-31 Crib was a belowgrade liquid waste site that was used from 1964 to 1966 to dispose of organic, Low-Salt, neutral to basic liquid waste from the 202-A Building L Cell, via the 241-A-151 Diversion Box. This waste stream had previously been discharged to the 216-A-2 Crib. The inventory discharged to the 216-A-31 Crib is estimated to include 371 Ci of Cs-137, 19,800 kg (43,700 lb) of TBP, and 8,491 kg (18,700 lb) of NPH (Figure 2-13). The site was deactivated in 1966 by blanking the L Cell nozzles to the diversion box.

The 216-A-31 Crib was taken out of service in November 1966 (ARH-231, *Hanford Low Level Waste Management Reevaluation Study*; ISO-698, *Radioactive Contamination in Liquid Wastes Discharged to Ground at the Separations Facility Through December, 1966*) because the PUREX organic waste was no longer being discharged to the ground (ARH-1562). Groundwater Well 299-E24-9 was installed in 1962 before the crib received any discharges.

The effluent volume was between 10,000 L (2,600 gal) (RHO-CD-673, *Handbook 200 Areas Waste Sites*) and 30,545 L (8,070 gal) (ARH-231), which is less than 1 percent of the estimated total soil pore volume between the bottom of the crib and the current water table surface. This makes it unlikely that effluent migrated any significant distance below the crib. Groundwater impacts are not plausible.

No investigation activities have been performed within the boundaries of the 216-A-31 Crib. Well 299-E24-9, located 21 m (69 ft) south of the crib, was geophysically logged in 1963, 1970, and 1975 with a scintillation logging system. No contamination was identified in the vadose zone (ARH-ST-156). The contaminant distribution model is based on an understanding of the 216-A-31 Crib waste stream, the limited contaminant inventory, the small volume discharged at the crib, and on data and information from the 216-A-2 Crib.

Because Cs-137 typically sorbs to soil immediately below the release point, concentrations are expected to be highest at 7.3 m (24 ft) bgs. Based on the estimated inventory and the limited volume of effluent discharged, concentrations at the base of the crib could potentially range from tens to hundreds of thousands of pCi/g. Cesium-137 concentrations are expected to decrease with depth and, due to the small discharge volume, notable concentrations are not expected to extend more than a few meters beyond the crib floor.

Organic constituents also are expected primarily near the bottom of the crib but could have traveled downward, and possibly laterally, farther than the less mobile Cs-137. Because of the small volume released, waste contaminants are not expected to have migrated laterally beyond the crib boundary or more than a few meters below the crib bottom. A fine-grained layer at about 15.5 m (51 ft) bgs was identified at the nearby 216-A-4 Crib. Contaminants reaching this less permeable layer may have spread laterally but are not expected to have moved deeper. Volatilization and biological degradation decrease organic concentrations over time. Data from the RI at the similar 216-A-8 Crib did not show significant organic contamination in the vadose zone.

Figure 2-13 presents the contaminant distribution model for the 216-A-31 Crib.

2.4.2.5 UPR-200-E-56 Unplanned Release

The UPR-200-E-56 site is located immediately north of the 216-A-24 Crib in the 200 East Area. The site has a surface elevation of approximately 196 m (643 ft). Groundwater is approximately 74 m (243 ft) bgs, based on nearby Well 299-E26-4 in March 2008.

The site originated as a sloping excavation intended to generate clean borrow material for backfilling around the then new, belowgrade 241-AN tanks. The final excavation ranged from 1.5 to 6.1 m (5 to 20 ft) deep (estimated), and was 131 m (430 ft) long, and an average of 33.5 m (110 ft) wide. During radiation monitoring performed in June 1979, the excavation was found to be moist and radioactively contaminated. The moisture and contamination appears to be effluent waste from the adjacent 216-A-24 Crib that had seeped laterally over the surface of a 10 cm (4 in.) thick hardpan crust approximately 4.6 m (15 ft) bgs. The location was not intended to receive effluent discharges, and no groundwater wells had been installed to monitor this area.

Upon discovery of contamination, the pit was refilled with contaminated soil retrieved from the 241-AN tanks location and UPRs associated with the 241-C Tank Farm and the 200 East Area (UPR-200-E-91, UPR-200-E-92, and UPR-200-E-93). These soils are expected to have low-level radioactive contamination that is homogeneously distributed as a result of mixing of soils during transfers. The site then was covered with 15 to 20 cm (6 to 8 in.) of clean soil. In 1985, contaminated soil from the 244-A Lift Station (UPR-200-E-100) was disposed at this site and the site was restabilized with 0.6 m (2 ft) of clean soil.

Neither the volume of effluent that migrated laterally from the 216-A-24 Crib to UPR-200-E-56, nor the associated contaminant inventory is known. The contaminant inventory contained in the soils imported from other sites also is not known.

The RI/FS process did not identify any existing soil analyses for the UPR-200-E-56 site. Based on the soil analyses at 216-A-8 Crib, which received effluents that are similar to those that were discharged to, and migrated from, the 216-A-24 Crib, the UPR site is expected to have no significant concentrations of nonradioactive contaminants.

Monitoring in 1979 identified moisture and radioactive contamination of 8,000 cpm in the excavated borrow pit next to the 216-A-24 Crib. Radionuclide logging at the backfilled site performed in 1994 identified 21.7 pCi/g of Cs-137 at 2.3 m (7.5 ft) bgs in Well 299-E26-68 and 5.0 pCi/g of Cs-137 at 2.3 m (7.5 ft) bgs in Well 299-E26-75.

In 2005 and 2006, spectral gamma geophysical logging was performed on six of the seven wells within the perimeter of UPR-200-E-56. Cesium-137 was the only manmade radionuclide detected. The highest Cs-137 concentrations identified were 80 pCi/g at 3.8 m (12.5 ft) bgs in Well 299-E26-66, and 46 pCi/g at 2.7 m (9 ft) bgs in Well 299-E26-69. Table 2-16 lists the maximum Cs-137 results for all six wells.

Table 2-16. Radiological Logging Results for UPR-200-E-56 Boreholes

Well	Maximum Cs-137 (pCi/g)	Depth of Maximum (ft bgs)	Total Depth (ft bgs)
299-E26-65	1	2.0	33.5
299-E26-66	80	12.0	37.65
299-E26-68	3	9.5	35.9
299-E26-69	46	9.0	31.8
299-E26-70	19	9.0	19.2
299-E26-75	11	8.5	20.5

Source:

Remedial Investigation Report for Plutonium/Organic-Rich Process Condensate/ Process Waste Group OU: Includes 200-PW-1, 200-PW-3, and 200-PW-6 OUs; Appendix E – Data Summary Tables for Waste Sites (DOE/RL-2006-51).

The identified Cs-137 concentrations are more than 61 m (200 ft) above groundwater. The volume of effluent that initially migrated to the site from the 216-A-24 Crib is not known, but residual contaminant distribution suggests it was readily retained within the upper 15 m (50 ft).

Figure 2-14 presents the contaminant distribution model for the UPR-200-E-56.

2.4.3 200-PW-6 Waste Sites

The following sections describe the waste sites assigned to the 200-PW-6 OU, located in the 200 West Area, and are presented in the following order: 216-Z-8 French Drain, 216-Z-10 Injection/ Reverse Well, 241-Z-8 Settling Tank, and 216-Z-5 Crib.

2.4.3.1 216-Z-8 French Drain

The 216-Z-8 French Drain is located east of the 234-5Z Building, and approximately 94 m (308 ft) northwest of the 216-Z-9 Trench in the 200 West Area. The surface elevation at the site is approximately 205.2 m (673.2 ft). Groundwater is approximately 70.2 m (230.4 ft) bgs based on nearby Well 299-W15-46 on May 18, 2008.

The French drain bottom dimensions form a 1.5 by 1.5 m (5 by 5 ft) square with angled walls. The bottom 0.9 m (3 ft) of the excavation is backfilled with clean, graded gravel. A seal of building paper was laid over the gravel with a 0.9 m (3 ft) diameter hole to match the two sections of a 0.9 m (3 ft) vitrified clay pipeline placed end-to-end over the hole. A concrete collar was poured around the bottom of the clay pipeline, on the top of the building paper. The clay pipeline was filled with gravel and capped with building paper and a wire mesh reinforced-concrete slab to seal the top of the structure. The overflow pipe from the 241-Z-8 Settling Tank entered through the center of the concrete cap of the French drain. Woven wire mesh was placed at the opening of the pipe into the French drain to ensure a void space at the waste inlet. The entire structure was backfilled, resulting in the top of the structure being 2.5 m (8 ft) belowgrade. Waste overflow entered the gravel-filled excavation at 4.4 m (14 ft) belowgrade from the 241-Z-8 Settling Tank. The total volume filled with gravel in the French drain was more than 4 m^3 (141 ft^3). The French drain was designed assuming a net porosity of 30 percent, such that more than 1,000 L (265 gal) of solution could be accommodated. This was sufficient capacity to permit the waste solution to percolate into the sediments beneath the French drain between batch discharges of waste and rinse water from the 241-Z-8 Settling Tank (RHO-RE-EV-46P, *216-Z-8 French Drain Characterization Study*).

The 216-Z-8 French Drain received low-level plutonium contaminated waste from the 234-5Z Building from 1955 to 1962. No organic waste was discharged to the 216-Z-8 French Drain. The waste stream was dilute and neutral, with no fission or activation product content, and was relatively low in both disposal rate and total disposal volume. It is estimated that 9,590 L (2,530 gal) of liquid waste containing an estimated 48.2 g (1.7 oz) of plutonium overflowed from the 241-Z-8 Settling Tank to the 216-Z-8 French Drain by the time it was retired in 1962 (RHO-RE-EV-46P).

The 216-Z-8 French Drain was taken out of service in June 1962 following a criticality accident in the 234-5Z Building in April 1962 that forced the closure of the RECUPLEX process (ARH-2155). No groundwater wells had been installed near the waste site.

A characterization well (299-W15-202) was drilled in 1980, and soil samples were collected to define the plutonium and americium distribution beneath the 216-Z-8 French Drain (RHO-RE-EV-46P). The well was located less than 1 m (3 ft) south of the 216-Z-8 French Drain, and was drilled to 53.6 m (176 ft) bgs. A maximum value of 457 pCi/g of Am-241 was reported at 6.1 m (20 ft) bgs, near the bottom of the 216-Z-8 French Drain. A maximum Pu-239 value of 4,620 pCi/g was reported at 7.6 m (25 ft) bgs. Results indicate that plutonium and americium were sorbed onto sediments within a few meters beneath the French drain. Based on these results, the nature and extent of contamination are suspected to be confined to a shallow vadose zone region directly adjacent to the 216-Z-8 French Drain. It is unlikely that waste from the 216-Z-8 French Drain reached groundwater.

Figure 2-15 presents the contaminant distribution model for the 216-Z-8 French Drain.

2.4.3.2 216-Z-10 Injection/*Reverse* Well

The 216-Z-10 Injection/Reverse Well is approximately 30.5 m (100 ft) east of the 231-Z Building in the 200 West Area. The 216-Z-10 Injection/Reverse Well also has been known as the 231-W Reverse Well, 231-W-151 Dry Well or Reverse Well, 231-Z Well, 299-W15-51, 231-W-150, and 216-Z-2. The surface elevation at the site is approximately 206.3 m (676.8 ft). Groundwater is approximately 71.3 m (234 ft) bgs based on nearby Well 299-W15-1 on February 27, 2008. Groundwater was approximately 58.8 m (193 ft) bgs at nearby Well 299-W15-1 in 1945.

The 216-Z-10 Injection/Reverse Well was drilled in September 1944. The well was 0.15 m (6 in.) in diameter and constructed of Schedule 40 steel pipe. The drilling log reported depth to bottom at 45.7 m (150 ft) bgs, with a capped flange extending approximately 0.31 m (1 ft) abovegrade. Three inlet pipes enter the well at 1.5 m (5 ft), 1.8 m (6 ft), and 2.1 m (7 ft) bgs. Historical drawings suggest that a 1.3 cm (0.5 in.) copper tube extends from ground surface to 0.6 m (2 ft) bgs, where it enters the 216-Z-10 Injection/Reverse Well, and may extend to the well bottom. The well was perforated from 36 to 45.7 m (118 to 150 ft) bgs, with a cement plug in the bottom. On November 24, 1944, the well was tested with 7,571 L (2,000 gal) of water pumped into the well at a rate of 379 L/min (100 gal/min.). The results of this test showed no static water 5 minutes after pumping had stopped (HW-9671, *Underground Waste Disposal at Hanford Works: An Interim Report Covering the 200 West Area*).

The 216-Z-10 Injection/Reverse Well received process and laboratory waste from the 231-Z Building via the 231-Z-151 Sump between February and June 1945. It is estimated that 988,000 L (260,000 gal) of liquid containing up to 50 g (1.6 oz) of plutonium was discharged to the well at approximately 76 L/min (20 gal/min). No other radionuclides were reported to have been released to the 216-Z-10 Injection/Reverse Well (HW-9671). During drilling of nearby Well 299-W15-42, it was estimated the depth to the highest recorded water table in the area of the 216-Z-10 Injection/Reverse Well was 58 m (191 ft) bgs. This suggests the water table did not rise near the 216-Z-10 Injection/Reverse Well perforated interval in later years.

The 216-Z-10 Injection/Reverse Well was taken out of service in June 1945 because the well had been plugged with sludge (RHO-LD-114, HW-9671). The well was deactivated by capping the waste feed piping at the 231-W-151 Diversion Box (231-Z-151 Sump). No groundwater wells had been installed near the reverse well.

In 1947, three monitoring wells (299-W15-59, 299-W15-60, and 299-W15-61) were drilled 4.6 m (15 ft) from the 216-Z-10 Injection/Reverse Well for the collection of characterization soil samples (HW-9671). The wells were drilled to 53.3 m (175 ft) bgs, which was 7.6 m (25 ft) below the bottom of the reverse well.

Characterization soil samples were collected at a minimum frequency of every 1.5 m (5 ft), and every 0.3 m (1 ft) where contamination was suspected to exist. A total of 210 soil samples from the three monitoring wells were collected, including field duplicates, and analyzed in the lab using an alpha counter (HW-9671). The method reporting limit used was not reported in HW-9671; therefore, the method reporting limit from HW-23769, *Calculation Constants Used by Regional Survey: Part II Alpha Sample Counting Rate Conversion Factors*, of 0.15 pCi/g was used as a surrogate value. Contamination, specifically plutonium, was not detected in any of the soil samples. In 2005, passive-neutron logging to detect alpha contamination was conducted in these three monitoring wells, and the results confirm the HW-9671 findings that plutonium has not moved 4.6 m (15 ft) laterally from the injection/reverse well toward the soil borings (completed as vadose zone Wells 299-W15-59, 299-W15-60, and 299-W15-61). However, logging did detect Cs-137, Co-60, and Eu-154 in Well 299-W15-59. Cesium-137 was detected near the ground surface at approximately 1 pCi/g and at 24 m (80 ft) near its minimum detection level of approximately 0.2 pCi/g. Cobalt-60 was detected between 40 and 41 m (131 and 134 ft) at concentrations less than 0.2 pCi/g. Europium-154 was detected between 29 and 30 m (96 and 98 ft). The maximum Eu-154 concentration was approximately 0.25 pCi/g. At Well 299-W15-60, Cs-137 was the only manmade radionuclide detected. Cesium-137 was detected at a few locations near its minimum detection level of approximately 0.2 pCi/g. At Well 299-W15-61, Cs-137 and Eu-154 were the manmade radionuclides detected. Cesium-137 was detected near the ground surface and at a few locations near its minimum detection level of approximately 0.2 pCi/g. Europium-154 was detected at 28 and 35 m (92.5 and 114.5 ft) near its minimum detection level of approximately 0.6 pCi/g (DOE-EM/GJ918-2005,

Log Data Report for 299-W15-59 [A7360]; DOE-EM/GJ919-2005, *Log Data Report for 299-W15-60 [(A7361)]*; and DOE-EM/GJ920-2005, *Log Data Report for 299-W15-61 [A7362]*). Any residual radionuclide contamination at the 216-Z-10 Injection/Reverse Well appears to be confined within the 9.1 m (30 ft) diameter lateral circle formed by the three vadose zone wells, and near the vertical perforated zone of the injection/reverse well.

Figure 2-16 presents the contaminant distribution model for the 216-Z-10 Injection/Reverse Well.

2.4.3.3 241-Z-8 Settling Tank

The 216-Z-8 Settling Tank is located in the 200 West Area, roughly 61 m (200 ft) east of the 234-5Z Building and 91 m (300 ft) west-northwest of the 216-Z-9 Trench. The surface elevation at the site is approximately 205.2 m (673.2 ft). Groundwater is approximately 70.2 m (230.4 ft) bgs based on nearby Well 299-W15-46 on May 18, 2008.

The 241-Z-8 Settling Tank is a cylindrical tank that is 12.2 m (40 ft) long and 2.4 m (8 ft) in diameter. It is constructed of 0.8 cm (0.31 in.) thick steel or wrought iron plate, and oriented horizontally at about 1.8 m (6 ft) belowgrade. The tank was fed by two 3.8 cm (1.5 in.) diameter SST pipes that enter the western end of the tank about 15 cm (6 in.) below the tank top. A single pipeline exits the opposite end of the tank, to direct overflow to the 216-Z-8 French Drain, approximately 11 m (36 ft) to the east.

The 241-Z-8 Settling Tank was in service from 1955 to 1962, receiving pH neutral effluent waste from back flushes of the RECUPLEX feed filters. Silica gel was added to the waste stream as a settling agent, and the effluent was flushed to the 241-Z-8 Settling Tank with nitric acid. Overflow from the tank was piped to the 216-Z-8 French Drain. It was 1957 before the volume of effluent discharged to the tank surpassed the tank capacity (58,500 L [15,435 gal]) and liquids might have begun overflowing to the 216-Z-8 French Drain. Physical measurements of the tank contents in 1959 showed the tank had reached its overflow capacity, indicating that waste was overflowing to the 216-Z-8 French Drain.

The 241-Z-8 Settling Tank was taken out of service in June 1962 following a criticality accident in the 234-5Z Building in April 1962 that forced the closure of the RECUPLEX process. No groundwater wells had been installed near the tank. Based on available records, the tank is assumed to have been filled to overflow capacity when it was taken out of service.

April 1974 surveillance data reported the tank contents as 29,000 L (7,650 gal) of liquids and 1,880 L (500 gal) of sludge. Because the tank was expected to be at capacity, the 27,580 L (7,285 gal) shortfall suggested a tank leak may have occurred, prompting efforts to remove residual tank liquids. Laboratory analysis of samples collected at the time of the surveillance and in May 1974 suggested a residual plutonium inventory of between 8 g and 1,444 g (WHC-SD-DD-TI-057, *Summary of Radioactive Underground Tanks Managed by Hanford Restoration Operations*). Liquids present in the tank had a pH of 6.

To mitigate any ongoing potential for leaks, all pumpable liquid was removed from the tank, and the tank was flushed with 18,800 L (5,000 gal) "fifty percent caustic solution," leaving approximately 18 cm (7 in.) of sludge, equivalent to 1,880 L (500 gal). A sample of this sludge collected in October 1974 contained a pH of 6.1 and a plutonium concentration of 0.02 g/L. This concentration, averaged across the residual sludge volume, would indicate a residual plutonium inventory of about 38 g. Based on the variability in plutonium concentrations detected in the earlier sludge sampling event, the total plutonium inventory in the residual sludge is estimated to be no more than 1,500 g, and may be less than one-half that amount.

The 241-Z-8 Settling Tank was characterized in 1984 (RHO-RE-EV-46 P) by installation of four wells south of the tank to a depth of 7.6 m (25 ft) bgs (Wells 299-W15-198, 299-W15-199, 299-W15-200, and 299-W15-201). Two sediment samples were collected from each well at 4.6 and 6.1 m (15 and 20 ft) bgs. In addition, four core samples were collected south of the tank from 0 to 30 cm (0 to 12 in.) bgs (core locations A, B, C, and D in Figure 2-17). The maximum plutonium concentration detected was 44 pCi/g in the sample from 0 to 15 cm (0 to 6 in.) bgs. The investigation identified no significant contamination in the soil column, suggesting that no leak occurred.

Figure 2-17 presents the contaminant distribution model for the 241-Z-8 Settling Tank.

2.4.3.4 216-Z-5 Crib

The 216-Z-5 Crib is in the 200 West Area, approximately 36 m (118 ft) east-northeast of the 231-Z Building. The surface elevation at the site is approximately 207 m (678 ft). Groundwater is approximately 71.3 m (234 ft) bgs based on nearby Well 299-W15-1 on February 27, 2008.

The 216-Z-5 Crib was a liquid waste site that was used from 1945 to 1947 to dispose of 231-Z Building process waste that accumulated in the 231-W-151 Vault. The crib consists of two, inline, interconnected 3.8 m (12 ft) square, 1.2 m (4 ft) deep wooden sump boxes that are open at the bottom. Each box was placed at the bottom of a 5.5 m (18 ft) deep rectangular excavation that was approximately 4.3 m (14 ft) square at the base, and then covered with fill to bring the site back to original grade. The two boxes were roughly 20 m (65 ft) apart on center. The crib was oriented north-south and effluent was piped in from the southern end. The crib was deactivated by capping the inlet line from the vault. The site was stabilized (a layer of clean soil added to the ground surface) in 1990.

The 216-Z-5 Crib was taken out of service in February 1947 because the soil porosity had been sealed by the sludge in the waste discharged to the crib (RHO-LD-114, HW-9671). Groundwater Well 299-W15-1 was installed in May 1947 after the crib had been taken out of service. None of the groundwater samples collected through January 1, 1950 "showed radioactivity above the significant or reporting level" (HW-17088, *The Underground Disposal of Liquid Wastes at the Hanford Works, Washington*).

In total, the 216-Z-5 Crib received 31,000,000 L (8,184,000 gal) of effluent. The discharged inventory was estimated to include 340 g (0.75 lb) of plutonium and 100,000 kg (220,000 lb) of nitrate (Figure 2-18). In 2007, a reevaluation of inventory discharged from the 231-Z Building derived a similar estimate for plutonium and a lower estimate for nitrate (SGW-35060, *Inventory Estimates for Liquid Discharges from the 231-Z Facility*).

Eight wells were drilled around the first crib structure in 1947 to assess plutonium distribution in the soils. None penetrated the bottom of the crib structures. Soil analyses indicated only 0.5 g (0.02 oz.) of the plutonium inventory could be accounted for and the remainder of the plutonium discharged to this crib likely remains directly beneath the crib bottom (HW-9671). Geophysical logging of six of these wells in 2005 supported the results of the 1947 effort, detecting no plutonium or other alpha emitters in the soil column. However, Cs-137, Co-60, and Eu-154 were detected at very low levels in all of the geophysical logs, with most inventory appearing to be between 12 m and 23 m (40 and 75 ft) bgs, although logging did consistently identify detectable concentrations as deep as the CCU.

The volume of effluent received 31,000,000 L (8,000,000 gal) is approximately 43 times the soil pore volume between the base of the crib and the current water table surface. This suggests mobile waste constituents, such as nitrate, could easily have reached the unconfined aquifer. Geologic changes at 18 m (60 ft) and 34 m (110 ft) may be zones of elevated concentrations of less mobile contaminants (e.g., fission products), and may also retain elevated concentrations of mobile contaminants discharged near the end of site operations. Future groundwater impacts from residual mobile constituents, primarily

nitrate, may be possible. However, because the residual contaminant mass is expected to be small, significant future impacts are not expected.

Plutonium (and americium from decay of Pu-241) are expected to be sorbed to soils directly under the crib. Based on data from similar sites, most of the contaminant mass is expected to be between 5.5 and 6.7 m (18 and 22 ft) bgs.

Figure 2-18 presents the contaminant distribution model for the 216-Z-5 Crib.

2.5 Plutonium Fate and Transport

Based on its insolubility and strong sorptive behavior toward the local sediments, plutonium is not very mobile under typical Hanford Site subsurface conditions. However, a 1966 study on the sorption characteristics of plutonium in the PRF High-Salt waste stream confirmed that there was little sorption of plutonium during initial soil/waste interactions for this waste stream (BNWL-CC-649, *Disposal Characteristics of Plutonium and Americium in a High Salt Aqueous Waste*). Based on the results of this 1966 study, management of the PRF High-Salt waste streams was conducted on a specific retention basis (SGW-39385, *Z Plant Complex Waste Streams Discharged to the Soil Column [1949 to 1973]*). This methodology was applied to discharges of the High-Salt PRF waste to the 216-Z-1A Tile Field and the 216-Z-18 Crib but not to previous discharges to the 216-Z-9 Trench (RHO-LD-114). Investigations at the 216-Z-1A Tile Field (RHO-ST-17) in the 1970s and at the 216-Z-9 Trench (DOE/RL-2006-51) in the 2000s have shown that plutonium and americium are present at depths of up to 33.5 m (110 ft) bgs (PNNL-17839, *Plutonium Mobility Studies: 216-Z-9 Trench Sample Analysis Results*). A similar distribution is assumed to be present at the 216-Z-18 Crib.

This "atypical behavior" of plutonium at the three 200-PW-1 OU waste sites that received High-Salt waste has been reviewed and re-evaluated in support of identifying remedial alternatives for these waste sites. Four reports have been completed recently that specifically address the plutonium waste streams and plutonium fate and transport:

- Cantrell and Riley, 2008a, *A Review of Subsurface Behavior of Plutonium and Americium at the 200-PW-1/3/6 Operable Units*
- Cantrell and Riley, 2008b, *Subsurface Behavior of Plutonium and Americium at Non-Hanford Sites and Relevance to Hanford*
- PNNL-17839, 2008, *Plutonium Mobility Studies: 216-Z-9 Trench Sample Analysis Results*
- SGW-39385, 2009, *Z Plant Complex Waste Streams Discharged to the Soil Column (1949 to 1973)*,

The key findings from these reports are first summarized in this section. The findings are then evaluated with regard to the range of remedial alternatives that should be considered for the 200-PW-1 OU waste sites.

Cantrell and Riley, 2008a and SGW-38395 present a conceptual model of plutonium and americium migration at the 200-PW-1 OU waste sites during conditions of both past artificial recharge and current natural recharge. Based on facility processes, the waste sites may be classified into two groups: Low-Salt near-neutral waste and acidic High-Salt waste with organic compounds. The physical/chemical properties of the wastes were more important in controlling the migration of plutonium and americium in the vadose zone than the liquid volume disposed. Characterization of the 216-Z-12 Crib (a Low-Salt waste site) shows there was little migration of plutonium and americium below the point of discharge during artificial recharge conditions despite the huge liquid volume (281 million L [74,240,000 gal]) disposed in

this crib. In contrast, the 216-Z-9 Trench (an acidic High-Salt waste site) only received 4,090,000 L (1,081,000 gal) of liquid wastes, yet contamination at this site is found deeper in the subsurface. The highly acidic waste disposed to the 216-Z-9 Trench moved down through the vadose zone and, over time, consumed the buffering capacity of the underlying sediments. Loss of sediment buffering capacity allowed highly acidic subsurface conditions to prevail and contaminants to migrate deeper as the waste discharge continued for 7 years.

During the past, artificial recharge conditions present during active waste management at the acidic High-Salt waste sites, the volumetric flux rate and presence of silt layers also influenced the depth of plutonium and americium migration, lateral spreading, and selective adsorption of these radionuclides on fine-grained layers. The acid components of the waste liquids that reached the CCU caliche layer appear to have been effectively neutralized and attenuated by the carbonate, since no significant plutonium and americium concentrations are present below the CCU.

Since cessation of artificial recharge about 45 years ago at the acidic High-Salt waste sites, reaction has occurred between plutonium, americium, co-contaminants, degradation products of TBP, and the subsurface sediments (aging process), whose initial physical/chemical properties were altered (loss of buffering capacity) as a result of continuous contact with highly acidic, High-Salt waste and coating of the particles by oily co-contaminants (i.e., lard oil, TBP, and DBBP). Subsequent laboratory characterization, leach testing, and analysis of selected sediment samples collected from the two RI wells (299-W15-46 and 299-W15-48) drilled near the 216-Z-9 Trench helped determine the form and potential for plutonium and americium to be mobilized under present and future natural recharge conditions (PNNL-17839).

In some instances at non-Hanford sites, where plutonium has been found to be unexpectedly mobile, colloidal transport has been invoked as a likely process. Cantrell and Riley (2008b) reviewed the transport behavior of plutonium at several sites where plutonium contamination has occurred and migration has been observed, both within the DOE complex as well as at one U.S. commercial site and one site in Russia. The sources, processes, and pathways of migration of plutonium and americium (when available) at the seven sites reviewed by Cantrell and Riley (2008b) have little in common with the 200-PW-1 OU waste sites. The deep migration found at the acidic High-Salt waste sites is due primarily to the unique features of the waste liquids disposed at these sites that do not occur at any of the other sites considered in their review. Cantrell and Riley (2008b) suggest colloid-facilitated transport has generally been overstated in the site assessments reviewed in their study. This position also is supported by Hanford-specific studies demonstrating colloid-facilitated transport of highly sorptive contaminants in groundwater is minimal (Cantrell and Riley, 2008b; PNNL-17839). Colloid-facilitated transport of highly sorptive contaminants in the vadose zone would be expected to be even less than in saturated groundwater, due to the much higher ratio of surface area to water volume and thin water film thicknesses, which would be conducive to filtration of particles from solution.

The four studies referenced previously provide additional details regarding the past mobility of plutonium and americium at the acidic High-Salt waste sites during waste management that resulted in the atypical distribution of these radionuclides down to the CCU. With regard to the future migration of plutonium and americium, these studies indicated the following:

1. Acidic conditions are required to mobilize plutonium and americium from vadose zone sediments.
2. As pH values approach those of typical Hanford Site groundwater (mildly alkaline, ~ pH 8) plutonium and americium will adsorb to sediments and be effectively sequestered.

3. Colloid-facilitated transport of plutonium and americium in the vadose zone is not a significant process.
4. TBP and its degradation products do not significantly increase the leachability of plutonium and americium.

Of these key findings, No 1 is the most important issue related to the range of remedial alternatives that should be considered for the High-Salt waste sites (i.e., reduce natural infiltration to the subsurface—Chapter 5). It is unlikely that a future scenario could discharge millions of liters (gallons) of acidic water to the High-Salt waste sites in sufficient quantity to mobilize plutonium and americium through the CCU, which effectively neutralized and attenuated the radionuclides during active waste management, and drive these contaminants all the way into the groundwater. In this unlikely scenario, the plutonium and americium would be expected to adsorb to sediments per No. 2 because of the mildly alkaline pH of Hanford Site groundwater.

2.6 Grouping of Waste Sites for Evaluation of Remedial Alternatives

All of the existing data for each of the waste sites in the 200-PW-1, 200-PW-3, and 200-PW-6 OUs were summarized in the RI report and in Section 2.4 of this FS. Review of these data indicates a correlation between waste type and contaminant distribution. In this section, the waste sites are organized into groups that have similar contaminant distributions to facilitate evaluation of viable remedial alternatives.

As discussed in Section 2.5, the mobility of plutonium and americium in the soil column appears to be a function of waste stream acidity. This correlation is substantiated by both characterization data and laboratory evaluation. Acidic conditions are required to mobilize plutonium in the vadose zone. Waste streams that were acidic at the time of discharge became neutralized by contact with the buffering sediments underneath the waste sites and the plutonium adsorbed to the sediments. At both High-Salt and Low-Salt sites, the highest concentrations of plutonium are found immediately below the base of the waste site. At High-Salt sites that received initially acidic liquids, lower concentrations of plutonium are observed to depths of approximately 27 to 30 m (90 to 100 ft) below the base of the waste site. At Low-Salt sites that received initially neutral to basic liquids, lower concentrations of plutonium are observed to depths of approximately 1.5 m (5 ft) below the base of the waste site. This correlation between waste type and plutonium distribution facilitated development of conceptual models for all of the 200-PW-1 and 200-PW-6 OU waste sites, and identification and evaluation of remedial alternatives.

At the 200-PW-3 OU waste sites, existing data show the highest Cs-137 concentrations are within the crib and in soils immediately below the crib. The data also show notable concentrations of Cs-137 at depths up to 15.2 m (50 ft) bgs. However, the concentrations seen between 7.6 and 15.2 m (25 and 50 ft) bgs are orders of magnitude lower than highest concentrations, and suggest Cs-137 mobility during artificial recharge conditions was not extensive, even at sites such as the 216-A-8 Crib that received 1,150,000,000 L (303,800,000 gal) of effluent. This pattern of Cs-137 distribution observed in existing characterization data supported development of conceptual models for all of the 200-PW-3 OU waste sites, and identification and evaluation of remedial alternatives.

Relying on this correlation between waste type and contaminant distribution, the waste sites were grouped by the type of waste they received to support evaluation of remedial alternatives for each waste group. Development and evaluation of remedial alternatives are discussed in this FS with respect to both specific sites and to specific waste groups; Table 2-17 shows the waste groupings.

Table 2-17. Grouping of Waste Sites in the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units

Waste Group	Operable Unit	Site
High-Salt (acidic at time of discharge and containing plutonium)	200-PW-1	216-Z-1A Tile Field
		216-Z-9 Trench
		216-Z-18 Crib
Low-Salt (neutral to basic at time of discharge and containing plutonium)	200-PW-1	216-Z-1&2 Cribs
		216-Z-3 Crib
		216-Z-12 Crib
	200-PW-6	216-Z-5 Crib*
Other	200-PW-6	216-Z-8 French Drain*
		216-Z-10 Injection/Reverse Well
Cs-137 (neutral to basic at time of discharge and containing Cs-137)	200-PW-3	216-A-8 Crib
		216-A-24 Crib
		216-A-7 Crib
		216-A-31 Crib
		UPR-200-E-56 Unplanned Release
Settling Tank	200-PW-1	241-Z-361 Settling Tank
	200-PW-6	241-Z-8 Settling Tank

* Although the 216-2-8 and 216-2-10 sites received Low-Salt waste, they are listed separately under the "Other" instead of the "Low-Salt" group due to the results of the risk assessment.

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3 Development of Remedial Action Objectives and Preliminary Remediation Goals

The remedial action objectives (RAO) for the 200-PW-1, 200-PW-3, and 200-PW-6 OUs are developed in this chapter. The anticipated future land use, the results of the baseline risk assessment, and chemical-specific potential ARARs are analyzed to formulate work statements (RAOs) that specify the media, final COPCs, potential exposure routes, and preliminary remediation goals (PRGs) to protect HHE, and ensure the waste site remedies comply with potential ARARs.

The RAOs are used throughout the FS process, first to aid in identifying technologies, and later as a basis for evaluating their effectiveness. The objectives for protection of HHE are achieved by eliminating, reducing, or controlling the site risks posed through each exposure pathway through treatment, engineering, or institutional controls.

Development of the RAOs and PRGs accounts for current and anticipated future land uses, current and future groundwater use, the conceptual exposure model (CEM) and the specific final COPCs. The potential ARARs also guided development of the RAOs and PRGs. These elements are discussed in the following sections.

3.1 Conceptual Exposure Model

This section summarizes the conceptual exposure model for the 200-PW-1, 200-PW-3, and 200-PW-6 OUs waste sites. A CEM establishes the framework for the BRA by identifying the pathways through which human and ecological receptors on or near the waste sites may come in contact with contaminants in environmental media. Information pertaining to contaminant sources, release mechanisms, transport media, exposure routes, and receptors is used to develop a conceptual understanding of potential risks and exposure pathways. Assumptions concerning potential receptors are based on current and anticipated future use of the land and groundwater.

3.1.1 Land Use

The current and reasonably anticipated future land use of the 200-PW-1, 200-PW-3, and 200-PW-6 OU areas are discussed in the following subsections. Land use forms part of the basis for exposure assessment assumptions and risk characterization conclusions.

3.1.2 Current Land Use

All current land use activities associated with the Central Plateau are industrial in nature. The facilities located in the Central Plateau processed irradiated fuel from the plutonium production reactors in the 100 Area. Most of the facilities directly associated with fuel reprocessing are now inactive and awaiting final disposition. Several waste management facilities operate in the Central Plateau, including permanent waste disposal facilities such as the Environmental Restoration Disposal Facility (ERDF), low-level radioactive waste burial grounds, and RCRA-permitted mixed waste trenches. Construction of high-level waste treatment facilities in the Central Plateau began in 2002. The 200 East Area is the planned disposal location for the vitrified low-activity tank wastes. Non-Hanford Site DOE organizations, and the U.S. Department of the Navy use the 200 East Area TSD units. In addition, U.S. Ecology, Inc. operates a commercial low-level radioactive waste disposal facility on a 40 ha (100 ac) tract of land at the southwest corner of the 200 East Area that is leased to Washington State.

3.1.3 Anticipated Future Land Use

The reasonably anticipated future land use for the Central Plateau is industrial (DOE worker) for at least 50 years and then industrial (DOE or non-DOE worker) thereafter.

The DOE worked for several years with cooperating agencies to define land use goals for the Hanford Site. The cooperating agencies and stakeholders included: the National Park Service; Tribal Nations; the States of Washington and Oregon; local, county, and city governments; economic and business development interests; environmental groups; and agricultural interests. A 1992 report, *The Future for Hanford: Uses and Cleanup: The Final Report of the Hanford Future Site Uses Working Group* (Drummond, 1992) was an early product of the efforts to develop land use assumptions. The report recognized that the Central Plateau would be used to some degree for waste management activities for the foreseeable future. Following the report, DOE issued the *Hanford Comprehensive Land Use Plan Environmental Impact Statement* (HCP EIS; DOE/EIS-0222-F) and associated HCP EIS Record of Decision in 1999 (ROD; 64 FR 61615, *Record of Decision: Hanford Comprehensive Land Use Plan Environmental Impact Statement*). The HCP EIS analyzes the potential environmental impacts of alternative land use plans for the Hanford Site and considers the land use implication of ongoing and proposed activities. Under the preferred land use alternative selected in the HCP EIS ROD, the Central Plateau was designated for industrial use, defined as areas suitable and desirable for TSD of hazardous, dangerous, radioactive, and nonradioactive wastes, as well as related activities (Figure 3-1).

Subsequent to the HCP EIS, the Hanford Advisory Board (HAB) issued HAB Advice No. 132 (HAB 132, "Exposure Scenarios Task Force on the 200 Area"). The HAB acknowledged that some waste would remain in the Central Plateau when cleanup is complete. The goal identified within HAB Advice No. 132 is that the waste area, (currently known as the Inner Area), be as small as possible and not include contaminated areas outside the Central Plateau's fenced areas. HAB Advice No.132 further stated that waste within this area should be stored and managed to make it inaccessible to inadvertent intruding humans and biota, and that DOE should maximize the potential for any beneficial use of the accessible areas. The HAB advised that risk scenarios for the waste management areas should include a reasonable maximum exposure (RME) to a worker/day user and to an intruder.

In response to HAB Advice No. 132, and for the purposes of this FS, the Tri-Parties have agreed to assume the following reasonably anticipated future land use: "industrial" for at least 50 years, which may include TSD of hazardous, dangerous, radioactive, and nonradioactive wastes (02-HAB-0006, "Consensus Advice No. 132: Exposure Scenarios Task Force on the 200 Area"). Following that period, the 200-PW-1, 200-PW-3, and 200-PW-6 OU areas are anticipated to be "industrial." Starting at least 100 years after active waste management (roughly 150 years from present), the potential for inadvertent intrusion into subsurface waste may increase because knowledge of hazards may not be widely held. As long as residual contamination remains above levels that allow for unrestricted use, institutional controls (ICs) will be required.

3.1.4 Regional Land Use

Communities in the region of the Hanford Site consist of the incorporated Cities of Richland, West Richland, Kennewick, and Pasco, and numerous other smaller communities within Benton and Franklin Counties. Section 2.3.6 presents the socioeconomics of the region. No residences are located on the Hanford Site. The inhabited residences nearest to the 200 Area are farmhouses on land approximately 16 km (10 mi) north across the Columbia River. The City of Richland corporate boundary is approximately 27 km (17 mi) to the south (PNNL-6415).

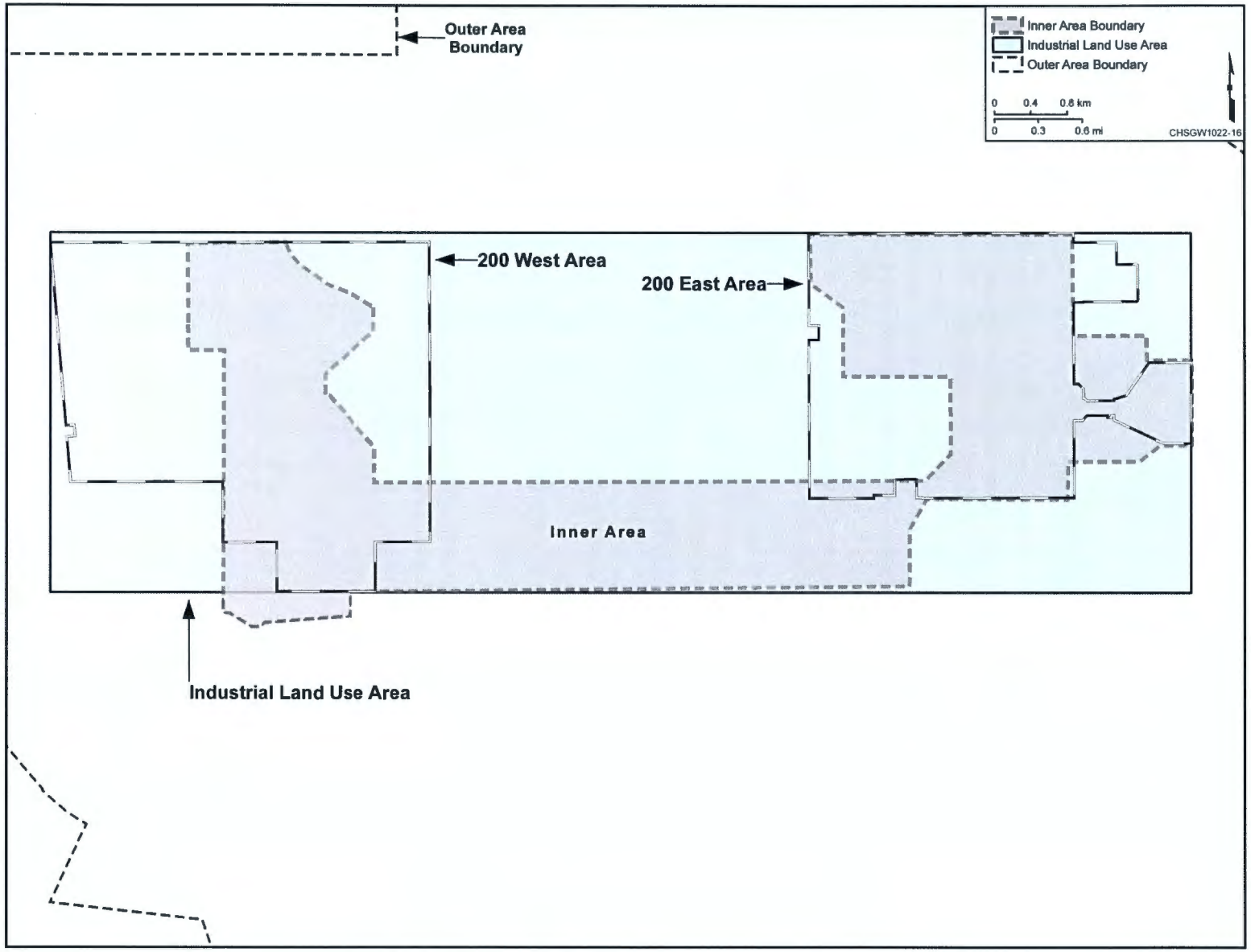

Figure 3-1. Location of the Industrial Land Use Area

3.1.5 Groundwater Use

Groundwater beneath the Central Plateau currently is contaminated and is not withdrawn for beneficial uses. This FS evaluates potential future impacts to groundwater from current vadose zone contaminants at the waste sites, but does not evaluate groundwater remediation underlying these waste sites. Groundwater remediation beneath the Central Plateau will be addressed by the four groundwater OUs (200-ZP-1 and 200-UP-1 OUs in the 200 West Area, and 200-PO-1 and 200-BP-5 OUs in the 200 East Area) and through other site-wide assessments.

3.2 Summary of the Baseline Human Health Risk Assessment

Several contaminant impact assessments typically included as part of the RI phase of the RI/FS (the BRA, the ecological risk assessment, and the fate and transport evaluation for groundwater protection) were completed during the FS phase and are, therefore, included as appendices to this FS report.

Two human health risk assessments were conducted for five of the waste sites located in the 200-PW-1, 200-PW-3, and 200-PW-6 OUs. One is a "baseline" assessment that evaluated a general U.S. population (Appendix A); the second is a separate assessment of risks to Native Americans (Appendix G). The Native American Risk Assessment was performed to provide stakeholders, such as the Tribal Nations, an evaluation of the potential risk based on their traditional lifestyle.

The waste sites evaluated in these assessments are the 216-A-8 Crib (Cesium-137 waste group), 216-Z-1A Tile Field and 216-Z-9 Trench (High-Salt waste group), the 216-Z-8 French Drain, and the 216-Z-10 Injection/Reverse Well (Low-Salt waste group). The evaluation of future risk reduction for various RTD remedial alternatives presented in Appendix F also includes a baseline risk evaluation of the 216-Z-12 Crib (Low-Salt waste group).

The BRA (Appendix A) evaluated exposure routes under an industrial land use scenario (to construction workers) and, for comparison, under an unrestricted land use scenario (to future well drillers and subsistence farmers). The results of the BRA indicate that under an unrestricted land use scenario there could be risks above the CERCLA acceptable risk range at the waste sites evaluated, except at the 216-Z-8 French Drain and the 216-Z-10 Injection/Reverse Well. Because of the similarities between waste sites in each waste site group discussed in Section 2.6, the baseline risk results indicate that to protect HHE, there is a need for remedial action at all of the waste sites (except at the 216-Z-8 French Drain and the 216-Z-10 Injection/Reverse Well).

The 241-Z-361 Settling Tank (settling tank waste group) was not included in the BRA because there have been no documented environmental releases at the tank (DOE/RL-2006-51). However, the kilogram quantity of plutonium in the sludge remaining in this tank presents potential future risks to HHE. This warrants remedial action of the remaining tank contents for the settling tank waste group.

The BRA (Appendix A) and the Native American risk assessment (Appendix G) evaluated both risks from soil at the 200-PW-1, 200-PW-3, and 200-PW-6 OUs and from groundwater at the 200-ZP-1 OU in an integrated manner. Both of these risk assessments were previously included in the FS for the 200-ZP-1 Groundwater OU (DOE/RL-2007-28, *Feasibility Study Report for the 200-ZP-1 Groundwater Operable Unit*).

3.2.1 Selection of Initial Contaminants of Potential Concern

The risk assessment primarily used the available soil data from the RI Report (DOE/RL-2006-51; the "RI Report") for the waste sites, supplemented by some additional historical data reports. Maximum detected concentrations in soil from each of the waste sites were compared to guidance from EPA

(EPA, 2006, *EPA Region 6 Human Health Medium-Specific Screening Levels 2007 and Supplemental Information*). This guidance generally provides more conservative values (i.e., lower concentrations) than cleanup levels calculated using equations published in *Washington Administrative Code* (WAC) 173-340, "Model Toxics Control Act-Cleanup." They were also compared to EPA generic residential screening levels for radionuclides to select COPCs in soil (from EPA/540-R-00-006, *Soil Screening Guidance for Radionuclides: Technical Background Document*, OSWER 9355.4-16).

EPA Region 10 does not calculate their own screening levels, but mandates the use of Region 6 screening levels at EPA projects in Region 10. EPA Region 10 guidance for selecting COPCs was followed in this manner: noncancerous human health screening levels were divided by 10 to account for cumulative toxic effects, but the screening levels for carcinogens were not divided by 10 (EPA 910/R-98-001, *EPA Region 10 Interim Final Guidance: Developing Risk-Based Cleanup Levels at Resource Conservation and Recovery Act Sites in Region 10*). Human health screening levels for carcinogens were not adjusted downward, because the screening levels are based on a 1×10^{-6} cancer risk level, and action generally is not required at a site unless a cancer risk level of 10^{-4} is exceeded.

If the maximum concentration exceeded its screening level, then further evaluation was conducted to determine if the contaminant exceeded a natural background level, and if its frequency of detection and frequency and magnitude of exceedance over screening levels warranted inclusion as a COPC (EPA-520/1-88-020, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, And Ingestion*). Further details on screening methodology and screening results are included in Section A2.2 and Section A2.3 of Appendix A.

Ten (10) contaminants (8 of 107 contaminants at the 216-Z-9 Trench and 2 of 46 contaminants at the 216-A-8 Crib) with maximum concentrations above a screening level were eliminated in the subsequent evaluation process because their health risks would be insignificant. These contaminants are discussed in depth in Appendix A, Section A2.3 and Section A6.1.1. Table 3-1 shows the selected initial COPCs.

Table 3-1. Selected Initial Contaminants of Potential Concern in Soil

Contaminant	216-Z-1A Tile Field	216-Z-8 French Drain	216-Z-9 Trench	216-A-8 Crib
Americium-241	√	√	√	
Cadmium			√	
Carbon-14				√
Carbon tetrachloride/ methylene chloride	√		√	
Cesium-137				√
Europium-152			√	
Manganese			√	
Neptunium-237			√	√
Nickel-63			√	
Plutonium-238		√	√	
Plutonium-239/240	√	√	√	√
Protactinium-231			√	
Radium-226			√	
Radium-228			√	√

Table 3-1. Selected Initial Contaminants of Potential Concern in Soil

Contaminant	216-Z-1A Tile Field	216-Z-8 French Drain	216-Z-9 Trench	216-A-8 Crib
Strontium-90			√	
Technetium-99			√	√
Thallium				√
Thorium-228			√	√
Thorium-230			√	
Source: Appendix A, Table ES-1, of this document				

No contaminants were detected in soil at the 216-Z-10 Injection/Reverse Well in samples collected from three boreholes located within 4.6 m (15 ft) of the well; therefore, no COPCs were selected at this waste site, and it was not evaluated further in the risk assessment.

Carbon tetrachloride and methylene chloride were selected as COPCs in soil at the 216-Z-1A Tile Field, because they are present at concentrations that indicate they pose a potential threat to groundwater in the future. An SVE system is in operation at the 216-Z-1A Tile Field, and VOCs are being collected; therefore, VOCs still present in soil at the 216-Z-1A Tile Field appear to be located deeper than 26 m (85 ft), which is consistent with the conceptual contaminant distribution model for this site discussed in Section 2.4. Because VOCs are present in soil gas and are still being extracted from the subsurface at the 216-Z-1A Tile Field, VOCs are considered COPCs in soil vapor beneath the 216-Z-1A Tile Field, as well as at the 216-Z-9 Trench.

3.2.2 Exposure Assessment

In the risk assessment, exposure pathways were evaluated for a worker scenario and for an unrestricted land use scenario. The worker scenario evaluates risks to adult workers from potential exposures under current and expected future industrial land use conditions, assuming that the existing institutional controls remain in place. The unrestricted land use scenario assumes that potential exposures to a subsistence farming population (adults and children) and a future working population (future well drillers) are hypothetically possible.

For workers, EPA has three general categories: outdoor workers not involved in active soil disturbance (for example, groundskeepers), indoor workers, and construction workers who would have intensive soil contact through active digging (OSWER 9355.4-24, *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*). In this risk assessment, regular workers include both outdoor and indoor workers. Outdoor workers primarily would be exposed only to surface soil over the long exposure durations (25 to 70 years) assumed in the risk assessment equations. Construction workers involved in active soil disturbance (for example, installing an underground utility line or constructing a building) could be exposed to soils at depth for much shorter durations; the EPA default exposure duration for construction workers is 1 year. The industrial worker scenario is used to develop the PRGs (discussed in Section 3.7). The exposure assumptions used for an industrial worker scenario are similar to those used to estimate risk to the regular indoor worker scenario used in the BRA.

The depth horizon for direct contact with subsurface soil in risk assessment is limited to depths up to 4.6 m (15 ft) bgs, because there would be very few instances of construction projects with deeper soil disturbance requirements (OSWER 9355.4-24; WAC 173-340, "Model Toxics Control Act–Cleanup"). At all four of the quantitatively evaluated waste sites, impacts to soil do not begin until more than 1 m

(3 ft) bgs and, in some cases, contamination also below 4.6 m (15 ft)—the depth interval limit for construction workers. Therefore, the direct soil contact pathways (that is, ingestion, inhalation, dermal contact, and external radiation) are only complete for a construction worker. Construction worker exposures are evaluated at each waste site except the 216-Z-9 Trench, where the depth to impacted soil and the concrete slab covering the trench preclude disturbance.

A future subsistence farmer scenario was evaluated where people could come into contact with groundwater and subsurface soil brought to the surface as drill cuttings from drilling a groundwater well. This scenario is assumed to occur 150 years in the future (year 2150). At that time, a future well driller and a future subsistence farming population could come into direct contact with impacted soil brought to the surface. Under the assumption that the impacted soil is spread in a garden, future subsistence farmers also could be exposed via ingestion of home-grown produce. The relationship of the exposure scenarios to the Central Plateau Cleanup Completion Strategy is described in Section 1.1.

Figure 3-2. Inner and Outer Areas of the Central Plateau

3.2.3 Native American Risk Assessment

In addition to the BRA in Appendix A, potential human health risks were also evaluated for certain Native American risk scenarios. These scenarios, like the subsistence farmer scenario in the BRA, are not consistent with the anticipated future land use but are evaluated to assist interested parties in providing input on the remedial alternatives as part of the CERCLA modifying criteria. Native American scenarios developed specifically by the Yakama Nation and the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) were evaluated, and the detailed assessment is included as Appendix G. These scenarios were used by DOE, as received by the two Tribes. For the waste sites with complete exposure pathways, the risks and hazards were above the CERCLA acceptable range. No significant differences in

risks or hazards exist between the Yakama Nation and CTUIR exposure scenarios. The subsistence farmer scenario and the two Native American scenarios are similar in that both assume full-time residence on the waste site and include consumption of food grown on the site. As a result of these similarities, there are no significant differences in risks or hazards between the subsistence farmer and the two Native American exposure scenarios.

3.3 Screening Level Ecological Risk Assessment

A screening level ecological risk assessment (SLERA) was performed for all 16 waste sites in the 200-PW-1, 200-PW-3, and 200-PW-6 OUs following EPA 540-R-97-006, *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments: Interim Final* and the "Terrestrial Ecological Evaluation Procedures" presented in WAC 173-340-7490. Appendix B presents this SLERA. Waste sites were considered with regard to exposure potential for plants and animals. Evaluating potential exposure pathways is one of the primary tasks of the screening level characterization of a site. For an exposure pathway to be complete, a contaminant must be able to travel from the source to ecological receptors and be taken up by the receptors through one or more exposure routes. If an exposure pathway is not complete for a specific contaminant, the exposure pathway does not need to be further evaluated.

A conceptual model of ecological exposure pathways identified the depths to which insects, animals (burrows), and plants (roots) are likely to occur within a biologically active zone in soil. Empirical data on arid adapted species shows that the burrow fraction and percentage of root biomass is heavily weighted to shallow soils. Based on this conceptual model, the working hypothesis for purposes of this SLERA is that biological activity at the 200-PW-1, 200-PW-3, and 200-PW-6 OUs is limited largely to the top 2.44 to 3.05 m (8 to 10 ft). In addition, a depth of 4.6 m (15 ft) reflects the standard point of compliance for protection of ecological receptors as described in WAC 173-340-7490(4)(b).

Under current conditions, stabilized soil covers and institutional controls are in place at the waste sites in the 200-PW-1, 200-PW-3, and 200-PW-6 OUs to discourage biotic access to buried wastes. These include the following controls:

- At least an annual visual site inspection to look for evidence of subsidence or animal intrusion
- A surface radiological survey performed in any areas where radiation is detected, covered with soil, or posted for further action
- Herbicide application performed several times a year to control any vegetation
- Pesticides applied as needed to control ants and termites

However, conditions at 200-PW-1, 200-PW-3, and 200-PW-6 OU waste sites might provide ecological exposure pathways under future conditions, which may require further evaluation as part of the alternatives evaluation. Evaluation of baseline conditions for purposes of determining if remedial alternative may be needed to address ecological risks requires the assumption that the soil covers and institutional controls may not be maintained in the future. Under baseline conditions, is it uncertain that wastes are buried deeper than plants and animals can access at all of these sites. While many of the sites currently do not support habitat, these conditions might not be present in the future.

The results from the comparison of the conceptual ecological exposure model with the waste site information, presented in Appendix B, Chapter B2.0, allows classification of the waste sites in terms of potential ecological exposure pathways likely to be complete and potential ecological exposure pathways

unlikely to be complete. The following waste sites are where complete ecological exposure pathways are likely to be present:

- 216-Z-1&2 Cribs
- 216-Z-12 Crib
- 216-Z-18 Crib
- 2126-Z-1A Tile Field
- 216-Z-3 Crib
- 2126-Z-9 Trench
- 216-A-24 Crib
- 216-A-31 Crib
- 216-A-7 Crib
- 216-A-8 Crib
- UPR-200-E-56
- 2126-Z-5 Crib

The following waste sites are where complete ecological exposure pathways are not likely to be present:

- 241-Z-361 Settling Tank
- 216-Z-10 Reverse Well
- 216-Z-8 French Drain
- 241-Z-8 Settling Tank

Ecological exposures were not characterized as part of this SLERA. Characterization of ecological exposures was not required to help determine if remedial action was needed for these waste sites. For all of the waste sites, concentrations in soil were associated with human health risks, or presented a potential threat to groundwater. It is anticipated that at least one of the remedial alternatives evaluated in the FS (an alternative evaluating RTD of soils to a depth of 4.6 m [15 ft]) for protection of human health or groundwater also would address contaminants potentially posing a threat to ecological receptors. Therefore, for the purposes of the detailed evaluation of remedial alternatives, quantitative assessment of ecological exposures and risks was not done. However, the demonstration that cleanup of contaminated soils will also protect ecological receptors will be addressed as part of remedial design/remedial action. Ecological screening values or PRGs, which can be used for confirmation sampling, will be identified in the Remedial Action Work Plan for the 200-PW-1, 200-PW-3, and 200-PW-6 sites.

3.4 Evaluation of Groundwater Protection

Several volatile and nonvolatile COPCs from the 200-PW-1, 200-PW-3, and 200-PW-6 OU waste sites exceeded groundwater protection screening values. The results of the fate and transport modeling indicate that only a small number of contaminants in the vadose zone beneath the waste sites are present in amounts that could potentially migrate through the soil and impact groundwater above the drinking water level within 1,000 years (see Appendix E). The number and type of COPCs that pose potential threats to groundwater vary with the estimated long-term recharge rate, and are also affected by a number of significant uncertainties and biases associated with the factors that affect the estimated amounts of contamination in the vadose zone. Table 3-2 summarizes the modeling results and associated uncertainties.

Modeling for the 216-A-8 Crib showed that carbon-14 and technetium-99 were determined to pose a potential threat to groundwater for relatively high (22 mm/yr) long-term recharge rates. Only two VOCs (carbon tetrachloride and methylene chloride) and one inorganic contaminant (nitrogen in nitrate+nitrite) were determined to pose potential groundwater threats at the 216-Z-1A, and 216-Z-18 waste sites. At the 216-Z-9 Crib, four VOCs (carbon tetrachloride, methylene chloride, chloroform, and tetrachloroethene), and two non-organic contaminants (nitrogen in nitrate+nitrite, and technetium-99) pose potential threats to groundwater. However, VOCs have unacceptable impacts to groundwater only at relatively high (22 mm/yr) long-term recharge rates (Table 3-2).

Table 3-2. Summary of Model Results on Groundwater Impacts and Associated Uncertainties for Vadose Zone Contaminants at PW-1/3/6 Waste Sites

216-A-8 Crib COPCs	Groundwater Impacts Exceed ARARs?			Sources of Significant Uncertainties in Evaluation					
Long-Term Recharge Rate (mm/yr)		4	22	Source Term (Mass)					
Source Term Length: Waste Site Length		≤1X	≤1X	Sample/ Concentration Bias	Data Sparsity	Contaminated Soil Volume	Data Age	Suspect Data	Contaminant Release/ Retention Terms
Carbon-14			Yes	Yes	Yes	Yes			Yes
Technetium-99			Yes	Yes	Yes	Yes			Yes
	Groundwater Impacts Exceed ARARs?			Sources of Significant Uncertainties in Evaluation					
Long-Term Recharge Rate (mm/yr)	0.5	4	22	Source Term (Mass)					
Source Term Length: Waste Site Length	2X	2X	1X	Sample/ Concentration Bias	Data Sparsity	Contaminated Soil Volume	Data Age	Suspect Data	Contaminant Release/ Retention Terms
216-Z-1A Tile Field COPCs									
Carbon tetrachloride		Yes	Yes	Yes		Yes	Yes		Yes
Methylene chloride	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes
Nitrogen in nitrate+nitrite		Yes	Yes	Yes	Yes				Yes
216-Z-18 Crib COPCs									
Carbon tetrachloride			Yes	Yes		Yes	Yes		Yes
Methylene chloride	Yes	Yes	Yes	Yes		Yes	Yes		Yes
Nitrogen in nitrate+nitrite	Yes	Yes	Yes	Yes	Yes				Yes
216-Z-9 Trench COPCs									
Carbon tetrachloride			Yes	Yes			Yes		Yes
Chloroform			Yes	Yes			Yes		Yes
Methylene chloride			Yes	Yes			Yes		Yes
Tetrachloroethene			Yes	Yes			Yes		Yes
Nitrogen in nitrate+nitrite	Yes	Yes	Yes	Yes	Yes				Yes
Technetium-99	Yes	Yes	Yes	Yes	Yes				Yes

It is notable that the primary risk drivers for the protection of groundwater pathway at the 200-PW-1 and 200-PW-3 waste sites involve contaminants for which the uncertainties in the model results are largest. This is important for remedy selection and implementation decisions because these are reducible uncertainties that can have significant effects on the model results and risk drivers.

The two main sources of uncertainties associated with the PW-1 and PW-3 fate and transport modeling are: (1) the data and factors that affect contaminant source term estimates, that is, contaminant volumes and soil concentrations, and (2) the manner in which contaminant release and retention are modeled (contaminant behavior conceptual and mathematical models). The primary consideration in source term uncertainty is how well the samples and data represent the contaminant conditions in the vadose zone. Sample and data representativeness issues include biases in sampling spatially, temporally, and sampling frequency (for example, sparse data and/or frequency bias). Contaminant release/retention issues concern the consistency between predicted and observed contaminant behaviors.

The model results reported here generally overestimate the groundwater impacts for most contaminants, and especially the VOCs, because of the effects that the uncertainties identified in Table 3-2 have on the magnitude and direction of the model results. For example, VOC concentrations at the PW-1 waste sites are overestimated because the available data on the contaminant levels at the 216-Z-1A and 216-Z-18 waste sites are from 1992-93, prior to the nearly 10 years of operation of the SVE system. Utilization of this aged data can result in a temporal sampling bias imparted to the modeling. Similarly, the data for the 216-Z-9 Crib, from 2004-2006, do not account for the subsequent years of SVE operation. This Data Age uncertainty is significant because the concentrations of the VOC contaminants beneath the 216-Z-9 Crib in 2006 were over three orders of magnitude (one thousand times [1000×]) lower than those in 1992-92 due to the SVE operation, and are projected to be as much as ten times (10×) less in 2010 than in 2006. Thus, the SVE remedy initiated in 1992-93 would appear to be an effective remedy capable of reducing, or which has already reduced, the VOC contaminant mass and concentration levels beneath the PW-1 waste sites to levels of groundwater protection greater than those predicted in the modeling.

The majority of sampling and data uncertainties stem from the estimation of source term amounts from sparse data, and/or data bias resulting from the tendency for preferential sampling of the more contaminated portions of contaminant plumes and associated sampling and measurement frequency bias. The model results indicate that the levels of nitrogen in nitrate+nitrite in the vadose zone pose a potential threat to groundwater at all of the evaluated PW-1 waste sites (Appendix E, Section 5-5). Based on the effect that these uncertainties have on the magnitude and direction of model results used to characterize the risks to groundwater from vadose zone contamination, sampling of nitrate and technetium-99 should be conducted during remediation to confirm contaminant levels. This sampling would provide representative data on contaminant plume geometry, concentration gradients, and contaminant mass. Reducing uncertainties associated with contaminant source term release includes the addition of new scientific information in revisions to the conceptual models and laboratory evaluations of contaminant release from site-specific contaminated vadose zone soils to corroborate the conceptual model revisions. One of the largest potential sources of uncertainty in the modeled impacts to groundwater is due to the processes and rates of contaminant release from, and retention within the vadose zone contaminant source terms. The findings and results of recent studies of contaminated sediments throughout the Hanford Site indicate that the release of contaminants from vadose zone sediments involves coupled equilibrium and kinetically controlled processes from multiple domains and/or contaminant "pools." This type of release behavior represents an important change in the contaminant behavior conceptual model and in the manner in which contaminant release is calculated. It is indicated by the weight of evidence from studies over the past several years on the release of uranium from Hanford vadose zone sediments that such behavior is applicable to most, if not all vadose zone sediments, and is likely applicable to other contaminants (Liu et al., 2004, "Dissolution of Uranyl Microprecipitates from Subsurface Sediments at Hanford Site,

USA;" Liu et al., 2006, "Microscopic Reactive Diffusion of Uranium in the Contaminated Sediments at Hanford, United States;" Qafoku et al., 2005, "Kinetic Desorption and Sorption of U(VI) During Reactive Transport in a Contaminated Hanford Sediment;" PNNL-17031, *A Site Wide Perspective on Uranium Geochemistry at the Hanford Site*; Wellman et al., 2008, "Advective Desorption of Uranium (VI) from Contaminated Hanford Vadose Zone Sediments under Saturated and Unsaturated Conditions;" and PNNL-17674, *Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site*). The release behavior differs from equilibrium-only constructs in that: (1) only a fraction of the contaminant effectively released by faster equilibrium-controlled (desorption) processes; (2) much of the contaminant is released by slower diffusion-limited kinetically-controlled processes; and (3) not all contamination is necessarily released or is "releasable" to recharge waters (effective retention). Together, these factors tend to produce contaminant release mechanisms comparable to the effective release behavior of less mobile contaminants. These findings have significant implications for vadose zone fate and transport modeling and model uncertainties because this type of release behavior results in lower effective contaminant release rates, greater effective retention, and lower maximum leachate concentrations and groundwater impacts than predicted by equilibrium processes alone.

The uncertainties under the category of Contaminated Soil Volume in Table 3-2 refer to overestimation in the amounts of carbon tetrachloride and methylene chloride in the 216-Z-1A and 216-Z-18 Cribs in the source term volumes used to model the base cases with long-term recharge rates of 0.5 and 4.0 mm/yr. This overestimation is the result of using twice the waste site length for the calculation of the contaminated soil volumes rather than the length dimension determined to be appropriate for the VOCs in Appendix E4.3. Although twice the waste site length was found to be appropriate for nitrate (nitrogen), and other nonvolatile contaminants that tend to follow the water plume, the use of larger soil volumes results in overestimation of the contaminant masses and groundwater impacts.

Based on the effect that these uncertainties have on the magnitude and direction of model results used to characterize the risks to groundwater from vadose zone contamination, it would be prudent to consider conducting efforts capable of reducing the uncertainty in the assessment of the risk, as opposed to allocating resources to design and implement remedies in an attempt to mitigate risks that are so uncertain, and may not exist. The efforts with the greatest capability to reduce the uncertainties associated with source term definition is the acquisition of additional characterization data designed to provide representative data on the contaminant plume geometry, concentration gradients, and contaminant mass. Additional post-ROD sampling that includes technetium-99 and nitrogen appears to be warranted to improve the approximations of the distribution of contaminants in the vadose zone, and to improve estimates of the potential threat to groundwater. Efforts most conducive to the reduction of uncertainties associated with contaminant source term release include the inclusion of existing new scientific information in revisions to the conceptual models and the models themselves and laboratory evaluations of contaminant release from site-specific contaminated vadose zone soils to corroborate the conceptual model revisions.

If the results of the sampling and revised risk modeling indicate that the risk posed by the contaminants appears to be valid, then the preferred alternative will be adjusted as necessary to incorporate requisite groundwater protection elements. Because technetium-99 and nitrate have been shown to have a future potential to migrate to groundwater, both constituents will be considered as final COPCs. However, due to the significant uncertainties in the modeling assessment, neither technetium-99 or nitrate will have a PRG established. Instead, as part of the preferred alternative, additional characterization data will be collected at the High-Salt and Low-Salt waste sites to reduce the uncertainties associated with sample bias and the limited data set. This information will be used to perform additional detailed and site-specific modeling evaluations for technetium-99 and nitrate to further assess the potential threat to groundwater indicated by the screening level evaluation.

3.5 Final Contaminants of Potential Concern

In the risk assessment process, contaminants are referred to as initial COPCs until the health risk evaluation is complete. Contaminants that exceed target health goals at the end of the risk evaluation process are referred to as final COPCs. In addition, final COPCs may be selected because of their intrinsic toxicological properties, because they are present in large quantities, or because they are presently in or potentially may move into critical exposure pathways (for example, drinking water supply) (EPA/540/G-89/004). The human health risk assessments are summarized in Section 3.2 and included in Appendices A and G.

Although the baseline risks were calculated for an industrial land use scenario as well as for a subsistence farmer scenario, cleanup goals and decisions generally will be based on industrial land use exposures as being consistent with the current industrial nature of the waste site areas. The area of the waste sites is anticipated to remain industrial with existing institutional controls for the foreseeable future, and groundwater will not be used as a drinking water source as long as institutional controls are functioning and concentrations remain above cleanup levels.

Risk estimates presented in Appendix A (Table ES-2) represent exposure to a current construction worker and identified americium-241, plutonium-239, plutonium-240, and cesium-137 as the primary contributors to risk and exceed the 10^{-4} target cancer risk threshold.

The SLERA that was conducted for all 16 waste sites in the 200-PW-1, 200-PW-3, and 200-PW-6 OUs ruled out further consideration of these sites with regard to ecological risk potential (see Section 3.3 and Appendix B). Therefore, no final COPCs were identified by the ecological risk assessment process.

The 200-ZP-1 Groundwater OU underlies the 200-PW-1 and 200-PW-6 OU waste sites. The 200-PO-1 Groundwater OU underlies the 200-PW-3 OU waste sites. To evaluate future potential threats to the underlying groundwater, a fate and transport evaluation was conducted of the COPCs at these waste sites that may migrate through the vadose zone and impact groundwater in concentrations that exceed MCLs. Section 3.4 summarizes the results of this evaluation (discussed in Appendix E).

The risk assessment and groundwater protection evaluations identified final COPCs for the waste sites that were included in those evaluations. Based on the similarities of the waste sites in each waste site group and the contaminant inventory for each waste site presented in Section 2.4, the final COPCs identified for each waste site group are summarized in Table 3-3 for each risk receptor/exposure pathway.

In addition to the identification of final COPCs, it is important to determine which final COPCs are principal threat contaminants and which are low-level threat contaminants, because these waste sites are characterized as "source material" for contamination in the vadose zone and, in some cases, the groundwater. Source material is defined as material that includes or contains hazardous substances, pollutants, or contaminants that act as a reservoir for migration of contamination to groundwater, surface water, or air, or acts as a source for direct exposure (EPA 540-R-97-013, *Rules of Thumb for Superfund Remedy Selection*). In general, principal threat wastes are those source materials considered to be highly toxic or highly mobile that generally cannot be contained in a reliable manner or would present a significant risk to HHE, should exposure occur. Conversely, low-level threat wastes are those source materials that generally can be reliably contained and that would represent only a low risk in the event of exposure. The Code of Federal Regulations lists five expectations applicable to source materials, principal threat wastes, and low-level threat wastes that were utilized in the development of remedial alternatives presented in Chapter 5 (40 CFR 300.430(a)(1)(iii), "Remedial Investigation/Feasibility Study and Selection of Remedy").

Table 3-3. Summary of Final COPC for the 200-PW-1, 200-PW-3, and 200-PW-6 OUs

	Risk Receptor/Exposure Pathway					
Waste Site Group (Waste Sites)	**Current/Future Worker**	**Future Well Driller**	**Current/Future Subsistence Farmer**	**Future Native American**	**Ecological Receptors**	**Migration to Groundwater Pathway**
High-salt (216-Z-1A, 216-Z-9, 216-Z-18)	Plutonium-239/240, Americium-241[a]	--	Plutonium-239/240, Americium-241, Europium-152, Neptunium-237, Radium-226	Plutonium-239/240, Americium-241, Neptunium-237, Radium-226	--	Carbon Tetrachloride, Methylene Chloride, Technetium-99[b], Nitrate[b]
Low-salt[c] (216-Z-1&2, 216-Z-3, 216-Z-5, 216-Z-12)	--	--	Plutonium-239/240, Americium-241	--	--	Technetium-99,[d] Nitrate[d]
Cesium-137 (216-A-7, 216-A-8, 216-A-24, 216-A-31, UPR-200-E-56)	Cesium-137[b]	--	Cesium-137[d]	Cesium-137	--	--
Settling tanks[e] (241-Z-8, 241-Z-361)	Plutonium-239/240, Americium-241[f]	--	Plutonium-239/240, Americium-241[f]	Plutonium-239/240, Americium-241[f]	--	--
216-Z-8	--	--	--	--	--	--
216-Z-10	--	--	--	--	--	--

Note: -- Indicates no final COPCs were identified in the risk evaluation process.

a. Final COPCs for 216-Z-1A where direct contact risks are possible.

b. As part of the preferred alternative, additional characterization data will be collected to reduce uncertainties associated with the future threat to groundwater.

c. Final COPCs for the Low-Salt waste site group are based on the final COPCs identified for the High-Salt waste site group.

d. Only at 216-A-7, 216-A-8, and UPR-200-E-56 where direct contact risks are possible.

e. Final COPCs for the settling tanks waste site group are based on the final COPCs identified for the High-Salt waste site group.

f. Other potential final COPCs may include metals at 241-Z-361 based on the estimated tank inventory reported in Section 2.4.

Although no "threshold level" of risk has been established to identify principal threat waste, a general rule of thumb is to consider as a principal threat those source materials with toxicity and mobility characteristics that combine to pose a potential risk several orders of magnitude greater than the risk level that is acceptable for the current or reasonably anticipated future land use, given realistic exposure scenarios (EPA 540-R-97-013). Since the current and reasonably anticipated future land use is industrial, the realistic exposure scenario is to industrial workers that could be exposed to contaminants present in soil (see Section 3.2). By applying this general rule of thumb, the final COPCs identified in Table 3-3 that are considered to be principal threat contaminants found:

- Plutonium-239/240, americium-241, and cesium-137 (based on toxicity and baseline risk results).
- Carbon tetrachloride and methylene chloride (based on toxicity and mobility).
- The remaining final COPCs in Table 3-3 (neptunium-237, radium-226, cadmium, manganese, and thallium) are considered to be low-level threat contaminants.
- Nitrate and technetium-99 were retained as potential threats to groundwater.

3.6 Potential Applicable or Relevant and Appropriate Requirements

The ARARs identification process is based on CERCLA guidance (EPA/540/G-89/006, *CERCLA Compliance with Other Laws Manual: Interim Final*, and RI/FS guidance in EPA/540/G-89/004). Section 121 of CERCLA, as amended, requires, in part, that any ARAR standard, requirement, criterion, or limitation promulgated under any federal environmental law, or any more stringent state requirement promulgated pursuant to a state environmental statute, be met (or a waiver justified) for any hazardous substance, pollutant, or contaminant that will remain at the site after completion of remedial action. Section 121(e)(1) specifies CERCLA response actions conducted onsite are subject only to the substantive requirements and standards of other environmental laws and regulations, but not to procedural or administrative requirements. These substantive requirements are the ARARs.

"Applicable" means those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental, state environmental, or facility siting 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 are cleanup standards, standards of control, and other substantive requirements, criteria, or limitations that are promulgated under federal and state environmental, or facility siting laws that, while 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 eight comparison factors in 40 CFR 300.400(g)(2), "General," 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

In addition, potential ARARs were evaluated to determine if they fall into one of three categories: chemical-specific, location-specific, or action-specific. These categories are defined 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.

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, the use of control/ containment equipment, 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-PW-1, 200-PW-3, and 200-PW-6 OUs.

"To be considered" information is nonpromulgated advisories or guidance issued by federal or state governments that is not legally binding and does not have the status of potential ARARs. In some circumstances, "to be considered" information *will* be considered, along with ARARs, in determining the remedial action necessary for protection of HHE. Information to be considered complements the 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 "to be considered" information, may be helpful in defining appropriate remedial action goals.

Potential federal and state ARARs are presented in Appendix C. The chemical-specific ARARs likely to be most relevant and appropriate to remediation of the 200-PW-1, 200-PW-3, and 200-PW-6 OUs are federal regulations that implement the drinking water standards (40 CFR 141, "National Primary Drinking Water Regulations") and WAC 173-340-720(7)(b), "Ground Water Cleanup Standards," used in this FS report for protection of groundwater evaluation.

Action-specific ARARs that could be pertinent to remediation are state solid and dangerous waste regulations (for management of characterization and remediation of wastes and performance standards for waste left in place).

3.6.1 Waste Streams

Regarding waste management activities during remediation, a variety of waste streams may be generated under the remedial alternatives. It is anticipated that most of the waste will be designated as low-level waste. However, quantities of dangerous or mixed waste, PCB-contaminated waste, and asbestos and asbestos containing material also could be generated. The great majority of the waste will be in a solid form.

Waste designated as transuranic will be stored at the Central Waste Complex (CWC), with eventual disposal at a geologic repository such as the Waste Isolation Pilot Plant (WIPP).

The identification, storage, treatment, and disposal of hazardous waste and the hazardous component of mixed waste generated during the remedial action would be subject to the substantive provisions of RCRA. In the State of Washington, RCRA is implemented through WAC 173-303, "Dangerous Waste Regulations," which is an EPA-authorized state RCRA program. The substantive portions of the dangerous waste standards for generation and storage would apply to the management of any dangerous or mixed waste generated during this remedial action. Treatment standards for dangerous or mixed waste that is subject to RCRA land disposal restrictions are specified in WAC 173-303-140, "Land Disposal Restrictions," which incorporates 40 CFR 268, "Land Disposal Restrictions," by reference.

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

Removal and disposal of asbestos and asbestos containing material are regulated under the *Clean Air Act of 1990* and 40 CFR 61, "National Emission Standards for Hazardous Air Pollutants," Subpart M, "National Emission Standard for Asbestos." These regulations provide for special precautions to prevent environmental releases or exposure to personnel of airborne emissions of asbestos fibers during remedial actions. Packaging requirements are identified in 40 CFR 61.52, "Emission Standard." Asbestos and asbestos containing material would be removed, packaged as appropriate, and disposed at ERDF.

Waste designated as low-level waste that meets ERDF waste acceptance criteria is assumed to be disposed at ERDF, which is engineered to meet the appropriate performance standards of 10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste." In addition, waste designated as dangerous or mixed waste would be treated as appropriate to meet land disposal restrictions and ERDF acceptance criteria, and would be disposed at ERDF. ERDF is engineered to meet minimum technical requirements for landfills under WAC 173-303-665, "Landfills." Applicable packaging and pre-transportation requirements for dangerous or mixed waste generated at the 200-PW-1, 200-PW-3, and 200-PW-6 OUs would be identified and implemented before any waste was moved. Alternate disposal locations may be considered when the remedial action occurs, if a suitable and cost-effective location is identified. Any potential alternate disposal location will be evaluated for appropriate performance standards to ensure it is adequately protective of HHE.

Waste designated as PCB remediation waste likely would be disposed at ERDF, depending on whether it is low-level waste and meets the waste acceptance criteria. PCB waste that does not meet ERDF waste

acceptance criteria would be retained at a PCB storage area that meets the requirements for *Toxic Substances Control Act of 1976* storage and would be transported for future treatment and disposal at an appropriate disposal facility.

CERCLA Section 104(d)(4) states that where two or more noncontiguous facilities are reasonably related on the basis of geography, or on the basis of the threat or potential threat to the public health or welfare or the environment, the facilities can be treated as one for purposes of CERCLA response actions. Consistent with this, the 200-PW-1, 200-PW-3, and 200-PW-6 OUs and ERDF are considered to be collectively onsite, and pursuant to Section 121 of CERCLA, response actions conducted in this onsite area are not subject to permitting but must comply with the substantive requirements identified in the ARARs. Since they are collectively onsite, the offsite transportation rule of 40 CFR 300.440, "Procedures for Planning and Implementing Off-Site Response Actions," does not apply.

All alternative actions will be performed in compliance with the waste management ARARs. Waste streams will be evaluated, designated, and managed in compliance with the ARAR requirements. Before disposal, waste will be managed in a protective manner to prevent releases to the environment or unnecessary exposure to personnel.

3.6.2 Airborne Emissions

Response actions have the potential to generate airborne emissions of both radioactive and criteria/ toxic pollutants.

The *Revised Code of Washington* (RCW) 70.94, "Public Health and Safety," "Washington Clean Air Act," requires regulation of radioactive air pollutants. The State implementing regulation WAC 173-480, "Ambient Air Quality Standards and Emission Limits for Radionuclides," sets standards that are as stringent or more so than the federal *Clean Air Act of 1990* and Amendments, and under 40 CFR 61, Subpart H, "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities." EPA's partial delegation of the 40 CFR 61 authority to the State of Washington includes all substantive emission monitoring, abatement, and reporting aspects of the federal regulation. The state standards protect the public by conservatively establishing exposure standards applicable to even the maximally exposed public individual. Under WAC 246-247-030(15), "Radiation Protection—Air Emissions," "Definitions," the maximally exposed individual is any member of the public (real or hypothetical) who abides or resides in an unrestricted area, and may receive the highest total effective dose equivalent from the emission unit(s) under consideration, taking into account all exposure pathways affected by the radioactive air emissions. All combined radionuclide airborne emissions from the DOE Hanford Site facility are not to exceed amounts that would cause an exposure to any member of the public of greater than 10 mrem/yr effective dose equivalent. The state implementing regulation WAC 246-247, which adopts the WAC 173-480 standards and the 40 CFR 61, Subpart H standard, requires verification of compliance with the 10 mrem/yr standard, and would potentially be applicable to the remedial alternatives.

The WAC 246-247 further addresses emission sources emitting radioactive airborne emissions by requiring monitoring of such sources. Such monitoring requires physical measurement of the effluent or ambient air. The substantive provisions of WAC 246-247 that require monitoring of radioactive airborne emissions would be applicable to the remedial alternatives.

The state implementing regulations further address control of radioactive airborne emissions where economically and technologically feasible (WAC 246-247-040[3] and -040[4], "General Standards," and associated definitions). To address the substantive aspect of these requirements, best or reasonably achieved control technology will be addressed by ensuring that applicable emission control technologies

(those successfully operated in similar applications) will be used when economically and technologically feasible (that is, based on cost/benefit). If it is determined that there are substantive aspects of the requirement for control of radioactive airborne emissions, controls will be administered as appropriate using reasonable and effective methods.

Under WAC 173-400, "General Regulations for Air Pollution Sources," and WAC 173-460, "Controls for New Sources of Toxic Air Pollutants," requirements are established for the regulation of emissions of criteria/toxic air pollutants. The primary nonradioactive emissions resulting from these remedial alternatives will be fugitive particulate matter and the treated air from the SVE system and Alternative 2-ISV hood system. In accordance with WAC 173-400-040, "General Standards for Maximum Emissions," reasonable precautions must be taken to: (1) prevent the release of air contaminants associated with fugitive emissions resulting from excavation, materials handling, or other operations; and (2) prevent fugitive dust from becoming airborne from fugitive sources of emissions. The use of treatment technologies as part of the SVE and ISV remedy components that would result in emissions of toxic air pollutants would be subject to the substantive applicable requirements of WAC 173-460. Treatment of some waste encountered during the removal action may be required to meet ERDF or WIPP waste acceptance criteria. In most cases, the type of treatment anticipated would consist of solidification/stabilization techniques, and WAC 173-460 would not be considered an ARAR. If more aggressive treatment is required that would result in the emission of regulated air pollutants, the substantive requirements of WAC 173-400-113(2), "Requirements for New Sources in Attainment or Unclassifiable Areas," and WAC 173-460-060, "Control Technology Requirements," would be evaluated to determine applicability.

Emissions to the air will be minimized during implementation of any of the remedial alternatives through the use of standard industry practices such as the application of water sprays and fixatives. These techniques are considered to be reasonable precautions to control fugitive emissions as required by the regulatory standards.

3.7 Remedial Action Objectives

The RAOs are descriptions of what the remedial action is expected to accomplish (that is, medium-specific or site-specific goals for protecting HHE). They are defined as specifically as possible and usually address the following variables:

- Media of interest (for example, contaminated soil and groundwater)
- Types of contaminants (for example, radionuclides, inorganic, and organic chemicals)
- Potential receptors (for example, humans, animals, and wildlife including plants and invertebrates)
- Possible exposure pathways (for example, external radiation and ingestion)

Levels of residual contaminants may remain following remediation (that is, contaminant levels below cleanup standards or below a range of levels for different exposure routes).

The RAOs provide a basis for evaluating the capability of a specific remediation alternative to achieve compliance with potential ARARs and/or an intended level of risk protection for HHE. Specific RAOs for this FS were defined based on the RME assumptions used in the risk assessment, the risk assessment results, fate and transport of contaminants, and the current and reasonably anticipated future industrial land use for the waste site areas. The RAOs for this FS are further discussed in the following subsections.

3.7.1 Remedial Action Objective 1

RAO 1—Prevent or mitigate unacceptable risk to human health and ecological receptors associated with radiological exposure to wastes or soil contaminated above risk-based criteria by removing the source or eliminating the pathway.

For the purposes of this FS, RAO 1 is satisfied for radiological COPCs when the following objectives are met:

- Prevent or mitigate direct contact exposure to radiological COPCs by industrial workers, in the top 4.6 m (15 ft) of the waste site that would exceed an ELCR of 1 in 10,000.
- Prevent or mitigate direct contact exposure to radiological COPCs by terrestrial receptors (wildlife, plants, and biota) that would exceed a dose rate of 0.1 rad/day.

With respect to this RAO, the principal threat final COPCs include americium-241 and plutonium-239/240 at the 200-PW-1 OU and 200-PW-6 OU waste sites and cesium-137 at the 200-PW-3 OU waste sites. In addition, RAO 1 can be achieved by maintaining at least 4.6 m (15 ft) of separation between the ground surface and contaminated soils exceeding the PRGs for these final COPCs. The PRGs for these final COPCs are listed in Table 3-4.

Table 3-4. Summary of Soil Preliminary Remediation Goals for Industrial Worker Exposures

Risk Driver	PRG, Based on a Target Risk of 1×10^{-4} (pCi/g)
Americium-241	940
Plutonium-239	2,900
Plutonium-240	2,900
Cesium-137	17.7

3.7.2 Remedial Action Objective 2

RAO 2—Prevent or mitigate unacceptable risk to human and ecological receptors associated with nonradiological exposure to wastes or soil contaminated above risk-based criteria by removing the source or eliminating the pathway. With respect to this RAO, there are no principal threat final COPCs.

For purposes of this FS, RAO 2 is satisfied for nonradiological COPCs when the following objectives are met:

- Prevent or mitigate direct contact exposure to nonradiological COPCs in the top 4.6 m (15 ft) of the waste sites that would exceed the WAC 173-340-745(5)(b), Standard Method C industrial soil cleanup based on an ELCR of 1 in 10,000 or an individual noncancerous hazard quotient (HQ) of 1 or a total hazard index (HI) of 1.
- Prevent or mitigate direct contact exposure to nonradiological COPCs by terrestrial receptors (wildlife, plants, and biota), that would exceed an individual ecological noncancerous HQ of 1 or a total ecological HI of 1.

3.7.3 Remedial Action Objective 3

RAO 3–Control the sources of potential groundwater contamination to support the Central Plateau groundwater goal of restoring and protecting the beneficial uses of groundwater, including protecting the Columbia River from adverse impacts.

With respect to this RAO, the principal threat final COPCs are carbon tetrachloride and methylene chloride, technetium-99, and nitrate are potential COPCs. For purposes of this FS, RAO 3 is satisfied for nonradiological COPCs when the following objectives are met:

- Soil concentrations are less than WAC 173-340-747(4) soil concentrations for groundwater protection.
- Fate and transport modeling demonstrates that soil concentrations would not impact groundwater above MCLs.

RAO 3 is satisfied for radiological COPCs when additional fate and transport modeling demonstrates that soil concentrations would not impact groundwater above MCLs.

Protection of the Columbia River from contaminants in these waste sites is achieved through the groundwater protection objective. There is no surface water in the immediate vicinity of the waste sites that requires a separate remedial action objective.

3.8 Preliminary Remediation Goals

PRGs are the more specific statements of the desired endpoint concentrations or risk levels, for each exposure route, that are believed to provide adequate protection of HHE based on the available site information. However, because contaminant levels for technetium-99 and nitrate have not been determined, screening levels will be established. The screening level for nitrate will be based on WAC 173-340-747(3)(a), "Deriving Soil Concentrations for Groundwater Protection." Using the anticipated future land use, the RME assumptions, and the RAOs as a basis, the PRGs are identified for final COPCs and exposure pathways. The RME assumptions are based on acceptable levels of human health and ecological risk, ARARs, "to be considered" guidance, and remediation timeframes. The PRGs will be used to assess the effectiveness of remedial alternatives in meeting the RAOs. The final cleanup levels, not PRGs, are documented in the ROD that selects the remedial alternative for the 200-PW-1, 200-PW-3, and 200-PW-6 OU waste sites.

Typically, PRGs are identified for individual hazardous substances identified as final COPCs. If multiple contaminants are present at a site, the suitability of using individual PRGs as final cleanup values protective of HHE is evaluated based on site-specific information and the potential for contaminant interaction. Meeting these PRGs, the potential ARARs (and by extension, achieving RAOs) can be accomplished by reducing concentrations (or activities) of contaminants to the PRG levels or by eliminating potential exposure pathways/routes.

Contaminant-specific PRGs for soils are presented numerically as concentrations (milligrams per kilogram [mg/kg] or micrograms per kilogram [μg/kg]) or radioactivity (picocuries per gram [pCi/g]). The PRGs for soil final COPCs are developed based on risks to the industrial worker from the 200-PW-1, 200-PW-3, and 200-PW-6 OU waste sites, and on the groundwater protection evaluation as discussed in the following subsections. The expedited response action at the High-Salt waste sites has reduced some of the identified potential risks, and continued remedial actions are expected to prevent future risk.

The PRGs do not need to be calculated for every initial COPC at a waste site. In general, PRGs are calculated in two cases.

1. The contaminant exceeds target health goals.
2. The contaminant does not exceed a target health goal but contributes a significant percentage to total site risks (that is, it is a concern not necessarily alone, but contributes substantially to the site's cumulative risks).

For the purposes of evaluating remedial options and long-term protectiveness in this FS, PRGs have been calculated based on the industrial worker who would encounter long-term exposure to contamination in

soil. The PRG values are based on a 70 kg (150 lb) industrial worker who has 250 days of exposure to shallow zone soils over a 25-year exposure duration. The industrial worker exposure scenario assumes the workplace is the key source of contaminant exposure with 6 hours per day spent indoors and 2 hours per day spent outdoors. Potential routes of exposure to soil include direct external exposure, incidental soil ingestion, and inhalation of dust generated from wind or maintenance activities. An external gamma shielding factor of 0.4, an incidental soil ingestion rate of 50 mg/day, and an inhalation rate of 20 m^3/day (26 yd^3/day) are assumed.

The RESidual RADioactivity (RESRAD) dose model code was used to estimate risks from exposure to shallow zone soil. Preliminary Remediation Goals were calculated using a generic site model that assumes the area of the contaminated zone is 10,000 m^2 (12,000 yd^2), the calculated soil concentrations will be protective for sites with contaminated zone areas smaller than 10,000 m^2 (12,000 yd^2), and very slightly understate risks for sites with areas larger than 10,000 m^2 (12,000 yd^2). ECF-200CW5-10-0075, *Calculation of Preliminary Remediation Goals in Soil for an Industrial Worker Exposure Scenario*, documents the methodology, assumptions and inputs, and results used to calculate the PRGs. Table 3-4 shows the PRG values based on a target risk level of 10^{-4}.

Target cancer risks, rather than radiological doses were used in the PRG calculations based on cleanup levels established for CERCLA sites with radioactive contamination, which state PRGs should be based on the CERCLA target risk range of 10^{-6} to 10^{-4} and not on dose (Luftig and Weinstock, 1997, "Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination," OSWER 9200.4-18). Further, Luftig and Page, 1999, "Distribution of OSWER Radiation Risk Assessment Q&A's Final Guidance," state:

> *...cleanup levels 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.*

The PRGs for each of the individual risk drivers were calculated to be protective of the maximum acceptable cancer risk level of 10^{-4}. However, combined exposures to each of the risk drivers at the PRGs could result in an exceedance of the target health goals. The PRG adjustment downwards to account for cumulative exposures are applied on a location-specific basis because risk drivers may not all be present at the same location and the high concentrations of the risk drivers may not be co-located. Therefore, risk managers consider potential cumulative exposures to the final COPCs when applying the PRGs in the evaluation of the protectiveness of various remedial alternatives.

3.8.1 Industrial Worker Preliminary Remediation Goals

This section describes the development of the preliminary remediation goals for a industrial worker.

3.8.1.1 Radioactive Contaminants

The waste sites in the 200-PW-1, 200-PW-3, and 200-PW-6 OUs are within the boundaries of the industrial land use area described in DOE/EIS-0222-F. The anticipated future land use of the waste site areas is industrial, as described in Section 3.1. Therefore, the PRGs were calculated based on an industrial worker for the soil final COPCs (americium-241, plutonium-239/240, and cesium-137). The PRGs were calculated for these final COPCs that could be present in soil above a depth of 4.6 m (15 ft) and could be protective of the maximum acceptable cancer risk level of 10^{-4} for all three applicable pathways for this exposure scenario (that is, combined exposures to inhalation, ingestion, and external radiation). Discussion of the calculation details for the PRGs is provided in Section 3.8. Table 3-4 shows the PRGs for radioactive final COPCs in soil for the industrial worker.

3.8.1.2 Nonradioactive Contaminants

No nonradioactive final COPCs were identified for the industrial worker from exposure pathways due to inhalation, ingestion, and external radiation. Therefore, no PRGs were developed for nonradioactive contaminants for this exposure scenario.

3.8.2 Considerations Used to Establish Groundwater Preliminary Remediation Goals

The following subsections describe the PRGs for protection of groundwater for human receptors from radioactive and nonradioactive final COPCs.

3.8.2.1 Radioactive Contaminants

Protection of groundwater for the 200-PW-1, 200-PW-3, and 200-PW-6 OU waste sites was evaluated as discussed in Section 3.4 and Appendix E. Based on this assessment, only technetium-99 was determined to have a potential to migrate to groundwater. An interim PRG for technicium-99 based on screening value will be established. As part of the preferred alternative, additional characterization data will be collected at the high-salt and low-salt waste sites to reduce the uncertainties associated with sample bias and the limited data set. This information will be used to perform additional detailed and site-specific modeling evaluations for technetium-99 to further assess the potential threat to groundwater indicated by the screening level evaluation.

3.8.2.2 Nonradioactive Contamination

Because nitrate has been shown to have a future potential to migrate to groundwater, nitrate will be considered a final COPC. An interim PRG for nitrate will be established based on screening value per WAC 173-340-747 (3)(a). As part of the preferred alternative, additional characterization data will be collected at the High-Salt and Low-Salt waste sites to reduce the uncertainties associated with sample bias and the limited data set. This information will be used to perform additional detailed and site-specific modeling evaluations for nitrate to further assess the potential threat to groundwater indicated by the screening level evaluation.

The protection of groundwater evaluation identified carbon tetrachloride as one of the final COPCs at the High-Salt waste sites. Since 1992, an expedited response action using SVE has been conducted at the three High-Salt waste sites. Between April 1991 (when the pilot test was conducted) and September 2009, 79,557 kg (175,391 lb) of carbon tetrachloride have been removed from the vadose zone with the SVE system. Carbon tetrachloride concentrations in the extracted soil vapor have decreased significantly at the three sites during operation of the SVE system. Initial carbon tetrachloride concentrations in extracted soil vapor were approximately 30,000 ppmv at the 216-Z-9 Trench Well Field and 1,500 ppmv at the 216-Z-1A Tile Field/216-Z-18 Crib Well Field. In contrast, concentrations in extracted soil vapor were approximately 14 ppmv at the 216-Z-9 Trench Well Field in September 2009 and 9 ppmv at the 216-Z-1A Tile Field/216-Z-18 Crib Well Field in July 2009. The mass of carbon tetrachloride extracted each year by the SVE system also continues to decline. From 1991 through 1997, approximately 74,851 kg (165,000 lb) were removed. In comparison, from FY 1998 through FY 2009 only 4,706 kg (10,375 lb) were removed (SGW-44694, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Fiscal Year 2009*).

A rebound study was conducted from October 1996 through September 1997 to evaluate the magnitude, extent, and rate of rebound in carbon tetrachloride vapor concentration during the 8-month shut-down period (BHI-01105, *Rebound Study Report for the Carbon Tetrachloride Soil Vapor Extraction Site, Fiscal Year 1997*). The study indicated that the readily available mass has been removed and the availability of the remaining carbon tetrachloride is limited by diffusion from the lower permeability zones and micropores. The maximum carbon tetrachloride rebound concentrations were detected at the

25 to 40 m (82 to 131 ft) depth, suggesting that the remaining carbon tetrachloride at the 216-Z-9 Trench, 216-Z-18 Crib and 216-Z-1a Tile Field is associated with the lower permeability silt layer and the Plio-Pleistocene (Cold Creek) zone. Continued cyclic operation (6 months operation and 6 months of rebound) of the SVE system, since that time indicates the carbon tetrachloride rebound concentrations continue to decline. In most years, the fine-grained layers near the Cold Creek unit exhibited significant rebound; however, in 2008 and 2009, the maximum rebound concentrations were associated with the silt layer at a depth of 20 m (65 ft). This indicates that the fine-grained layers near the source sites remain the most lively source zones for the carbon tetrachloride vapor in the vadose zone.

The continued operation of the SVE system is proposed as a component of the final remedy at the High-Salt waste sites to address VOCs (see Chapter 5). Although the focus of the SVE has been carbon tetrachloride, it should be noted that SVE is an effective remedial alternative for any VOCs that are commingled with the carbon tetrachloride or reside in the same remedial sphere of influence of the SVE system.

The cleanup goal for carbon tetrachloride in the vadose zone is based on achieving a condition where the amount of carbon tetrachloride that could migrate to the groundwater is minimized and therefore protective of the underlying groundwater. The groundwater protection standard for carbon tetrachloride is 3.4 μg/L under the state of Washington "Ground Water Cleanup Standards" (WAC 173-340-720).

The future shutdown criteria for the existing SVE system will be developed to demonstrate that this level of protectiveness is achieved prior to the decision to terminate the operation of the SVE remediation system. Groundwater beneath the site is being remediated under another ROD (ZP-1) and the SVE system will be operated as long as necessary to avoid recontamination of groundwater that has been remediated under the ZP-1 ROD. The performance standard for the SVE system and the quantitative tools for determining compliance with a ROD will be set using federal agency guidelines and procedures. The U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency have outlined processes for assessing closure and transition of SVE systems using several types of analyses, including estimation of contaminant mass flux to groundwater from the vadose zone and the resultant groundwater concentration (EM 1110-1-4001, *Engineering and Design: Soil Vapor Extraction and Bioventing*, and EPA/600/R-01/070, *Development of Recommendations and Methods to Support Assessment of Soil Venting Performance and Closure*). The former document (EM 1110-1-4001) states the following:

> *Shutdown strategies based on the need to protect groundwater are becoming more common. In most cases, the removal of contaminant mass in the vadose zone must continue until the residual mass will not leach to the groundwater in quantities that would cause exceedence of groundwater quality standards. This typically is evaluated through the use of leaching models and the assumption that some mixing of the leachate and groundwater occurs below the water table.*

EPA/600/R-01/070 provides additional recommendations that are consistent with EM 1110-1-4001:

> *Any approach used to assess performance of a venting system should encourage good site characterization, design, and monitoring practices since mass removal can be limited by poor execution of any of these components. Also, any approach used to assess closure of a venting system must link groundwater remediation to vadose zone remediation since the two are interrelated... These components form converging lines of evidence regarding performance and closure.*

For example, volatilization of carbon tetrachloride from the groundwater into the vadose zone may contribute to vapor phase concentrations measured in the vadose zone, and this transfer from the groundwater into the vadose zone may impact the mass flux measurements discussed above.

3.8.2.3 Endpoint Development

As part of the feasibility study, a target vadose zone remediation endpoint was developed using currently available data and applying quantitative methods to relate vadose zone contamination to resultant groundwater concentrations. Field data collection using the SVE system can be used to refine the conceptual model of the site for use in supporting refinement of the remediation endpoint. The target endpoint presented herein is based on the following assumptions: (1) the SVE is only effective in porous soil within the radius of influence (ROI); (2) the Cold Creek Unit has a low permeability and therefore will marginally be influenced by the SVE; (3) the only mechanisms of contaminant movement are through the vapor phase or as a solute in the aqueous phase; and (4) the vadose zone source remains constant over time.

For the 216-Z-9 site, the target endpoint takes into account aquifer thickness, groundwater flow, and lithology as depicted in Oostrom et al., 2010, "Three Dimensional Simulation of Volatile Organic Compound Mass Flux from the Vadose Zone to Groundwater."

In this approach, mass flux is a measurement of contaminant mass movement over time. As shown by Truex et al., 2009, "Estimating Persistent Mass Flux of Volatile Contaminants from the Vadose Zone to Ground Water," under site arid conditions, the vapor phase contaminant mass flux to the groundwater is much greater than the mass flux due to aqueous phase movement. Oostrom et al. (2010) demonstrated that diffusion is the dominant vapor transport process in the vadose zone under Hanford conditions. Through diffusion proportions, the measured vadose zone contaminant source mass flux can be used to estimate the contaminant mass flux across the water table and into the groundwater. The mass flux across the water table can be described in units of mass per time (for example, mg/day). The resultant groundwater concentration can be computed from mixing of the vadose zone contaminant with the flowing groundwater. The mixing calculation is the rate of contaminant mass moving across the water table (mg/day) divided by the groundwater flow rate (liters/day), and provides the resulting groundwater concentration as mass per volume (for example, mg/L). The metric for the vadose zone remediation endpoint is the mass flux from the vadose zone source that results in a groundwater concentration equal to or lower than the groundwater remediation goal. As reported in EPA et al., 2008, *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton County, Washington*, the groundwater remediation goal for carbon tetrachloride contaminant concentration is 3.4 µg/L. Should the measured mass flux consistently rise above the endpoint mass flux established, the need for a contingency action would be triggered. The endpoint mass flux cannot be used in the near term until current groundwater concentrations are significantly decreased.

A refined estimate of the endpoint mass flux can be made using the three-dimensional modeling approach described by Oostrom et al., 2010, and a resultant groundwater concentration from the endpoint mass flux described by Truex et al., 2009, with consideration of the potential combined commingled impact to the groundwater and will be included in the RD/RA Work Plan and related RD/RA documentation along with additional data collected that supports refinement of the endpoint value.

3.8.3 Preliminary Remediation Goals for Protection of Ecological Resources

The SLERA that was conducted for all 16 waste sites in the 200-PW-1, 200-PW-3, and 200-PW-6 OUs ruled out further consideration of these sites with regard to ecological risk potential (see Section 3.3 and Appendix B). Therefore, no PRGs were developed for protection of ecological resources.

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4 Identification and Screening of Remedial Technologies

A primary objective of this FS Report is to identify viable remedial technologies and process options that meet the RAOs for the 200-PW-1, 200-PW-3, and 200-PW-6 OUs, and combine them into a range of remedial alternatives for further evaluation. This chapter of the FS Report discusses the remedial technology selection process.

The potential remedial technologies are identified based on their capability to mitigate the identified risks or achieve compliance with potential ARARs for the remedial action. Those selected for evaluation are then screened with respect to their implementability, effectiveness, and relative cost in accordance with EPA guidance (OSWER Directive 9355.3-01FS3, *The Feasibility Study: Development and Screening of Remedial Action Alternatives*, Fact Sheet; EPA/540/G-89/004); and the NCP (40 CFR 300.430[e]).

CERCLA requires development and evaluation of a range of responses, including a No Action Alternative, to ensure an appropriate remedy is identified and selected. The selected final remedy must protect HHE and must comply with ARARs. The technology screening process consists of the following series of 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 options for each technology type

Following the technology screening, the representative process options are assembled into remedial alternatives (Chapter 5) that are evaluated further in the detailed and comparative analyses of alternatives (Chapters 6 and 7, respectively).

4.1 General Response Actions

The GRAs describe those actions that will satisfy the RAOs. Chapter 3 identifies the RAOs for the 200-PW-1, 200-PW-3, and 200-PW-6 OUs. Briefly, the GRAs are intended to accomplish the following objectives:

- Reduce risks to human health from final COPCs present in contaminated soil for the representative industrial worker scenario to within the range of 10^{-4} to 10^{-6} for excess lifetime cancer risk (ELCR), or to an HI of 1 or less for non-cancer effects
- Prevent migration of final COPCs to groundwater in concentrations that exceed federal or state drinking water standards

The following five GRAs were selected that will satisfy the RAOs:

- No action—baseline GRA required by CERCLA
- Institutional controls—to mitigate risk by controlling access to, and use of, the contaminated waste sites
- Containment—to mitigate risks by physically inhibiting direct contact with contaminants, and by controlling migration of contaminants

- Removal of contaminated media, treatment as necessary, and disposal—to mitigate risks by excavating contaminated media, treating it as necessary, and disposing of it in an appropriate onsite or offsite disposal facility
- In situ treatment of contaminated media—to mitigate risks by treating contaminated media in place to reduce contaminant toxicity, mobility, or volume

4.2 Technologies

The GRA and potential implementing technologies were first addressed in the Implementation Plan (DOE/RL-98-28). That document provided an initial framework to guide the RIs in the 200 Area and documented a preliminary screening of remedial technologies appropriate to the contaminants, media, and conditions found in the arid environment in the 200 Area.

This section discusses the subsequent evaluation of remedial technologies, which focused more specifically on the final COPCs and conditions encountered at the 200-PW-1, 200-PW-3, and 200-PW-6 OU waste sites, and the associated risks. In accordance with CERCLA guidance, technologies were evaluated based on their effectiveness, implementability, and relative cost.

4.2.1 Screening of Remedial Technologies

The potential remedial technologies were reviewed based on the contaminant distribution models for each waste site presented in Section 2.4. A search was also conducted to identify new and emerging remedial technologies. A variety of remedial technology criteria were provided in HAB 207 "Criteria for Development of the Proposed Plan for 200-PW-1, -3, and -6." The list of technologies retained through these activities and considerations was subjected to a review that considered the results of the BRA (Section 3.2). The technologies were screened based on their effectiveness, implementability, and relative cost. Table 4-1 summarizes the technology screening results. Table 4-2 lists the retained remedial technologies and associated process options, which are discussed in the following sections.

An earlier study (DOE/RL-2003-52, *Tank 241-Z-361 Engineering Evaluation/Cost Analysis*) assessed sludge removal and stabilization technologies for the 241-Z-361 Settling Tank. The technologies recommended in that document were reviewed to consider any changes in implementability and relative cost and are discussed in Section 4.2.2.

4.2.2 Summary of Remedial Technologies and Process Options

Subsequent subsections describe the remedial technologies, grouped by GRA. Although the no action response, institutional controls, and MNA are not technologies, they are included because they constitute potential general response actions.

4.2.2.1 No Action

The NCP (40 CFR 300) requires that a No Action Alternative be evaluated as a baseline for comparison with other alternatives. The No Action Alternative would leave a waste site in its current state, with no need for additional remedial activities, monitoring, or access restrictions. The No Action Alternative does not preclude non-remedial activities, and OSWER Directive 9355.3-01FS3 specifically allows environmental monitoring as part of a no action response. At the Hanford Site, this would be implemented as a component of the sitewide environmental monitoring program, which has administrative controls that would trigger appropriate responses if monitoring indicated unsafe conditions.

Table 4-1. 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	Warning Notices	Signs	IMRO	Effectiveness: Does not reduce contamination. Effective in supporting mitigation of potential for direct contact with residual contaminants if consistently well implemented for duration of risk. Prevents disturbance of ongoing remedies. Implementability: Easy to implement, requires ongoing surveillance and maintenance. Cost: Low.	Retained
	Entry Restrictions	Procedural Requirements for Access Warning Signs Fencing	IMRO		
	Land Use Management	Land Use and Real Property Controls (e.g., Deed Restrictions) Excavation Permits	IMRO	Effectiveness: Does not reduce contamination. Effective in mitigating potential for direct contact with residual contaminants if consistently well implemented for duration of 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	IMRO	Effectiveness: Ensures no improper use of groundwater. Implementability: Easily implemented, but requires ongoing action. Cost: Low.	Retained
	Waste Site Information Management	Administrative	IMRO	Effectiveness: Ensures access to information on the location and nature of contamination. Implementability: Readily implemented, but requires ongoing action. Cost: Low.	Retained
Containment	Surface Barriers	Arid Climate Engineered Cap	IMRO	Effectiveness: Effective, but requires surveillance and maintenance for duration of risk. Those with capillary breaks are susceptible to damage by subsidence and seismic activity. Monofill barrier is self-healing. All engineered surface caps are susceptible to weathering. Implementability: Easily implemented, although design and construction complexity varies greatly between the two options (monofill and capillary break ET barriers). Cost: Moderate capital and maintenance costs for both ET barriers; monofill barrier lower cost because design, construction, and maintenance are less complex.	Retained
	Intrusion Barriers	Controlled Density Fill	IMRO	Effectiveness: Effective. Implementability: Easily implemented. Cost: Low to moderate capital cost (depending on material).	Retained
		Physical Barrier	IMRO	Effectiveness: Effective. Implementability: Easily implemented. Cost: Moderate capital cost (depending on materials used).	Retained
	Vertical Barriers	Vertical Barriers	IMRO	Effectiveness: Not effective in addressing the risk scenarios identified to date. They are considered here as ancillary technologies to support the application of surface barrier technology. Implementability: Implementable. Cost: Cost varies with depth, low to moderate capital cost.	Retained as supplementary technology to support surface barriers
		Grout Curtains	IMRO	Effectiveness: Effective. 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.	Retained as supplementary technology
	Vertical Barriers	Slurry Walls (Cement-Bentonite Slurry)	IMRO	Effectiveness: Effective for shallow application to contain lateral movement of contaminants and infiltrating water and as a barrier to intrusion. Application envisioned would be as a supplement to engineered surface barriers, when lateral extension of surface barrier is constrained. Durability may be an issue if contaminants are very long lived. Implementability: Easily implemented but walls constructed in contaminated soil likely to have increased waste handling and equipment decontamination issues. Cost: Low to moderate capital cost (dependent on depth and thickness of wall and need for specialized slurry formulations). No maintenance costs.	Retained as supplementary technology to support surface barriers

Table 4-1. Summary of Technology Screening Results

General Response Action	Technology Type	Process Option	Target Contaminants	Evaluation	Results
Containment (continued)	Subsurface Barriers	Dry Air Barrier (Soil Desiccation)	IMRO	Effectiveness: Effective in controlling vertical movement of moisture and contaminants through the more permeable intervals of the soil column. Technology also will support localized control of vapor transport pathways. Implementability: Implementable. Complexities in geology, size, and depth of target area, number of wells, and emission controls are factors affecting ease of implementation. Use of existing SVE system components and wells may simplify implementation. Dry air barriers can be operated in a pulsed manner similar to SVE rebound to minimize long-term operation costs (tens to hundreds of years). Cost: Capital cost is moderate, varying with the number of wells, the size, and depth of the target area(s), the design capacity of the system, and whether any treatment is needed for the system air emissions or effluent. Costs can be reduced if coupled with existing SVE system components and infrastructure. O&M costs are moderate, varying with size of system and waste streams generated, frequency of operation, and full duration of implementation.	Retained
Removal	Excavation	Conventional Excavation	IMRO	Effectiveness: Effective. Implementability: Readily implemented, although control and containment of airborne radionuclides may add to the complexity. Cost: Moderate capital costs, moderate O&M costs; control and containment of airborne radionuclides may increase cost substantially.	Retained
		Remote Excavation	IMRO	Effectiveness: Effective for excavation when access restrictions or worker health and safety concerns preclude conventional excavation. Implementability: Readily implemented. Difficulty increases with depth and with increased levels of risk. Specialized equipment and trained personnel expected to be readily available. Cost: Moderate capital costs, moderate to high O&M costs.	Retained
		Soil Vacuum Excavation	IMR	Effectiveness: Effective for precise removal of soils. Implementability: Readily implemented. Equipment and trained personnel expected to be readily available. Emission controls are required. Cost: Moderate capital and O&M costs.	Retained as supplementary technology
	Deep Excavation	Barrier Walls	IMRO	Effectiveness: Effective if adjacent structures limit surface area available for excavation. Implementability: More difficult to implement than conventional excavation—need specialty contractors and equipment. Use of mud or slurries in contaminated soils increases waste handling and equipment decontamination issues. Cost: High capital costs that increase with depth.	Not retained
		Piles	IMRO	Effectiveness: Effective if adjacent structures limit surface area available for excavation. Implementability: More difficult to implement than conventional excavation—need specialty contractors and equipment. Use of mud or slurries in contaminated soils increases waste handling and equipment decontamination issues. Soldier piles easiest to implement of all pile technologies. Cost: High capital costs that increase with depth.	Soldier piles retained for waste sites where surface area of excavation must be limited
		Ground Improvement	IMRO	Effectiveness: Effective if adjacent structures limit surface area available for excavation. Implementability: Grouting is implementable, but can be difficult to verify continuity of injection zone. Soil nailing is not implementable in unconsolidated Hanford formation soils. Cost: Cost varies with depth and thickness of grout injection zone. Low to moderate capital cost.	Grouting retained as supplementary technology

Table 4-1. Summary of Technology Screening Results

General Response Action	Technology Type	Process Option	Target Contaminants	Evaluation	Results
Disposal	Landfill Disposal	Onsite Landfill (ERDF)	IMRO	Currently the only path forward for onsite disposal of hazardous waste, low-level waste, and mixed low-level waste generated by CERCLA activities. Effectiveness: Effective. Implementability: Readily implemented. Cost: Moderate.	Retained
		Offsite Landfill	IMO/IMRO	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 (WIPP)	IMRO (as transuranic waste)	Effectiveness: Effective. Excavation may generate suspect transuranic wastes. Currently the WIPP is the only path forward for disposal of transuranic wastes. 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.	Retained
Ex Situ Treatment (assumes excavation)	Thermal Treatment	Thermal Desorption	O	Effectiveness: An EPA presumptive remedy for VOCs, but provides limited benefit because the VOCs are collocated with transuranics, so the soil will still be designated as a radioactive waste. Soils expected to meet disposal facility acceptance criteria without treatment. Implementability: Difficult to implement because of risks posed by collocated radionuclides. Equipment and personnel are readily available. Concerns with the potential for radiological contamination of the equipment may increase costs or preclude use of certain vendors. Cost: Competitive costs for removal of VOCs when used for large soil volumes (greater than 750 m^3 [1,000 yd^3]). Protection of workers and environment from the radiological risks will increase costs substantially.	Not retained
		Ex situ Vitrification	IMRO	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
	Physical/ Chemical Treatment	Vapor Extraction	O	Effectiveness: Effective for removing volatile organics. Most effective with coarse-grained materials. Fine-grained soils may need to be disaggregated to make contaminants more accessible. Implementability: Readily implemented. Emissions and condensate must be controlled and treated as secondary waste streams. Cost: Low capital and O&M costs. May be able to use existing SVE infrastructure and equipment to support implementation, providing significant cost savings.	Retained
		Soil Washing	IMRO	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 minimize waste volume and related management and disposal costs. Implementability: Readily implemented. Cost: Low.	Retained
		Solidification/ Stabilization	IMR (Sludge)	Effectiveness: Effective. Implementability: Readily implemented, although as-low-as-reasonably-achievable concerns may add complexities. Cost: Moderate.	Retained specifically for use on the 241-Z-361 and 241-Z-8 Settling Tanks

Table 4-1. Summary of Technology Screening Results

General Response Action	Technology Type	Process Option	Target Contaminants	Evaluation	Results
In Situ Treatment	Chemical/ Physical Treatment	SVE	O	Effectiveness: Effective, although it can be slow to achieve PRGs if VOCs are in fine-grained soils. Implementability: Readily implemented, but does require design work and optimization. Emissions and effluent are regulated. Cost: Moderate to high capital costs; moderate to high O&M cost depending on size, duration of operation, and volume of waste streams.	Retained
		Passive SVE	O	Effectiveness: Minimally effective as a primary technology for VOCs in fine-grained material, although useful as supplementary technology. Slow in achieving goals. Implementability: Readily implemented. Intended here as a supplementary technology, making use of existing wells. Cost: Low capital and O&M costs as implemented here.	Retained as supplementary technology
		Soil Mixing	IMR	Effectiveness: Not effective for deeper contamination or with high levels of organic contamination. Implementability: Subsurface structures and Hanford formation sediments limit implementation. Cost: Low to moderate.	Not retained
	Thermal Treatment	Electrical Resistance Heating with SVE	O	Effectiveness: Effective; preferentially heats fine-grained soils. Rate of volatilization increases in proportion to the induced increase in temperature. Supports increased VOC removal rate, which supports more rapid attainment of remedial goals. Implementability: Moderately difficult to implement, depending on the size, depth, and configuration of the target area, and the availability of infrastructure to support the power demands. Cost: Moderate to high.	Retained
		ISV	IMRO	Effectiveness: Effective in mitigating long-term risk. Implementability: Moderate level of technical difficulty. Infrastructure requirements. May need treatability studies. Cost: Moderate to high.	Retained
Natural Attenuation (not a technology or treatment process)		Monitored Natural Attenuation	RO	Effectiveness: Effective for Cs-137, reducing contaminant mass by 50 percent roughly every 30 years (radiological decay). Effectiveness for carbon tetrachloride under evaluation by others, but carried forward as potentially viable. Assume 200 years to reduce carbon tetrachloride mass by 50 percent. Implementability: Readily implemented, requiring only monitoring for verifying progress toward PRGs. Cost: Low.	Retained

I = inorganic, nonmetallic contaminants
M = heavy metals contaminants
O = organic contaminants
R = radionuclide contaminants
VOC = volatile organic compound

Table 4-2. Retained Remedial Technologies

General Response Action	Technology Type	Remediation Technology	Target Contaminants
No Action	No Action	No Action	IMRO
Institutional Controls	Land Use Management	Deed Restrictions	IMRO
		Deed Notices	IMRO
		Declaration of Environmental Restrictions	IMRO
		Information Distribution	IMRO
		Restrictive Covenants	IMRO
		Federal/State/County/Local Registries	IMRO
	Warning Notices and Entry Restrictions	Signs/Fences	IMRO
		Entry Control	IMRO
	Monitoring	Surveillance/Monitoring	IMRO
Containment	Surface Barriers	Monofill and Capillary ET Caps	IMRO
	Intrusion Barriers	Physical Barrier	IMRO
	Vertical Barriers	Slurry Walls and Grout Curtains	IMRO
	Dry Air Barrier	Soil Desiccation	IMRO
Removal	Excavation	Conventional Excavation	IMRO
		Remote Excavation	IMRO
		Soil Vacuum Excavation	IMR
	Deep Excavation	Soldier Piles	IMRO
		Grouting	IMRO
Disposal	Landfill Disposal	Onsite Landfill	IMRO
		Offsite Repository	IMRO (as transuranic)
Ex Situ Treatment (assumes excavation)	Physical/ Chemical Treatment	Vapor Extraction	O
		Automated Segregation Based on Radioactivity	R
		Solidification/ Stabilization	IMR
In Situ Treatment	Chemical/ Physical Treatment	SVE	O
		Passive SVE	O
	Thermal Treatment	Thermally Enhanced SVE	O
		ISV	IMRO
Attenuation Processes	Natural Attenuation*	MNA	RO

* Not a treatment process.
ET = evapotranspiration
I = inorganic, nonmetallic contaminants
M = heavy metal contaminants
R = radionuclide contaminants
O = organic contaminants

4.2.2.2 Institutional Controls

Institutional controls are restrictions imposed on land use to prevent or reduce exposure to hazardous wastes or hazardous constituents. They are intended to administratively and institutionally separate the public from levels of contamination that exceed acceptable health risks. Restrictions may include land use restrictions, natural resource use restrictions, well drilling restriction areas, deed restrictions, deed notices, and declaration of environmental restrictions, access controls, monitoring requirements, site posting requirements, information distribution, and 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 institutional control to meet a performance standard must include a mechanism to ensure its maintenance for protectiveness over time, or until exposure to hazardous substances would not result in exceedance of health risks. Only certain types of institutional controls have such mechanisms (e.g., easements, zoning, and use restrictions). Institutional controls that do not have these mechanisms require other alternatives for maintaining protectiveness.

Operations at the Hanford Site are expected to terminate in approximately 2050, and active institutional controls are assumed for approximately another 100 years following the termination of operations. However, because the 200-PW-1 and 200-PW-6 waste sites contain radionuclides that have very long half-lives (24,000+ years for Pu-239, 6,500+ years for Pu-240, and 432 years for Am-241), any remedial alternatives that result in residual contamination remaining on the Hanford Site that could result in exceedance of health risks will require institutional controls to prevent exposures. The cost estimates of some remedial alternatives for these waste sites presented in Chapters 6 and 7 include the costs of maintaining institutional controls for 1,000 years.

4.2.2.3 Containment

This section discusses technologies that mitigate risk by blocking potential exposure pathways, including technologies that prevent direct contact with contaminants or that control migration of contaminants. The discussion includes arid climate engineered surface barriers, intrusion barriers, vertical subsurface barriers, and dry air (soil desiccation) barriers.

Arid Climate Engineered Surface Barrier

Engineered surface barriers are constructed over waste sites to control the amount of precipitation that infiltrates into contaminated media, thereby reducing the potential for migration of contaminants to groundwater. They also may serve as barriers to intrusion by potential human and ecological receptors. To remain 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 (O&M) programs that include surveillance and monitoring, to ensure their physical integrity and functionality. Surface barriers can address all contaminants at all of the waste sites by controlling infiltration of precipitation from the ground surface into the contaminated media. Several types of barriers were considered that incorporate an evapotranspiration (ET) feature into their design, including a Hanford Site-like barrier design and 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-PW-1, 200-PW-3, and 200-PW-6 OUs. 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 may be placed over waste sites to provide a stable foundation for barrier construction. The uppermost portion of the barrier typically includes materials (e.g., pea gravel) to control 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 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, net recharge is close to zero (PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*).

The Hanford-type barrier was screened out early in this evaluation. Relative to the other technologies, the complexities in design and construction place it last with respect to implementability and cost.

The monofill and capillary break ET barriers are a type of modified RCRA barrier. For the purposes of the FS, the monofill and capillary break barriers 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 biobarrier. 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 control 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 4-1). The thickness of the barrier has been designed to eliminate downward flux from precipitation. The barrier sits on top of 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.

Relative 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, which are important considerations 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 sideslope requirements to ensure slope stability and barrier integrity. Generally, monofill ET barriers, because of their relatively greater thickness, will have a larger footprint than thinner, multilayer barriers, so they may be more likely to encroach on adjacent sites, facilities, or infrastructure.

Capillary Evapotranspiration Barriers

For this FS report, a capillary ET barrier consists of a fine-grained soil layer placed on top of a relatively coarse-grained soil layer, as depicted in Figure 4-2. The distinct textural interface between the two soil layers creates a capillary break, which functionally increases the water-holding capacity of the fine-grained soil, and produces relatively low moisture conditions in the coarse-grained soil. Alternately, the barrier can incorporate a synthetic membrane as the structural feature that inhibits vertical flow of infiltrating water. The barrier would be constructed on top of a layer of engineered fill material, and the upper portion of the top soil layer will incorporate pea gravel to control erosion.

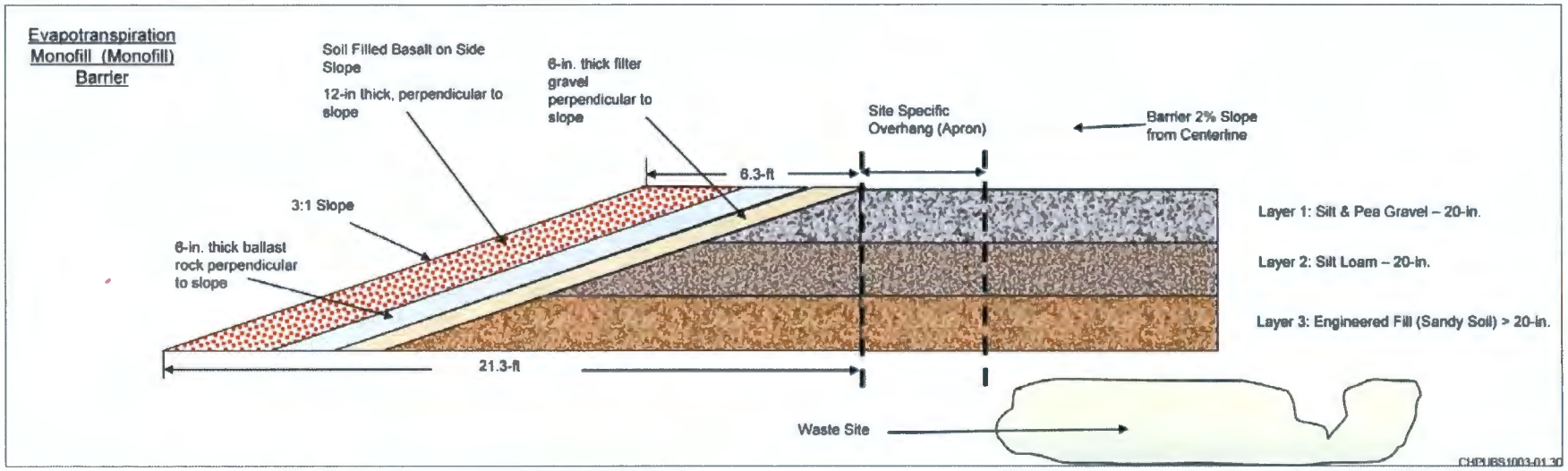

Figure 4-1. Conceptual Schematic: Perimeter of a Monofill Evapotranspiration Barrier

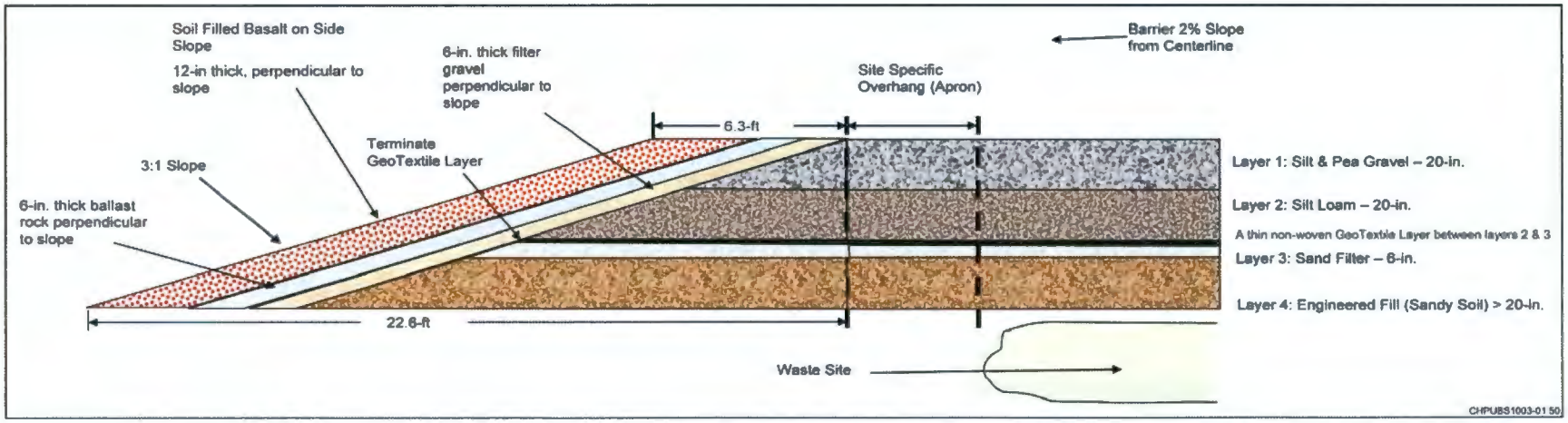

Figure 4-2. Conceptual Schematic: Perimeter of a Capillary Evapotranspiration Barrier

By increasing the water-holding capacity of the fine-grained soil, it is possible to achieve the same functional requirements with a thinner, fine-grained soil layer (relative to the thickness of the soil layer in a comparable monofill ET barrier). More of the infiltrated water is held within the near surface evaporative regime and within the root zone of the more shallow-rooted plants. In addition, the low-moisture conditions in the coarse-grained soil may limit biointrusion and maximize root retention in the fine-grained layer.

The structural interface between the fine- and coarse-grained soil layers is a critical functional component of capillary ET barriers. This interface can be compromised locally by differential settling, subsidence, and seismic events; these issues must be taken into consideration during design and construction. Another potential issue with capillary and monofill barriers is water flow between the two contrasting soil layers and the resulting potential for moisture discharges near or at the toe slope of the barrier. Some form of water routing (e.g., subsurface French drains) may need to be incorporated into the final barrier design.

Capillary ET barriers are thinner than comparable monofill ET barriers and will have a smaller footprint, so they are less likely to encroach on adjacent sites, facilities, and infrastructure.

Intrusion Barrier

An intrusion barrier inhibits direct contact with residual contaminated media and helps mitigate radiation exposures to an inadvertent intruder. Protection can be achieved by establishing and maintaining sufficient depth of cover or by incorporating structural components that provide an equivalent level of protection. Two types of intrusion barriers are considered in this document. The simplest is controlled density fill (CDF). The second, referred to here as a physical barrier, is more robust. Intrusion barriers are considered for sites where shallow contaminants pose a direct contact risk to potential human and ecological receptors, and existing cover materials or an infiltration barrier may not be sufficient to mitigate the targeted risk.

Controlled Density Fill

Typically, CDF is a blend of cement, fly ash, sand, and water, usually employed as a low-strength, flowable backfilling material. Because it is flowable, self-leveling, and self-compacting, it can be deployed in situations where physical access restrictions may preclude other backfilling options. Formulation can be varied to modify several parameters, including compressive strength and excavatability (difficulty encountered when excavating or drilling into the material). Like cement, it also can be dyed, an application that is employed as a visual warning in CDF that is used to backfill underground utility trenches. CDF can be formulated to make intrusion difficult, but not impossible. Application of CDF as an intrusion barrier would also rely on its anomalous appearance (with respect to typical soils in the area) to alert an inadvertent intruder. A reasonable person who excavated or drilled into the subsurface and encountered CDF would realize they had encountered abnormal subsurface conditions.

Physical Barrier

The actual design of the physical barrier, if used, will be determined in the remedial design phase. For the purposes of the FS report, the physical barrier carried forward for evaluation is a coarse basalt layer, overlain by gravel and sand layers intended to prevent overlying fine-grained material from settling into the void spaces of the basalt layer. If the coarse basalt was encountered during drilling, it would cause a sudden, noticeable, and undesirable change in drilling progress that would alert a reasonable person to the presence of abnormal subsurface conditions. The basalt is difficult to excavate or burrow through and, because the void spaces do not retain moisture, it will discourage plant root penetration.

Both CDF and the physical barrier are carried forward as containment technologies to mitigate direct contact risks to human and environmental receptors.

Vertical Subsurface Barriers (Slurry Walls and Grout Curtains)

Slurry walls and grout curtains were retained in the Implementation Plan (DOE/RL-98-28). 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 (slurry) 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.

Neither technology will be effective as a standalone technology to mitigate identified risks; however, they are retained as supplementary technologies for situations where it is necessary or desirable to limit the lateral extent of an engineered surface barrier.

Dry Air Barrier (Soil Desiccation)

Drying vadose zone soils by injecting dry air and extracting soil moisture at SVE wells reduces the hydraulic drive of moisture needed for the downward transport of contaminants. When implemented in conjunction with surface controls to prevent infiltration of precipitation, soil desiccation has the potential to significantly reduce the migration of vadose zone contaminants to groundwater. However, it is not intended as a very long-lived (hundreds of years) barrier. It also may be used to supplement other technologies. By removing moisture from the soil pore space, it may improve access to residual contaminants and enhance volatilization of VOCs. It also would support capture of VOC vapors generated by other remedial technologies, by creating preferential flow paths for the vapors. Additionally, injection of heated air, a process option, may further enhance volatilization and accelerate abiotic degradation. These supplemental applications are unproven and would require treatability testing.

The construction and operation of air injection wells and air supply blowers is proven and relatively easy to implement. Capital and operating costs are well defined. Soil desiccation is retained for further consideration at sites where potential contaminant migration to groundwater is identified.

4.2.2.4 Removal

Excavation employs earth-moving equipment to remove contaminated soil and debris from the site, thereby reducing site-specific risks. In combination with appropriate treatment of the excavated soil and debris, if needed, and disposal options, it can be used to reduce contaminant mass, reduce residual risk to acceptable levels, achieve PRGs and compliance with ARARs, and, depending on the depth of contamination, it may be able to eliminate the need for long-term maintenance and institutional controls at a site. Excavation is most practical, implementable, and cost effective at sites with shallow contamination where the excavation depth is typically up to 7.6 m (25 ft). Deeper excavations are less practicable, have more implementation issues, and the costs increase with depth regardless of excavation technology (conventional or deep methods). Per HAB 207, deep excavation technologies were evaluated and are discussed as follows.

The material handling aspects of excavation methods are well known from their wide application and use in construction and mining. Besides the land disturbance at the waste site, adequate land is also needed for haul roads, stockpiling and storage of clean overburden, contaminated soil, and debris in containers awaiting transport to the disposal site, radiological screening area, clean backfill soil, earthmoving equipment and servicing, and possibly an equipment decontamination area. Earthmoving equipment is used to remove clean overburden, which can be stockpiled near the waste site for later use in backfilling,

and to remove the contaminated soil and debris. Conventional excavation technologies do not require the extent of contamination be precisely known before excavation begins. Rather, characterization can occur as the excavation proceeds, and the extent of contamination can be determined using an observational approach. Contaminated soil and debris are typically removed in lifts (layers of uniform thickness) to allow for screening of contamination. Field screening supports worker safety, waste designation, and helps determine when remedial goals are achieved. Potential implementability issues associated with excavation include the following:

- Excavation and handling of contaminated soil and debris increase the short-term exposure risks to workers and the environment. Risk mitigation, especially for the waste sites with plutonium and americium contamination, requires engineering controls that limit excavation productivity, increase costs, and increase the time to complete the remedial action.
- Excavations require stable side slopes for both worker safety and to maintain an open excavation. In conventional excavation, the sideslope angles necessary to maintain slope stability in the unconsolidated sand and gravel at the waste sites result in significant lateral surface expansion of the excavation as depth increases. The proximity of adjacent waste sites, facilities, and infrastructure is a limitation to this method. Deep excavation technologies can reduce the lateral surface expansion with depth, but they also have unique implementability issues, as discussed below.
- Land disturbance at both the waste site and borrow area (used to obtain clean backfill soil) may impact natural and cultural resources.
- Contaminated soil removal with disposal at the ERDF has been used for waste sites in the 100 and 300 Areas and has been demonstrated to be effective at the Hanford Site.

Most of the waste sites in the 200-PW-1 and 200-PW-6 OUs have transuranic contaminants in the soil at various depths. The contaminated soil and debris excavated from these sites that contains alpha-emitting transuranic isotopes with half-lives exceeding 20 years in concentrations that exceed 100 nCi/g would require disposal offsite at WIPP. Such soils must be managed and disposed in accordance with ARARs. Remedies that may generate transuranic waste must be planned and implemented in coordination with the Hanford Transuranic Waste Certification Program—a step that would be documented during the remedial design phase.

Conventional Excavation

Conventional excavation, employing standard earthmoving equipment such as excavators, front-end loaders, and haul trucks, is a viable technology for contaminated soil at waste sites, although access issues and worker safety concerns may preclude its use for portions of some sites. Conventional excavation would typically use a side slope angle of one unit vertical to 1.5 units horizontal (1V:1.5H) to maintain stability in the unconsolidated sand and gravel at the waste sites. Benching, a stair step pattern of side slopes and horizontal working surfaces (benches) would likely be required for deep excavations and is typically used in open pit mining, as it is the least costly method of excavation.

Remote Excavation

Where access issues or worker safety concerns preclude conventional excavation methods, robotic or extended-reach excavators may be used to remove contaminated soil. Remote excavation was successfully implemented at the 216-Z-9 Trench in the mid-1970s, when a 0.3 m (1 ft) layer of highly radioactive contaminated soil was removed from the trench floor to mitigate potential criticality concerns. Remote excavation has been successfully implemented for the F and H fuel storage basins at the Hanford Site. Although more expensive than conventional excavation, remote excavation can be a cost-effective solution to mitigate site access issues or worker safety concerns from highly toxic contaminants.

Soil Vacuum Excavation

High vacuum systems can be employed as a soil excavation technology. Alternately, a wand with a supersonic air stream is delivered through a nozzle under high pressure to break up soil and move soil particles. A secondary air vacuum withdraws loose soil from the excavation to a collection vessel. Soil vacuum excavation processes facilitate removal of contaminated soil with minimal damage to adjacent pipelines or utilities and may be invaluable where excavation encroaches on underground structures. Soil vacuum or air jet excavation techniques are less effective where large gravel and cobbles or debris are encountered. The implementability, effectiveness, and cost of the technology are well known. Soil vacuum excavation has been successfully demonstrated through use of the soil vacuum excavation equipment in the 300 Area and as part of the 200-PW-1, 200-PW-3, and 200-PW-6 OUs RI soil vapor probe installations around the PFP.

Deep Excavation Technologies

Deep excavation technologies employ specialty contractors and equipment to provide structurally sound vertical to near-vertical side walls for deep excavations, which minimizes the surface area required compared to conventional excavation methods. These technologies may be viable for specific waste sites where conventional excavation methods would encounter or affect adjacent facilities or waste sites. Deep excavation technologies utilize a variety of techniques to provide side slope support as the excavation is deepened. These technologies include barrier walls (diaphragm walls and soil mix walls), sequential excavation using benching and vertical soil supports such as secant or tangent piles, sheet piles, or soldier piles with timber laggings, and ground improvement (grouting and soil nailing). A summary of the key aspects of these technologies, and an evaluation of the effectiveness, implementability, and relative cost follows.

Barrier Walls

Diaphragm wall—A diaphragm wall is a structure formed and cast in a slurry trench. The slurry trench technique involves excavating a narrow trench that is kept full of an engineered fluid or slurry (typically a clay/water mix). As the excavation progresses belowgrade, the stabilizing slurry supports the excavation walls and acts as shoring to prevent caving or collapse of the walls. Various types of excavation equipment can be used depending on site conditions and depths in excess of 46 m (150 ft) are possible. Diaphragm walls are constructed of alternating primary and secondary panels that are usually 2.4 to 6 m (8 to 20 ft) long and 0.6 to 1.5 m (2 to 5 ft) wide. After excavation is complete, a steel reinforcement cage is placed in the center of each panel and concrete is tremied in (poured or pumped through a pipe) under bentonite slurry from the bottom until all of the slurry is replaced with concrete. The slurry is displaced and recovered for reuse. After the concrete sets, secondary panels are constructed between the primary panels to create a continuous wall.

Soil mix wall—A soil mix wall is built from the top down by the in situ mechanical mixing of soil with cementitious material (cement slurry or dry power reagent binder) using a hollow-stem mix tool. Sets of one to three shafts with mixing tools, up to 2.4 m (8 ft) in diameter, are used to mix soft and loose soils to depths of 30 m (100 ft). The hollow stem is used to pump the cementitious material and mix the soil as the tool advances or withdraws, resulting in a column of treated soil. This technique creates spoils consisting of cement slurry and soil that are continuously ejected from the boring cavity as the injected slurry displaces soil cuttings. The presence of gravel, cobbles, and boulders in the Hanford formation sediments would limit implementation of a soil mix wall as a deep excavation technology.

Sequential Excavation using Benching and Vertical Soil Supports

Secant and tangent piles—Secant and tangent piles are another form of top-down construction for vertical soil supports at depths of 23 to 46 m (75 to 150 ft). Secant piles are constructed of intersecting concrete piles measuring 0.5 to 0.9 m (1.6 to 3 ft) in diameter that are installed by drilling under mud or

augering and then placing concrete from the bottom up by tremie pipe. Secant piles are constructed of alternating primary and secondary piles. After the primary piles are constructed, secondary piles are installed between and overlapping the primary piles. In a tangent pile wall, the piles do not overlap and are constructed flush with each other.

Sheet piles—Sheet piles are typically thin, interlocking steel sheets that are driven into the ground to form a continuous wall. Sheet pile walls can be cantilevered or anchored to support soil slopes. Uniform soil conditions are preferable for installing sheet piles. The presence of gravel, cobbles, and boulders in the Hanford formation sediments would limit the implementation of sheet piles as a deep excavation technology.

Soldier piles—Soldier piles, also commonly known as king piles or Berlin wall, are constructed of wide-flange steel H piles that are driven into the ground about 2 to 3 m (6 to 10 ft) apart prior to excavation. As the excavation proceeds, horizontal timbers (lagging) are inserted behind the H piles to support the soil walls. Compared to other retaining walls, they are easier and faster to construct and are the least expensive. Pile depth depends on site-specific soil conditions; however, in the building construction industry, excavations have been completed to depths of 30 to 46 m (100 to 150 ft).

Ground Improvement

Grouting—Grouting includes permeation and chemical grouting where cement or chemical grouts are injected into predominantly granular soils to improve the soil strength prior to excavation. Most permeation grouting is accomplished with cement although bentonite cement, resins, silicates/emulsions, polyurethane, and acrylate are also used in chemical grouting. The grout is injected into the soil through pipes that have been strategically placed to define the zone of soil to be treated.

Soil nailing—Soil nailing is also a top-down construction process that consists of a soil slope excavated to a vertical or near-vertical angle that is then internally supported by closely spaced steel reinforcing bars (e.g., the nails) that are fully grouted into the soil slope. Soil nail slopes are difficult to construct in soils that are subject to caving, especially granular soils. The unconsolidated granular soils of the Hanford formation would limit the implementation of soil nailing as a deep excavation technology.

The deep excavation technologies discussed in this subsection are all considered to be effective techniques to stabilize side slopes and minimize the surface area of a deep excavation and they have proven use in the building construction industry. However, besides the implementation issues noted for specific techniques as discussed previously, a variety of implementation issues limit the usefulness of these techniques to only those waste sites that could not otherwise be excavated using conventional methods. These implementability issues include the following:

- Site-specific soil conditions must be well known in order to design, engineer, and construct structurally sound vertical soil support systems. Geotechnical soil borings and soil testing for structural properties will be needed for design; soil contamination at waste sites increases the complexity and cost of investigation and soil testing.
- Specialty contractors are required to design and construct deep excavation support systems; only a limited number of these contractors exist. The primary application of these systems is in the building construction industry in large cities where conventional excavation methods are not feasible due to adjacent buildings and structures. Application of these techniques is not widespread in the environmental remediation industry. Prompt support and workmanship are needed to minimize soil movements.

- Excavation technologies that utilize slurries will create additional waste handling and disposal issues if contaminated soils are encountered. These technologies could be implemented if waste site characterization has defined the subsurface limits of contamination and the technology is constructed in adjacent clean soil. Some excavation of clean soil within the deep excavation area would increase the cost of these techniques.

In many cases, the types of specialized equipment used in these techniques comprise heavy loads that may require Hanford Site access and haul road improvements to specific waste sites as well as consideration in the excavation design and impact on adjacent facilities or structures. Unless the excavation technology is constructed in clean soil, equipment decontamination issues and costs may limit the usefulness of these methods.

The best geometry for barrier walls and piles is circular to provide a self-supporting structure. This geometry must be considered for implementability at specific waste sites. Internal support could also be provided by an internal grid of wall panels or piles, but excavation and construction of these internal panels or piles will encounter contaminated soils, which would create additional waste handling and disposal issues, as discussed previously.

In general, the relative costs of deep excavation technologies are greater than the costs of conventional methods for similar depths and the costs of both deep and conventional technologies increase with depth. Compared to other deep excavation wall systems, soldier piles are the easiest, fastest, and least expensive to construct. Soldier piles and grouting are retained as deep excavation technologies for evaluation if site-specific conditions are not amenable to the use of conventional excavation methods.

4.2.2.5 Ex Situ Treatment

Characterization data presented in the RI Report (DOE/RL-2006-51) suggest that no treatment will be necessary to meet disposal facility waste acceptance criteria for waste site soils, although the sludge in the two settling tanks is expected to require solidification/stabilization prior to disposal. However, ex situ treatment technologies have been considered in this section for their ability to minimize the volume of material that may require disposal. These technologies (thermal desorption, vitrification, vapor extraction, soil washing, automated segregation based on radioactivity, and solidification/stabilization) are described in detail in the following subsections.

Thermal Desorption

Thermal desorption has been identified as a presumptive remedy by EPA (EPA 540-F-93-048, *Presumptive Remedies: Site Characterization and Technology Selection for CERCLA Sites with Volatile Organic Compounds in Soils*, OSWER Directive 9355.0-48FS) for the removal of VOCs from soil. This technology uses heat to volatilize organic contaminants from soil, typically employing a rotary kiln to disaggregate soils to facilitate volatilization. A carrier gas or vacuum is used to collect and transport the volatilized organics to a gas treatment system. Concentrated contaminants can be removed (e.g., by carbon adsorption) from the process stream or destroyed using a secondary combustion chamber or catalytic oxidizer. Residual liquids and spent activated carbon require further treatment. With low temperature thermal desorption, the decontaminated soil retains its physical properties and its ability to support biological growth.

Current characterization data show that all VOCs are co-located with radiological contaminants; therefore, thermal treatment (such as thermal desorption or incineration) that reduces or eliminates the VOCs will not reduce waste volume and most likely will not affect selection of the disposal facility. Current data also suggest the waste soils will meet disposal facility waste acceptance criteria without

treatment. Thus, the short-term risks and costs incurred in implementing ex situ thermal desorption would provide little benefit. This technology is not retained for further evaluation.

Ex Situ Vitrification

Vitrification of excavated material can be conducted at a facility or at the waste site using in-container vitrification. The in-container vitrification process mixes silica-rich contaminated soil with sand and insulation in a large steel box. Electrodes heat the mixture to over 1,300°C (34°F) to vitrify the waste material. The entire container with glass and electrodes can then be disposed. Vitrification addresses all contaminants for all waste sites by melting excavated materials to form glass or other crystalline solids.

Ex Situ Vapor Extraction

Vapor extraction is a standard method for removing VOCs from excavated soil by inducing airflow through the soil. Based on current understanding, it would be used only if soils were excavated from the 19.8 m (65 ft) depth interval on the south side of the 216-Z-9 Trench. This technology would be implemented, if needed, to reduce carbon tetrachloride concentrations to meet ERDF and WIPP waste acceptance criteria.

Soil Washing

Contaminants sorbed onto fine soil particles are separated from bulk soil in an aqueous-based system on the basis of particle size. The wash water may be augmented with a basic leaching agent, surfactant, pH adjustment, or chelating agent to help remove organics or heavy metals. This is a media transfer technology; wash water subsequently is treated. Complex waste mixtures (e.g., metals with organics) make formulating washing fluid difficult. No previous studies were identified that showed this process to be effective, or potentially effective, with Pu-239/240 or Am-241, or with the very high concentrations of Cs-137 anticipated. Other technologies are more effective with the identified organic contaminants. Soil washing is not retained for further consideration.

Automated Segregation Based on Radioactivity

Systems have been developed that convey excavated soil past radioactivity sensors. 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. A segmented gate system has been demonstrated by Eberline Corporation. The effectiveness, implementability, and cost for this technology have been demonstrated and are well defined. Automated segregation is retained for further consideration where such a separation function on excavated contaminated soil is appropriate.

Solidification/Stabilization

As assessed here, solidification/stabilization addresses inorganic and radionuclide contaminants for the 241-Z-8 and 241-Z-361 Settling Tanks by mixing extracted sludge with a binding agent to form an encapsulated mass that inhibits contaminant mobility. Contaminants are physically bound or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants, to reduce their mobility (stabilization). 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. Most solidification/stabilization processes have limited effectiveness with organic contaminants. Solidification/stabilization is retained for further consideration. DOE/RL-2003-52 identified a recommended remedial action for the ex situ stabilization of the sludge in the 241-Z-361 Settling Tank. Power Fluidics™ technology would be used to remove the sludge from the tank and place it

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™ Power Fluidics is a trademark of NuVision Engineering, Inc., Pittsburgh, Pennsylvania.

in standard waste boxes, where it would be stabilized with a polymer absorbent (e.g., WaterWorks SP-400 Superabsorbent Crystals®). This previously recommended stabilization technology is retained.

4.2.2.6 In Situ Treatment

The in situ treatment technologies discussed below include SVE, passive SVE, soil mixing, electrical resistivity heating and SVE, and ISV.

Soil Vapor Extraction

The SVE process is a conventional process for remediating soils contaminated with VOCs and has been identified by EPA as a presumptive remedy (EPA 540-F-93-048, OSWER Directive 9355.0-48FS). SVE with carbon adsorption currently is implemented as an expedited response action at the 200-PW-1 OU. The SVE technology has proven very effective, removing approximately 79,380 kg (175,003 lb) of carbon tetrachloride from the vadose zone between 1991 and September 2008 (SGW-40456). However, the mass of carbon tetrachloride removed annually continues to diminish.

The SVE process involves inducing airflow through the soil matrix with an applied vacuum that facilitates the mass transfer of adsorbed, dissolved, or free phases to the vapor phase. Vapors are drawn to the surface through vapor extraction wells for treatment.

Carbon adsorption is the most commonly employed vapor treatment process and is adaptable to a wide range of VOC concentrations and process flow rates. The treatment process using skid-mounted, offsite regenerated carbon canisters generally is employed for low soil vapor flow volumes, as encountered at the waste sites. The process can be used alone or with other methods. Spent carbon requires treatment or disposal. Radiological contamination may preclude disposal or regeneration offsite.

Passive Soil Vapor Extraction

Passive SVE removes underground VOCs by enhancing the natural air pressure changes that occur in subsurface soils in response to naturally occurring changes in atmospheric pressure. In wellhead passive SVE, airflow results when the surface and subsurface soils are connected by a well. A valve at the wellhead allows air to flow out of the well but not back into the well. An adsorber can be added to the system to remove VOCs from the exhaust air stream, if warranted. The passive SVE systems have been successfully tested at multiple DOE sites including the Hanford Site. The passive SVE process with carbon adsorption currently is implemented as an interim response at the 216-Z-1A/Z-18 Well Field in the 200-PW-1 OU. Approximately 5 kg (11 lb) of carbon tetrachloride were removed from the vadose zone using passive SVE in FY 2008; between October 1999 and September 2008, approximately 90 kg (198 lb) of carbon tetrachloride were removed (SGW-40456).

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 physically encapsulate or chemically bind contaminants. One limiting factor that can influence the effectiveness of the stabilization and solidification processes is organic solvents. Depending on the type of binding agent, organic solvents can react in ways that are problematic to the effectiveness of the technology. As a result, it is not suitable when organic solvents are present. The gravel, cobbles, and boulders in the Hanford formation sediments would also limit the application of this technology, as would the underground pipes and other structures of the waste sites. Soil mixing is not retained for further evaluation.

® WaterWorks Crystals is registered trademark of WaterWorks America, Inc., North Royalton, Ohio.

Electrical Resistance Heating and Soil Vapor Extraction

Thermally enhanced SVE is an active technology that uses heating to increase the volatilization rate of VOCs and SVOCs and then captures and treats the vapors. Electrical resistance heating (ERH) uses an electric current to heat soils, preferentially heating fine-grained soils where the remaining vadose zone mass of organic contaminants is located at the 216-Z-1A Tile Field and the 216-Z-9 Trench. Wells are drilled into the contaminated media in a polygon pattern. Electrodes are placed in the wells and power is applied to initiate the flow of electrical current through the soil matrix. The electrical resistance of the soil generates heat. The elevated temperature accelerates volatilization of the contaminants and also may accelerate naturally occurring attenuation processes such as biotic and abiotic degradation.

In Situ Vitrification

ISV technology, as assessed here, is the GeoMelt® vitrification process. This process originated as an in situ treatment method developed at PNNL for contaminated soils at DOE sites. Today, GeoMelt is available as two distinct treatment options: subsurface planar vitrification (SPV), which is a mature second generation in-place (i.e., subsurface) treatment technology based on improvements to the original in situ technology; and an ex situ method, in-container vitrification, also known as bulk vitrification at the Hanford Site. The in situ SPV treatment technology is evaluated here. Figure 4-3 shows a conceptual schematic of this ISV treatment technology.

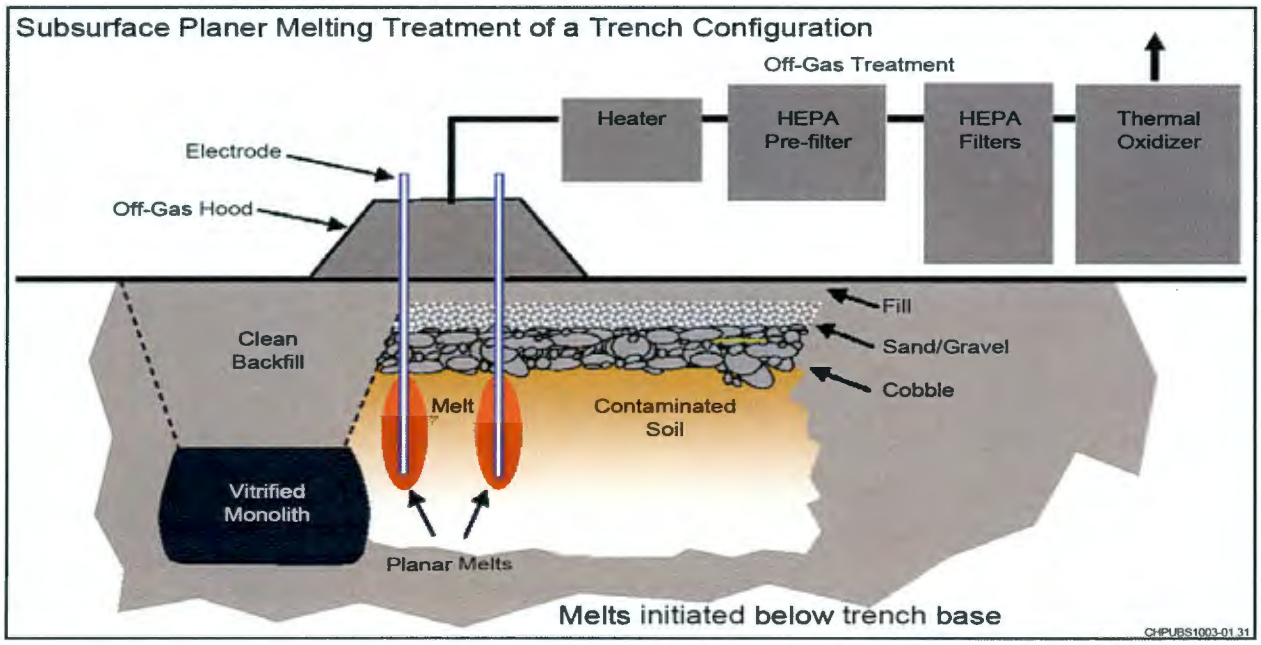


Figure 4-3. Conceptual Schematic: In-Situ Vitrification

The GeoMelt process represents a group of vitrification technologies that can be configured in various ways to meet a wide range of treatment requirements. In all GeoMelt applications, a mixture of waste and glass formers, usually soil, is electrically melted to destroy, remove, or permanently 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 durable semicrystalline glass. This glass is very durable and has excellent long-term leach characteristics.

® GeoMelt (Subsurface Planar Vitrification and In-Container Vitrification processes) is a registered trademark of AMEC plc, London, England.

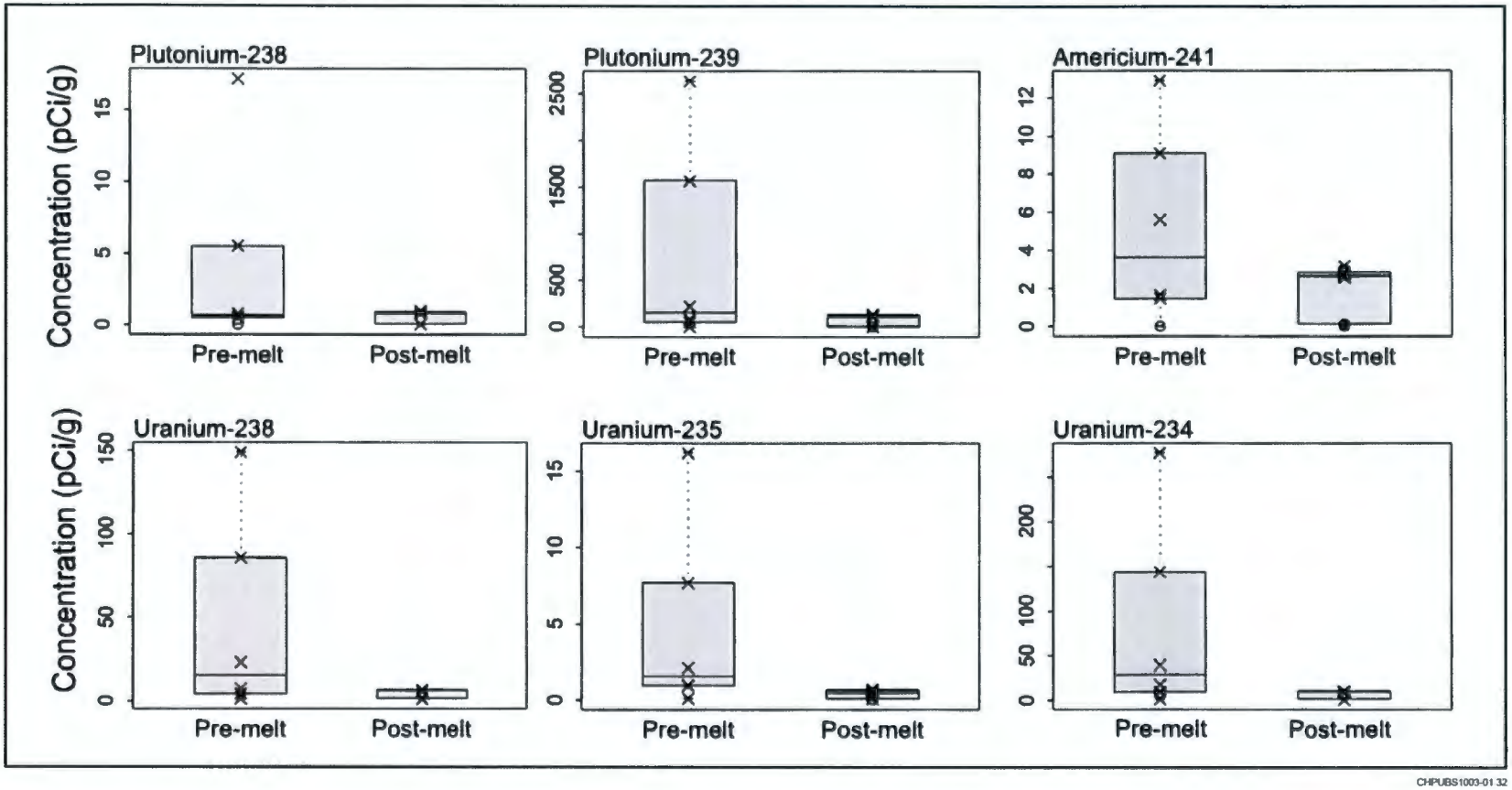
The SPV process is a mobile thermal treatment process that involves the in-place electric melting of contaminated soils, sludges, or other earthen materials and debris for the purpose of permanently destroying, removing, and/or immobilizing hazardous and radioactive contaminants. A conductive starter path is injected between two sets of electrodes to enable subsurface electrical current flow. Starter path installation is performed remotely with conventional drilling methods, thus reducing worker exposure risk. As electricity flows through each starter path, the surrounding soil melts through resistive (joule) heating. Once the soil is molten, it too becomes electrically conductive. Continued application of power results in joule heating within the molten media between and around the electrodes. Because the process is initiated with two, independent, vertically oriented planar melts that merge together horizontally late in the treatment process, the potential for restricting the flow of gases generated below the melts is reduced significantly. By the time the melts have grown sufficiently to merge into a single melt, all volatile materials have been effectively and safely removed from the treatment zone and captured in the offgas treatment system. To accommodate soil densification (caused by vitrification), 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 homogeneously 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 used to immobilize high-level wastes.

The vitrified material retains plutonium, other radionuclides, and hazardous metals in an extremely durable form. Plutonium oxide has a fairly high solubility limit in most glasses (in the range of 2 to 5 wt percent) and, in the case of GeoMelt, would be distributed throughout the glass by convective mixing. The homogeneity of radionuclide species within GeoMelt glass from convection is well established. Figure 4-4 depicts the pre- and post-melt radionuclide concentrations from the SPV project (LA-UR-03-6494, *IM Completion Report for the NTISV Hot Demonstration at SWMU 21-018(a)-99 (MDA V)*). As shown, analytical data identified both a general reduction in radionuclide concentrations in post-melt glass (maximum measured concentrations are approximately one order of magnitude less in the post-melt glass than in the pre-melt absorption bed samples), and a more uniform distribution of radionuclides as a result of the convective mixing that occurs during the melting process.

Criticality Issues

Transuranic radionuclides that emit neutrons can reach criticality if they are sufficiently concentrated or if the moderation properties of the media are suitably altered. The GeoMelt process changes the physical and chemical nature of the contaminated media. These changes prevent conditions necessary for a criticality event to occur. Because plutonium is a strong reducing agent, it is converted to an oxide during the vitrification process. It will chemically reduce species such as iron oxide (Fe_2O_3, naturally present on Hanford Site soil) to form an oxide that is particularly stable at high temperatures. Any plutonium metal in the melt would oxidize rapidly. In fact, if any plutonium metal exists in the soil, it most likely would be fully oxidized in the high-heat environment ahead of the advancing melt. Figure 4-5 shows the standard free energy of the formation of the oxide for several metals including plutonium.



Source: From LA-UR-03-6494, *IM Completion Report for the NTISV Hot Demonstration at SWMU 21-018[a]-99 [MDA V]*.

Figure 4-4. Comparison of Pre- and Post-GeoMelt Subsurface Planar Vitrification Radionuclide Concentrations

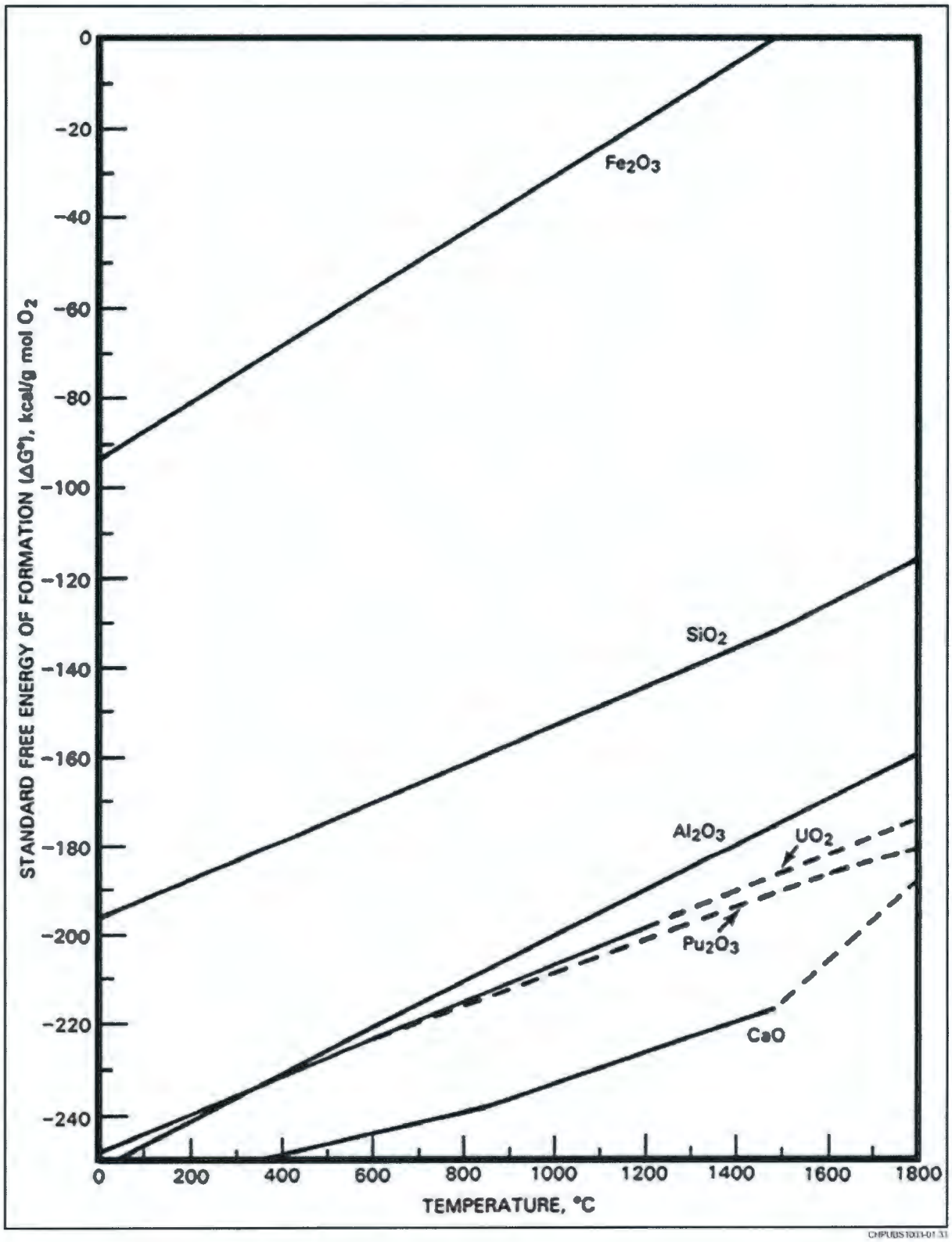


Figure 4-5. Standard Free Energy of Formation for Various Metal Oxides
Environmental Protection and Waste Management

The lower the $\Delta G°$ value, the more likely it is that the oxide species will exist. Figure 4-5 shows plutonium has a value of around -200 kcal/g mole O_2 at the temperatures achieved in the GeoMelt process. The data illustrate that to reduce plutonium to its metallic state in a typical multicomponent glass melt, numerous other species first would have to be reduced by the plutonium (such as iron oxide and silicon dioxide) before plutonium oxide could be reduced.

Plutonium oxide has a fairly high solubility limit in most glasses, in the range of 2 to 5 wt percent. Various programs under the DOE Office of Fissile Materials Disposition have achieved up to 10 wt percent plutonium in certain glass formulations (PNNL-11346, *Plutonium Dioxide Dissolution in Glass*).

Because of heat-driven convective mixing that occurs during the GeoMelt process, plutonium oxide is mixed throughout the glass. Previous GeoMelt projects (LA-UR-03-6494) have shown that plutonium is not reduced to its metallic state, is not concentrated as a result of the process, and is uniformly dispersed as an oxide within the glass.

Plutonium oxide is stable and soluble within the melt, has a very low vapor pressure at melt temperatures, and is not volatile. Consequently, most of the plutonium is retained in the melt. Empirical data from GeoMelt operations as well as other vitrification operations have established that typically >99.99 percent of the plutonium is retained within the melt. Only trace concentrations of the plutonium inventory are released from the melt to the offgas treatment system. Because of the very low inventories released to the offgas treatment system, there are no practical means to accumulate sufficient inventories of plutonium in the offgas treatment system to give rise to criticality concerns. In most applications, the first step of the offgas treatment system is particulate filtration, which is very effective at removing any particles from the gas stream. The particulate is, in most cases, recycled back into subsequent melts. In some melts, the high-efficiency particulate air (HEPA) filters contained no detectable activity, indicating near-total retention of plutonium in the glass. This excellent retention is a result of the enhanced depth capabilities of GeoMelt SPV and the use of cover soil.

Offgases generated by the process are contained under a steel hood that covers the treatment area and are withdrawn to an offgas treatment system that meets EPA and state standards (i.e., ARARs). Offgas treatment steps can vary depending on project requirements but generally consist of particulate filtration, quenching, wet scrubbing, a second stage of particulate filtration, and carbon adsorption and/or thermal oxidation.

Waste streams from the GeoMelt process include HEPA filters and liquid effluent from the offgas treatment system, drilling wastes (contaminated soils, equipment, and decontamination wastes), GeoMelt decontamination wastes, and personal protective equipment. Spent HEPA filters are fed back into the melt (except for the last ones of each melt). Liquid effluent from the offgas treatment system and decontamination activities likely can be disposed at onsite liquid waste disposal facilities. Most, if not all, of the remaining wastes can be disposed at ERDF. At sites with transuranic constituents, it is possible that some wastes may designate as transuranic wastes.

Developmental Maturity and Implementability

The SPV process is a mature, second generation technology based on improvements to the conventional ISV process that was developed by PNNL for DOE. As part of the development of the original ISV process, a full-scale test melt, was completed in a portion of the 216-Z-12 Crib (see Figure 1-2). Using the established U.S. Department of Defense Technology Readiness Levels (9-point scale used to assess technology maturity), the SPV technology is rated at Level 9: the actual system has been proven through successful project operations. SPV has been successfully deployed at full scale in several hot and cold demonstrations for Los Alamos National Laboratory, Idaho National Engineering Laboratory, and the

DOE Office of Cleanup Technologies. Figure 4-6 depicts the use of SPV equipment by AMEC at Los Alamos National Laboratory in 2000.

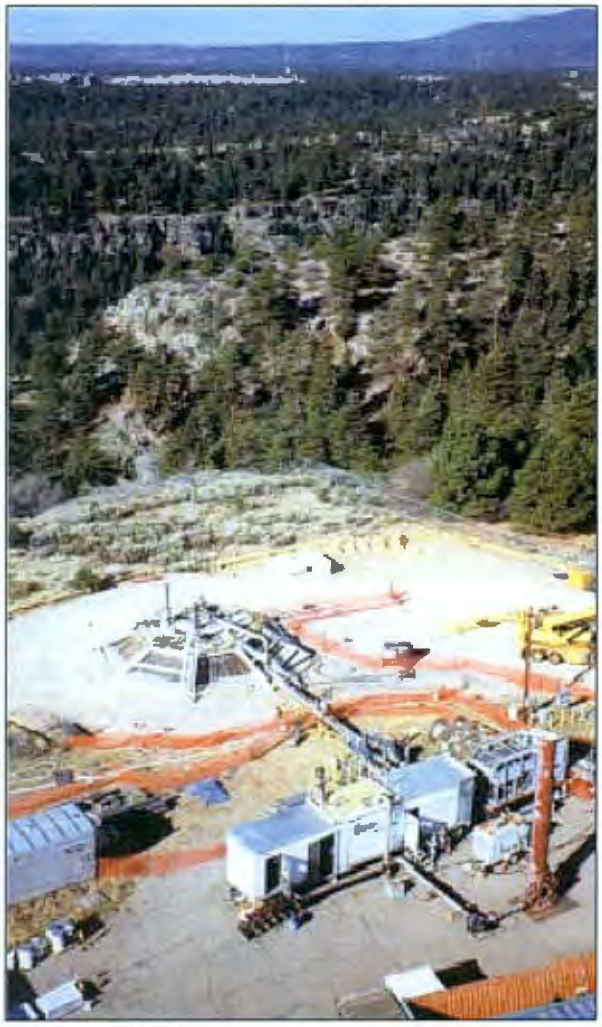


Figure 4-6. GeoMelt Subsurface Planar Vitrification Processing Equipment at Los Alamos National Laboratory in 2000

Summary

GeoMelt SPV ISV technology appears to warrant consideration. Although not in wide use, the technology has evolved substantially. The most likely application of this technology is at sites where excavation of contaminated soils might generate large volumes of waste with high levels of transuranic isotopes. A primary benefit of the GeoMelt SPV process is that it is an in situ treatment technology that can encapsulate the soils with Pu-239/240 and Am-241 to reduce the toxicity and mobility of these radionuclides. Vitrification safely immobilizes alpha emitters such that the risk from any subsequent direct contact is reduced. (AMEC has experience in the vitrification and subsequent removal of more than 4,600 metric tons [5,070 tons] of plutonium waste. During glass removal operations, plutonium contamination immobilized in the glass was nonsmearable, and there was no detectable airborne plutonium.) A significant secondary benefit of ISV is that the glass monolith forms a substantial physical barrier that inhibits both human and biological intrusion into the residual contamination that exists at depth. This technology is retained for further evaluation at sites with long-lived radionuclides.

4.2.2.7 Monitored Natural Attenuation

Although technically not a treatment process, MNA is included in this group because it occurs in situ. Remedies relying on MNA processes are implemented following EPA/540/R-99/009, *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*, OSWER 9200.4-17P. Protocols providing guidance for implementation of MNA for chlorinated solvents are available from EPA (EPA/540/G-89/004). Protocols for metals and radionuclides are being developed. MNA is retained for all waste sites and all contaminants that are amenable to MNA processes in reasonable timeframes.

The most significant reliance on MNA processes is expected to be at the 200-PW-3 OU waste sites contaminated with Cs-137. This radionuclide has a half-life of approximately 30 years, so natural radiological decay can achieve substantial reductions in contaminant mass in a relatively short period of time (e.g., MNA processes will eliminate more than 96 percent of the current Cs-137 mass by the year 2150).

At present, it does not appear that the other identified final COPCs can be addressed effectively in the vadose zone using MNA processes.

5 Remedial Action Alternatives

The alternatives presented in this chapter were developed by combining the process options identified in Chapter 4 into an appropriate range of remedial alternatives that will be more fully analyzed in the detailed analysis in Chapter 6. The development of remedial alternatives followed EPA guidance (EPA/540/G-89/004) and considered the nature and extent of contamination at each waste site from Chapter 2 and the risk evaluation, final COPCs, and RAOs from Chapter 3.

5.1 Development of Remedial Alternatives

The purpose of this FS and the overall remedy selection process is to identify remedial actions that eliminate, reduce, or control risks to HHE. The national program goal of the FS process, as defined in the NCP (40 CFR 300.430), is to select remedies that are protective of HHE, that maintain protection over time, and that minimize untreated waste. The NCP also defines the following five expectations applicable to the 200-PW-1, 200-PW-3, and 200-PW-6 OUs that are generally considered in developing appropriate remedial alternatives.

- 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.
- EPA expects to use engineering controls, such as containment, for waste that poses a relatively low long-term threat or where treatment is impracticable.
- EPA expects to use a combination of methods, as appropriate, to achieve protection of HHE. 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 ICs, as appropriate, for treatment residuals and untreated waste.
- EPA expects to use ICs 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. ICs may be used during the conduct of the RI/FS and implementation of the remedial action and, where necessary, as a component of the completed remedy. The use of ICs shall not substitute for active response measures (e.g., treatment and/or containment of source material, restoration of groundwaters to their beneficial uses) as the sole remedy, unless such active measures are determined not to be practicable, based on the balancing of tradeoffs among alternatives that is conducted during the selection of the remedy.
- 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.

For source control actions (such as the 200-PW-1, 200-PW-3, and 200-PW-6 OUs), the NCP also states the lead agency shall develop the following as appropriate.

- A range of alternatives in which treatment that reduces the toxicity, mobility, or volume of the hazardous substances, pollutants, or contaminants is a principal element. As appropriate, this range shall include an alternative that removes or destroys hazardous substances, pollutants, or contaminants to the maximum extent feasible, eliminating or minimizing, to the degree possible, the need for long-term management. The lead agency also shall develop, as appropriate, other alternatives that, at a minimum, treat the principal threats posed by the site but vary in the degree of treatment employed

and the quantities and characteristics of the treatment residuals and untreated waste that must be managed.

- One or more alternatives that involve little or no treatment, but provide protection of HHE primarily by preventing or controlling exposure to hazardous substances, pollutants, or contaminants, through engineering controls, for example, containment, and, as necessary, ICs to protect HHE and to ensure continued effectiveness of the response action.
- The lead agency shall develop one or more innovative treatment technologies for further consideration if those technologies offer the potential for comparable or superior performance or implementability; fewer or lesser adverse impacts than other available approaches; or lower costs for similar levels of performance than demonstrated treatment technologies.
- The No Action Alternative, which may be no further action if some removal or remedial action has already occurred at the site, shall be developed.

In addition to these requirements from the NCP, the development of remedial alternatives also considered the feedback obtained from an early involvement public workshop that was held on April 18, 2008, to present draft remedial alternatives for the 200-PW-1 OU waste sites. As a result of this workshop, the HAB issued Consensus Advice #207 (HAB 207) on June 6, 2008, containing considerations that the Board believes are important to the development of the Proposed Plan for this OU. This FS report incorporates the criteria provided by the Board regarding remedial alternatives and their evaluation.

5.2 Description of Remedial Alternatives

The process options identified in Chapter 4 were combined to formulate a range of remedial alternatives to satisfy the RAOs for the 200-PW-1, 200-PW-3, and 200-PW-6 OUs, as well as the requirements and considerations described in Section 5.1. Preliminary technical and functional requirements for the elements of each alternative are identified based on the RAOs and potential ARARs, as well as other considerations.

Table 5-1 summarizes the remedial alternatives as well as the GRA, technology type, process option, and the area or volume for each option. The remedial alternatives include the following:

"No Action" Alternative. The NCP requires consideration of a No Action Alternative. This alternative would leave a waste site "as-is" in its current state, with no additional remedial activities or access restrictions. This alternative is only acceptable if current waste site conditions are protective of HHE. This alternative is not discussed further in this section; however, the alternative is carried into the detailed analysis (Chapter 6).

Alternative 1—Barrier. This alternative provides no treatment for radionuclides, but prevents and controls exposure to hazardous substances through engineering controls and ICs to protect HHE.

Alternative 2—In Situ Vitrification. This alternative utilizes ISV to reduce the mobility of hazardous substances as a principal element. It is primarily considered applicable for the 200-PW-1 OU waste sites that contain plutonium and americium. ICs are also a component of this alternative at waste sites where the treatment process leaves residual contamination that will require long-term controls.

Table 5-1. Remedial Alternatives for 200-PW-1, 200-PW-3, 200-PW-6 OU Waste Sites

Medium	General Response Action	Technology Type	Process Option	Area or Volume	No Action	1 Barrier	2 ISV	3 RTD
Soil	Institutional Controls	Land Use Management	Deed Restrictions/ Covenants/Notices	All waste sites with residual contamination above acceptable risk levels		X	X	X
		Warning Notices and Entry Restrictions	Signs/Fences			X	X	X
			Entry Control			X	X	X
		Monitoring	Surveillance/Monitoring			X	X	X
	Containment	Surface Barriers	Monofill ET Barrier	Soil above risk levels and for groundwater protection		X		X
		Intrusion Barriers	Physical Barrier			X		
	Removal	Excavation	Conventional Excavation	Soil above risk levels				X
	Disposal	Landfill Disposal	Onsite Landfill	RTD sites				X
			Offsite Repository (WIPP)	Sites with >100 nCi/g transuranics				X
	In Situ Treatment	Chemical/Physical Treatment	SVE	200-PW-1 sites with carbon tetrachloride		X	X	X
		Thermal Treatment	ISV	Waste sites with plutonium as risk driver			X	
	Attenuation Processes	Natural Attenuation	MNA	Waste sites with cesium-137 as risk driver		X		X
Sludge	Ex Situ Treatment (after removal)	Physical/Chemical Treatment	Solidification/Stabilization	241-Z-8 and 241-Z-361 Settling Tanks				X

ET = evapotranspiration
ISV = in situ vitrification
MNA = monitored natural attenuation
OU = operable unit
RTD = removal, treatment, and disposal
SVE = soil vapor extraction
WIPP = Waste Isolation Pilot Plant

Alternative 3—Removal, Treatment, and Disposal. This alternative removes waste site soil, sludge, and/or debris, treating it as necessary to meet ARARs, and then disposing of it in an onsite (ERDF) or offsite (WIPP) disposal facility as appropriate. Five RTD options were developed to achieve different removal objectives, from partial removal of the highest contaminant concentrations to removal of concentrations posing greater than a 10^{-4} risk level. These RTD options and the approximate soil removal depth for each option at each waste site are described below. For the RTD options that leave residual contamination above risk levels, ICs and ET barriers are incorporated as components to protect HHE.

For all alternatives, pipelines connected to the waste sites are planned to be evaluated and assessed in accordance with the information outlined in Appendix H of this document. The details of these alternatives with regard to process options and specific waste sites are described as follows.

5.2.1 Common Components of Remedial Alternatives

Several common components are included in more than one remedial alternative (Table 5-1). To limit redundancy, they are discussed here and referenced in the discussion of each alternative.

- Institutional controls, long-term monitoring, and maintenance will be required where residual contamination remains above cleanup acceptable risk levels.
- Soil vapor extraction will be required to be continued at 216-Z-1A Tile Field, 216-Z-9 Trench, and 216-Z-18 Crib.
- Waste sites remediated under RTD will be sampled to confirm that cleanup goals have been achieved.
- Sampling of technetium-99 and/or nitrate will be required at some sites to determine if action is required.
- Sludge will be removed from the Settling Tanks and then they will be grouted.
- No Action is required at the 216-Z-8 French Drain and 216-Z-10 Injection/Reverse Well.

5.2.1.1 Institutional Controls

The Sitewide ICs plan (DOE/RL-2001-41) identifies the ICs for the current Hanford Site. It also describes how ICs are implemented and maintained, and it serves as a reference for the selection of ICs in the future. The current ICs are similar for all waste sites. The ICs that will be implemented following the remedy selection are expected to be comparable. They are intended to make sure the remedy remains protective in situations where waste remains in place above levels that would allow for unrestricted land use. ICs work in conjunction with the more active cleanup measures to protect HHE during the cleanup process, as well as following the completion of cleanup for areas containing residual contamination above risk levels. Therefore, existing ICs will continue as long as risks remain that make the site unsuitable for unrestricted use. ICs include the following:

- Administrative controls
  - Maintain the site listings and updates in the 200-PW-1, 200-PW-3, and 200-PW-6 OUs facility and land use plan; update changes or terminations agreed to by the agencies.
  - Provide public notices to stakeholders of changes in ICs.
  - Add new DOE directives, new DOE orders, or changes to List B of the O&M contract as they occur.

- Control the use of groundwater via use restrictions, easements for monitoring, restrictive covenants, or land withdrawal documentation that would be deemed necessary to further protect the public and the environment if land use or ownership changes.
- Maintain work control process in accordance with 10 CFR 835 and DOE G 441.1-1C, *Radiation Protection Programs Guide for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection.*
- Restrict and/or control soil disturbances to eliminate the potential spread of contamination.
- Access restrictions: Post and maintain visible access restrictions.

- Control access
  - Maintain Hanford Site access controls in accordance with DOE O 470.4A, *Safeguards and Security Program.*
  - Maintain restrictions on leasing or transferring property.
  - Maintain notification requirements in response to failed controls/corrective action.

As long as contaminants remain within the 200-PW-1, 200-PW-3, and 200-PW-6 OU waste sites at concentrations that exceed protective risk levels, a 5-year site review is required by the NCP (40 CFR 300.430[f][4][ii]). The 5-year reviews will be conducted to evaluate the effectiveness of the existing ICs, to evaluate the need for continued ICs, or to consider a supplemental action.

5.2.1.2 Expanded Soil Vapor Extraction

SVE is the preferred presumptive remedy for removing VOCs from the subsurface (OSWER Directive No. 9355.0-63FS, *User's Guide to the VOCs in Soils Presumptive Remedy*). SVE works by removing contaminants from the vadose zone soil by inducing airflow through the soil. The collected air from the subsurface may require treatment prior to being discharged to the atmosphere. The existing SVE system has been very effective in removing carbon tetrachloride from the surface. Through 2009, approximately 81,000 kg (179,000 lb) of carbon tetrachloride has been removed from 200-PW-1, which further indicates that it is an effective component of the proposed remedy. The proposed expansion of the SVE system will include additional wells to increase the area and volume of the influence of the SVE system.

Each remedial alternative for the three 200-PW-1 OU High-Salt waste sites (216-Z-1A, 216-Z-9, and 216-Z-18) with carbon tetrachloride as a final COPC also includes expansion of the existing SVE system. Conceptually, and for the cost estimating purposes of this FS, the expanded SVE system would include (1) the installation of up to 10 new SVE wells at each waste site, and (2) two new 14 m^3/min (500 ft^3/min) blower systems (one shared between 216-Z-1A and 216-Z-18 and one for 216-Z-9). The FS assumes the SVE systems will be operated a minimum of 6 months per year (approximately the current annual operating time), for a period of 10 years. The actual annual operating period and time until PRGs have been achieved will vary as a function of several performance metrics (e.g., mass removal rate) and operational considerations (e.g., effect of ambient temperature on the amount of contaminated condensate generated). Periodic evaluation of these metrics will be used to support optimal configuration and operation. Additionally, in conjunction with the remedial design process, a specific set of performance metrics will be developed to help identify when SVE technology has reached the limits of its effectiveness at these waste sites. Guidance provided in EPA/600/R-01/070 will be considered in developing this set of metrics and the associated performance monitoring plan and in deciding how to use those metrics to determine when SVE system operations have achieved the PRGs and should be terminated at the 200-PW-1 OU High-Salt waste sites.

5.2.1.3 216-Z-9 Trench Abovegrade Structures

The 216-Z-9 Trench includes three abovegrade structures that were constructed for the soil mining operation that was conducted from 1976 to 1977. These three structures include the 216-Z-9A Operations Support Building, the 216-Z-9B Operator's Cubicle, and the 216-Z-9C Equipment Enclosure. All of the remedial alternatives, except the No Action Alternative, include the removal and disposal of these three structures consistent with the slab-on-grade Preferred Alternative described in DOE/RL-2004-05, *Engineering Evaluation/Cost Analysis for the Plutonium Finishing Plant Above-Grade Structures*.

5.2.1.4 Sampling Activities

DOE/RL-98-28 served as a means to streamline remedial investigations and focus the CERCLA process to obtain a decision. Under this approach, sites were grouped by similar characteristics; for example, the High-Salt sites received the same type of waste stream over their operational lifetime. Therefore, data collected for one High-Salt (primary) site would be used to make remedial action decisions for all similar type sites in the group. The similar sites are assumed to have contaminant distribution and risk characteristics similar to those of the primary site, based on process knowledge and site conditions.

There were three primary sites identified for the 200-PW-1/3/6 OU: the 216-Z-1A Tile Field, the 216-A-8 Crib, and the 241-Z-361 Settling Tank. Evaluation of these sites in the 200-PW-1, 200-PW-3, and 200-PW-6 OUs was based on data acquired from field investigations. Evaluation of the similar sites used not only these data but also site-specific data where available. In addition, there were three sites that were evaluated with site-specific data only—the 216-Z-9 Trench, the 216-Z-10 Reverse Well, and the 216-Z-8 French Drain.

Future sampling will serve to augment the RI data, confirm the alternative selection, support remediation design, and provide information for final site closeout. Confirmatory sampling will confirm that the site contaminant distribution model used to evaluate the similar sites is appropriate to the site conditions and will confirm selection of the appropriate remedial alternative. Design sampling will obtain data necessary to design remedial action and refine costs estimated in the FS. Verification sampling ensures that implementation of the remedial alternative meets remedial goals. Sampling will be conducted to determine the nature and extent of mobile contaminants for protection of groundwater as discussed in Section 3.4.

Table 5-2 summarizes the confirmatory, design, and verification sampling requirements.

To ensure that contamination at the primary sites was appropriately extrapolated to the similar sites, 13 of the 16 waste sites will have supplemental data collected. The two sites in the Settling Tanks Waste Group are assumed to not require sampling. This sampling is described as follows:

- Confirmatory sampling as part of the Barrier, ISV, and RTD alternatives: This sampling will consist of one boring to a maximum depth of 22 m (75 ft), with soil samples collected every 1.5 m (5 ft) and tested for full suite analytical constituents. Appendix D of this document presents the costs for this sampling. This data will be used to confirm that the remedy selected is appropriate for the site and to evaluate the impact to ecological receptors.

- Nature and extent sampling for groundwater protection will ensure mobile contaminants will not reach the groundwater: This sampling will consist of five boreholes for each waste site, installed to a maximum depth of 22 m (75 ft), with soil samples collected every 1.5 m (5 ft) and tested for full suite analytical constituents. A minimum of 40 percent of the boreholes (two per waste site) will be collected in the most contaminated portions of the waste site. Appendix I of this document presents the costs for this sampling.

- Design and verification sampling requirements will be determined in the RD/RA work plan.

Sites considered for no action or continuation of existing conditions augmented by ICs may not need verification sampling depending on the amount, type, and quality of data available to support these decisions. CERCLA operations and maintenance sampling could include the monitoring of natural attenuation and performance monitoring of the engineered barrier.

Table 5-2. Future Sampling

	Confirmatory Sampling[a]		Design Sampling[a]	Verification Sampling[b]			Groundwater Protection
Alternative	**Confirm Appropriate Remedial Action**	**Ecological Sampling**	**Extent of Contamination**	**Verify No Action Alternative**	**Ecological Sampling**	**Verify RAO Attainment**	**Nature and Extent of Mobile Constituents**
No Action				X	X	X	
Alternative 1—Engineered Barrier							
Primary Site		X	X		X	X	X
Other Sites	X	X	X		X	X	X
Alternative 2—In Situ Vitrification							
Primary Site		X	X		X	X	X
Other Sites	X	X	X		X	X	X
Alternative 3—Remove, Treat, Dispose							
Primary Site		X	X		X	X	X
Other Sites	X	X	X		X	X	X

a. Confirmatory and design sampling can be conducted before or after the ROD.

b. Verification sampling is typically conducted after the ROD; however, as appropriate it may be conducted before the ROD.

5.2.1.5 Process Waste Pipelines

Process waste pipelines typically made of vitrified clay pipe or SST conveyed the liquid wastes to the 200-PW-1, 200-PW-3, and 200-PW-6 OU waste sites. Although many of these pipelines are within the 200-IS-1 OU, the interface boundary between these OUs is somewhat different depending on the remedial alternative. Regardless of the alternative, any 200-PW-1, 200-PW-3, or 200-PW-6 process waste pipeline not associated with the 200-IS-1 OU will be remediated in conjunction with the waste unit remediation. Appendix H contains a pipeline assessment discussion that evaluates remedial alternatives for these pipelines.

5.2.1.6 Well Decommissioning

Most of the waste sites are monitored with adjacent vadose zone and/or groundwater monitoring wells. During remedial design, any wells that cannot be integrated into a remedial alternative selected as the

remedy for that waste site will need to be properly decommissioned. Decommissioning would be conducted in accordance with the substantive requirements of the applicable portions of WAC 173-160-381, "Minimum Standards for Construction and Maintenance of Wells," "What are the Standards for Decommissioning a Well?" This FS assumes well decommissioning would not begin until expanded SVE operations were completed at the three 200-PW-1 OU waste sites, but the sequence of remedial actions will be developed during remedial design.

5.2.1.7 Environmental Surveillance and Groundwater Monitoring

For remedial alternatives that leave residual contamination at a waste site above risk levels, environmental surveillance and groundwater monitoring will help ensure the remedy is protective of HHE. These monitoring activities will be site-specific to a large extent, because they will address the risks and final COPCs identified at each waste site and the remedy that is implemented. Specific monitoring plans will be developed in conjunction with the remedial design.

Each alternative, including the No Action Alternative, would include groundwater monitoring to provide ongoing assessment for impacts from a waste site or group of waste sites. Implementation of the sitewide groundwater monitoring requirements that are outlined in DOE/RL-89-12, *Hanford Site Groundwater Protection Management Plan*, and DOE/RL-91-50, *Environmental Monitoring Plan United States Department of Energy Richland Operations Office*, is described in PNNL-11989, *Integrated Monitoring Plan for the Hanford Groundwater Monitoring Project*. This plan includes a description of the monitoring well networks, constituents, sampling frequencies, and criteria used to design the monitoring program; identifies federal and state groundwater monitoring requirements and regulations; and provides a list of wells, constituents, and sampling frequencies for groundwater monitoring conducted on the Hanford Site. Federal and state regulations include RCRA, CERCLA, and the WAC. Groundwater monitoring for groundwater OUs associated with the 200-PW-1, 200-PW-3, and 200-PW-6 OUs is incorporated and described in PNNL-SA-32196, *Apex-3D: Activity Prediction Expert System with 3D QSAR*; thus, no new groundwater monitoring components are required. Any changes to the monitoring approach would be defined during the remedial design phase.

The groundwater monitoring to assess future groundwater impacts from the 200-PW-1, 200-PW-3, 200-PW-6 OU waste sites will be integrated with the respective groundwater OUs. For instance, the selected remedy for the 200-ZP-1 Groundwater OU is estimated to require 125 years to achieve cleanup levels (EPA et al., 2008) and groundwater monitoring during that time period is expected to be a 200-ZP-1 OU activity. However, because of the long half-lives of some radionuclides at the 200-PW-1 and 200-PW-6 OU waste sites, monitoring may be needed for a longer time period. For the purpose of this FS, the long-term groundwater monitoring and ICs have a duration of up to 1,000 years in order to develop cost estimates for these remedy components. After the 200-ZP-1 OU cleanup levels have been achieved, it is anticipated the long-term groundwater monitoring would become part of the overlying vadose zone OU activities.

5.2.1.8 Nuclear Safety

The current nuclear safety authorization basis for waste sites with significant plutonium inventories (e.g., 216-Z-1A, 216-Z-9, and others) does not include remedial activities for these waste sites. Therefore, any remedial action at these sites would require an updated safety evaluation. Remedial actions that involve penetrating the ground surface (e.g., excavation or ISV) will require preparation of a new documented safety analysis (DSA) before the remedial actions are implemented, which would be prepared as part of the remedial design.

The nuclear safety analysis process includes hazard evaluations at conceptual, preliminary, and final design, accident analysis, preliminary DSA, and a DSA to support design, construction/fabrication, and

operations of the selected remedial alternative for a waste site. In addition, a criticality evaluation is required to ensure that modifications to the current configuration of the radionuclides in the waste site will not cause a criticality (uncontrolled nuclear reaction).

Remedial alternatives that are not considered intrusive would be evaluated through a nuclear safety screening process to determine whether they were adequately addressed by the approved DSA. Thus, all but the No Action Alternative would require some level of evaluation with respect to nuclear safety concerns before they were implemented. The level of effort necessary, and the associated costs, were not quantified in the FS but likely would be much greater for the more intrusive remedies.

5.2.1.9 Monitored Natural Attenuation

The primary risk driver at the 200-PW-3 OU waste sites is cesium-137. This radionuclide has a half-life of approximately 30 years, so natural radiological decay can achieve substantial reductions in contaminant mass in a relatively short period of time (e.g., MNA processes will eliminate more than 96 percent of the current cesium-137 mass by the year 2150). Based on the risk assessment results for the 216-A-8 Crib, the cancer risk to future populations under the unrestricted land use scenario would be below 10^{-4} in about 350 years due to the natural radiological decay of cesium-137. MNA of cesium-137 at the 200-PW-3 OU waste sites is a key component of several remedial alternatives. For remedial alternatives at the 200-PW-3 OU waste sites that leave residual contamination above risk levels, an IC period of 350 years was used to prepare the cost estimates.

5.2.2 Alternative 1—Barrier

This alternative provides no treatment, but prevents and controls exposure to hazardous substances through engineering controls and ICs to protect HHE. Two process options are considered for this alternative—a monofill ET barrier (ET barrier) and a physical barrier.

5.2.2.1 Monofill ET Barrier

An ET barrier would be installed over a waste site to limit infiltration and provide an added level of protection to HHE. The ET barrier would overlie the source area, and because some contaminants are relatively deep, it would extend some distance beyond the footprint of the contaminated soils, to protect against the lateral migration of infiltrating water. A generic overhang of 6.1 m (20 ft) is used in this FS to develop cost estimates for this alternative.

There is a possibility that contamination could be shallower than 4.6 m (15 ft) due to standing water accumulation in the waste units partitioning the contamination into the sidewalls of the waste unit and/or residual contamination in the gravels in which the waste distribution pipe is bedded. It would be expected that this contamination would not spread laterally to a significant extent. If a remedy selected required covering of the waste site, the barrier would overlap the sidewall contamination; thus, the potential for direct contact human health risk or for ecological risk would be eliminated.

The ET barriers contain a thick soil layer with a vegetated surface. ET barriers are designed to manage the water balance of the capped area such that deep infiltration through the barrier to underlying contaminated soil is minimized. Precipitation onto the barrier that does not run off is stored within the porosity of the thick soil layer. Soil moisture stored at shallow depths in the barrier profile can be removed by direct evaporation, while deeper soil moisture can be removed by barrier vegetation transpiration demand during the growing season.

The ET barrier exploits the high evaporation and transpiration demands exerted by arid and semiarid climates and native plants to maintain low soil moisture contents, thereby minimizing unsaturated hydraulic conductivity and infiltration. The soil layer serves to store water and sustain plants during dry

periods and also during periods when plants are inactive. Figure 5-1 shows the conceptual design of a monofill ET barrier, which includes a biobarrier that would only be applied to waste sites with residual contamination within 4.6 m (15 ft) of the ground surface that is above risk levels.

Several features would be incorporated into the ET barrier to protect the topsoil component from erosion. The top layer includes a mixture of pea gravel that will assist in armoring the barrier surface to protect it from wind erosion. Native vegetation will be established on the cover surface to further assist in reducing soil loss from wind and water erosion. The barrier design includes sufficiently thick soil layers to provide performance margins against long-term wind or water erosion (EDF-RWMC-523, *Evaluation of Engineered Barriers for Closure Cover of the RWMC SDA*).

A key design element for an ET barrier is to limit natural infiltration through the barrier materials so long-term infiltration rates will be maintained below a target value of 3 mm/yr (1/8 in./yr). This target infiltration rate is consistent with the approach EPA is currently using in identifying the equivalent performance to conventional RCRA Subtitle C covers (EPA 542-F-03-015). Evapotranspiration barriers have been demonstrated to provide infiltration control equivalent to RCRA Subtitle C barriers under some conditions (ITRC, 2003, *Technology Overview Using Case Studies of Alternative Landfill Technologies and Associated Regulatory Topics*; EGG-WM-10974, *A Simulation Study of Moisture Movement in Proposed Barriers for the Subsurface Disposal Area*). Evapotranspiration barriers would effectively reduce direct radiation exposures to future workers and reduce subsurface infiltration to ensure compliance with RAO No. 2.

5.2.2.2 Physical Barrier

For waste sites with long-lived plutonium and americium contamination, a physical barrier component is incorporated into the ET barrier. The purpose of the physical barrier component is to impede and warn future workers (driller or excavator) with durable materials that are significantly different than the surrounding native soils. Encountering these unexpected durable materials that are difficult to penetrate in the shallow subsurface would provide warning that subsurface conditions are not the same as the surrounding native soils.

Figure 5-2 shows the conceptual design of an ET barrier with a physical barrier component. The physical barrier component is a 1.3 m (4 ft) thick layer of coarse fractured basalt rock with no fine-grained soils. The top 0.3 m (1 ft) would be mixed with crushed rock to prevent the overlying soils from filling in the spaces between the basalt rocks. The fractured basalt is an effective barrier to burrowing, digging, and well drilling. It also creates a dry rocky environment that is not conducive to root penetration. The basalt would be overlain by engineering fill and then a silt layer, a silt and pea gravel layer that is planted with native vegetation, and the side slopes of the barrier would be protected with basalt rock and silt to prevent erosion.

Four of the waste sites (216-Z-1&2, 216-Z-3, 216-Z-5, and 216-Z-9) contain voids as part of their construction. As part of the barrier alternative at these waste sites, the voids would be backfilled with CDF, a flowable cement product. Optimal formulation(s) and placement of the CDF would be determined during remedial design. For the 216-Z-1&2 and 216-Z-9 sites, the CDF backfill would form a physical barrier 4.3 to 6.4 m (14 to 21 ft) thick. This thick CDF layer would replace the basalt layer in the barrier alternative at these sites.

The 216-Z-9 Trench also includes abovegrade and belowgrade structures and equipment constructed to support the soil mining conducted from 1976 to 1977. Alternative 1 at this site includes the removal and disposal of the abovegrade structures, but the belowgrade structures and equipment would be left in place and encased by the CDF backfill.

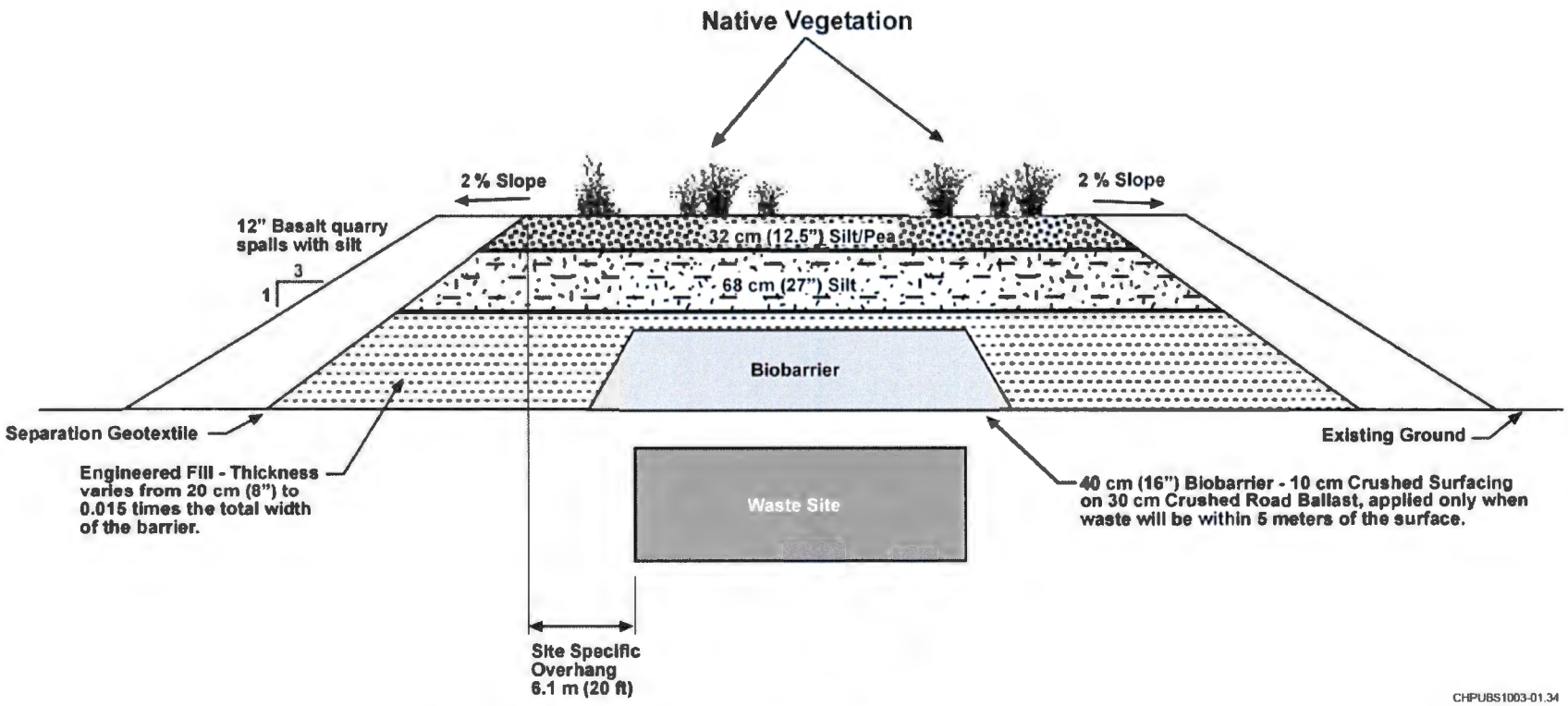


Figure 5-1. Conceptual Design of Alternative 1 Monofill Evapotranspiration Barrier

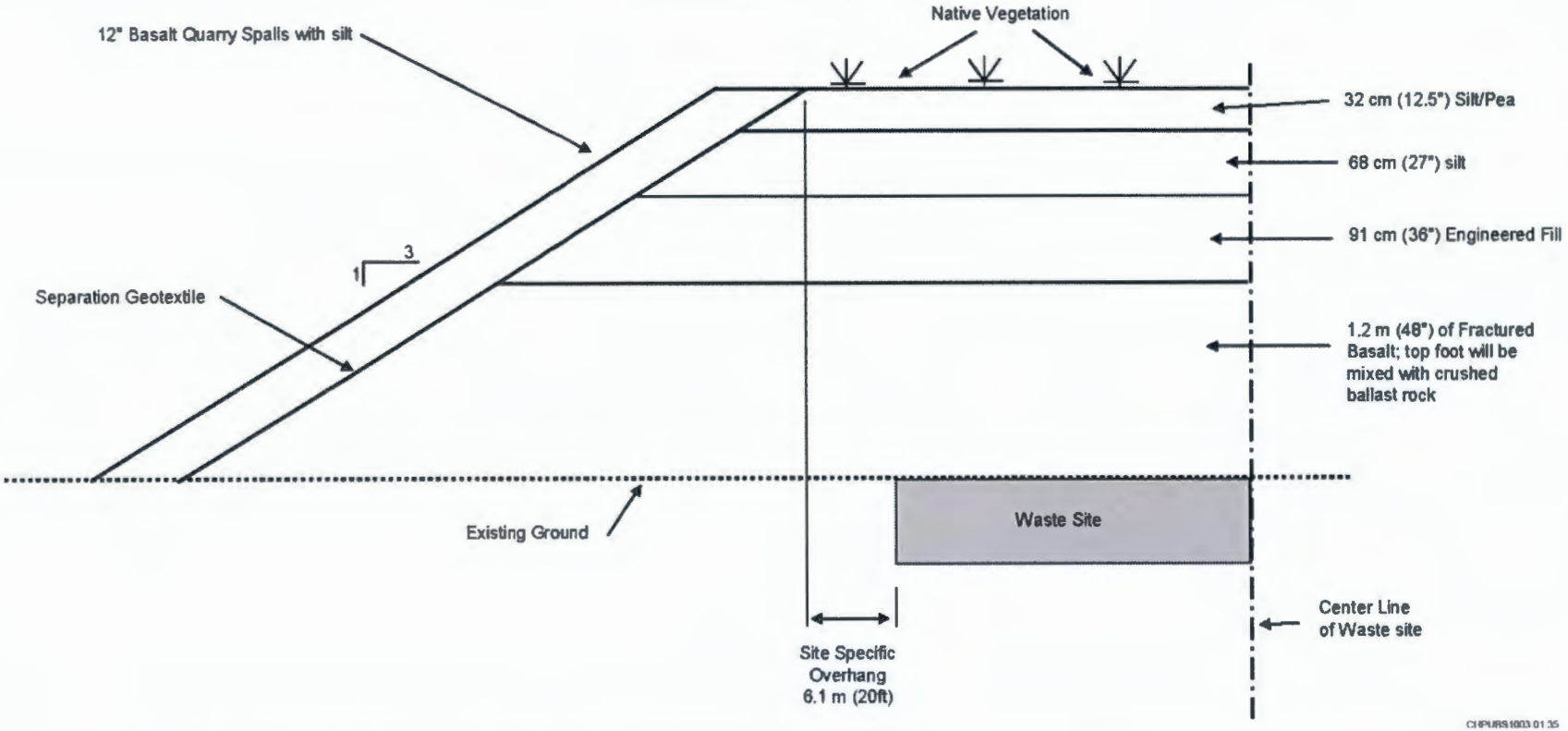


Figure 5-2. Conceptual Design of a Monofill Evapotranspiration Barrier with a Physical Barrier Component (Alternative 1)

5.2.3 Alternative 2—In Situ Vitrification

This alternative uses ISV to reduce the mobility of hazardous substances as a principal element. ISV uses an electric current to melt soil or other media at extremely high temperatures (1,600 to 2,000°C or 2,900 to 3,650°F). Radionuclides and other pollutants are immobilized within the vitrified glass, a chemically stable, leach-resistant material similar to obsidian or basalt rock. A vacuum hood is placed over the treated area to collect off-gases, which are treated before release. It is primarily considered applicable for the High-Salt and Low-Salt waste sites that contain plutonium and americium. ICs are also a component of this alternative at waste sites where the ISV process leaves residual contamination at a waste site that will require long-term controls. Figure 5-3 shows the conceptual schematic for ISV at the 216-Z-9 Trench.

The actual configuration and number of melts needed at each waste site would be determined during remedial design. The concrete cover and support columns at the 216-Z-9 Trench, as well as the abovegrade and belowgrade structures and equipment used for the 1976 to 1977 soil mining would need to be removed before ISV. At waste sites constructed of timbers and other flammable materials (216-Z-1&2 and 216-Z-5) partial excavation to remove these materials would be needed before ISV. Partial excavation at the 216-Z-3 Crib to collapse the culvert prior to ISV is also included in this alternative.

After any site-specific preparations have been conducted, as noted previously, the waste site would be covered by approximately 1.5 m (5 ft) of compacted clean sand to accommodate the melt-induced subsidence. Placement of the sand fill accomplishes the following:

- Covers the waste site to enhance radiological safety.
- Provides overburden material to compensate for the volume reduction of the treated soil due to vitrification (site soils have up to 30 percent void space; glass has none).
- Enhances radionuclide retention in the glass due to a sand filter effect (description follows):
  - **Sand filter effect.** Under normal melting conditions, some radionuclides exhibit a degree of volatility. The fraction that volatilizes typically moves upward in the soil column and condenses in the overlying sand. The sand above the melt moves downward, because of melt-generated subsidence, and is gradually incorporated into the melt during the process. Although the volatile species will continue to volatilize and then re-condense as the melt incorporates more and more of the overlying sand, a net decrease is seen over time as the cover soil eventually will be incorporated into the melt. The same is true for organic constituents that may re-condense in the sand cover material. As the cover soil moves downward, these organic species are carried into the thermally hot region where reactions such as catalytic dechlorination or pyrolysis can occur.

Subsequent pre-melt operations include electrode emplacement, starter-path injection, hood placement, electrical installation, and other support activities. The approximate electrode separation, melt size, and treatment depth envisioned for the ISV alternative have all been achieved in the past during radioactive soil remediation projects, notably at Los Alamos National Laboratory in 2000 (LA-UR-03-6494). As such, the process does not require scale-up for this alternative.

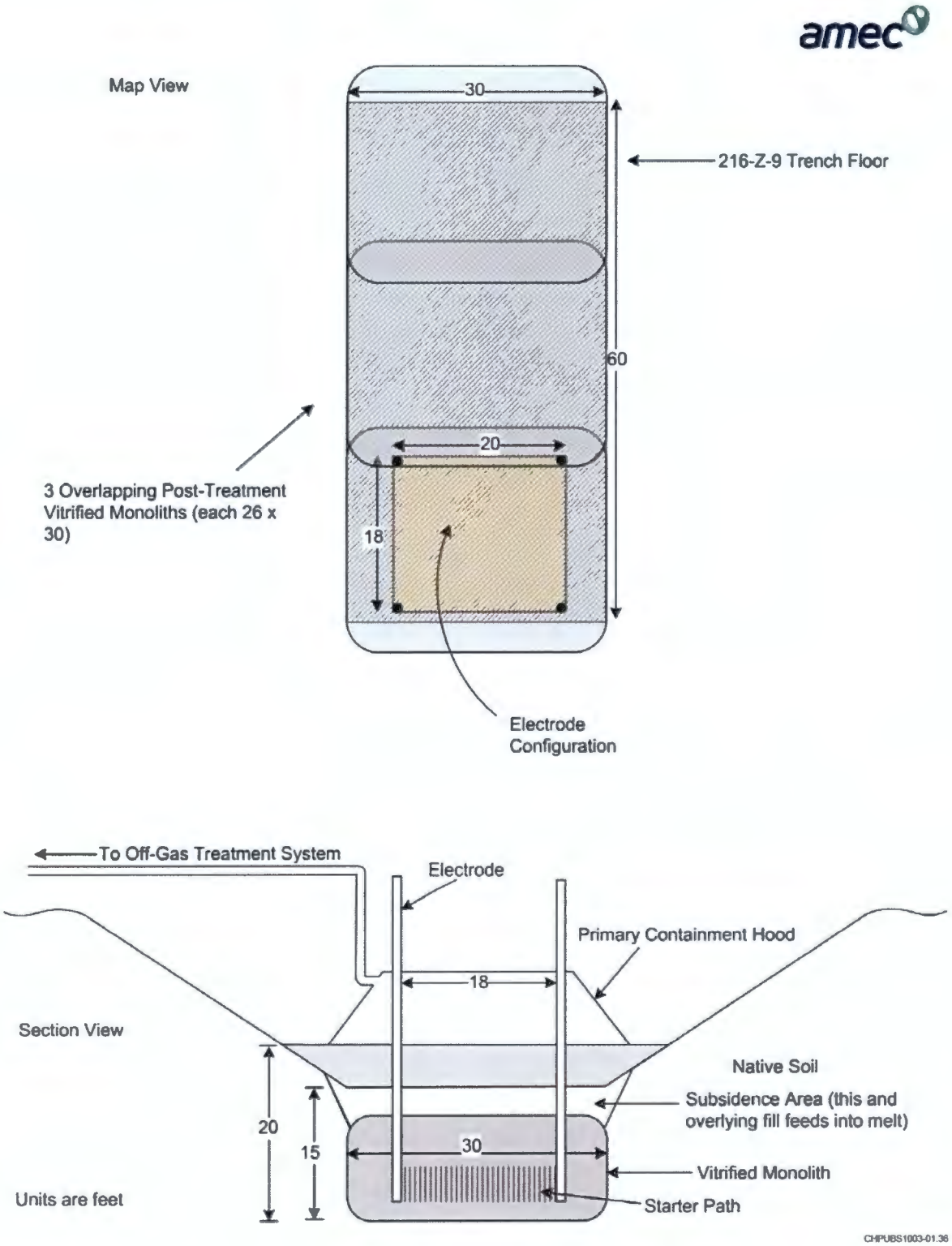


Figure 5-3. Conceptual Schematic: Alternative 2—In Situ Vitrification at the 216-Z-9 Trench

In general, the contaminated soils targeted for ISV are those from the base of a waste site to about 4.6 m (15 ft) below the base and over the entire footprint of the waste site base. For example, this would entail approximately three melts at the 216-Z-9 Trench (Figure 5-3) to cover the base of the waste site. These melts would be arranged to overlap, ensuring complete treatment of the trench floor area. Many GeoMelt projects have routinely involved overlapping melts. The starter path for each electrode pair would be remotely injected to a depth of approximately 3 to 4.6 m (10 to 15 ft) below the base of a waste site. For the purposes of the FS, it is assumed each melt would be advanced to a minimum of 4.6 m (15 ft) below the surface of the clean compacted fill. Previous GeoMelt SPV projects have achieved melt depths in excess of 7.6 m (25 ft).

After the melt operations are complete, the result would be a durable glass monolith, roughly 4 to 5 m (12 to 16 ft) thick (because of loss of pore space), with a lateral dimension of the base of the waste site. The volume reduction resulting from the melting process would result in a glass monolith that is approximately 60 percent of the volume of the original contaminated soil and cover soil in the treatment area. The subsidence area at each ISV site would be backfilled with clean fill to match the surrounding grade and the surface plus any disturbed areas would be replanted with native vegetation.

Plutonium oxide has a fairly high solubility limit in most glasses, in the range of 2 to 5 weight percent. Various programs under the DOE Office of Fissile Materials Disposition have achieved up to 10 weight percent plutonium in certain glass formulations (PNNL-11346). Based on an estimate of 48 kg (106 lb) of plutonium remaining in the soils at the base of the 216-Z-9 Trench (DOE/RL-2006-51), the glass monolith would contain on the order of 0.003 weight percent of plutonium.

The estimated duration to complete each melt is 8 to 9 days, based on a processing rate of approximately 70 metric tons (77 tons) per day. This estimate is based on the melt rate achieved in 1987 at the 216-Z-12 Crib using the older top-down melting approach, and does not account for the significant process improvements of the past 20 years.

Some of the advantages of the ISV alternative include the following:

- The relatively uniform distribution of contaminants in the glass may be an ideal final configuration with respect to concerns about nuclear safety and potential future use in weapons.
- The majority of the alpha emitters would be encapsulated within the glass, and pose no direct contact risk. Minor concentrations that remained on the exterior of the glass monolith would pose only moderate risks because the dispersion and inhalation exposure pathways are greatly reduced. In a previous glass removal operation after ISV, plutonium contamination immobilized in the glass was nonsmearable and there was no detectable airborne plutonium.
- The glass monolith would create a substantial physical barrier, inhibiting human and biological intrusion into any residual contamination at depth beneath the treated soils.
- The ISV process generates a relatively small volume of regulated waste, very little waste would require offsite disposal.

5.2.4 Alternative 3—Removal, Treatment, and Disposal

This alternative removes waste site soil, sludge, and/or debris, treating it as necessary to meet ARARs, and disposing of it in an onsite (ERDF) or offsite (WIPP) disposal facility as appropriate. Five RTD options were developed to achieve different removal objectives, from partial removal of the highest contaminant concentrations to removal of concentrations that pose greater than a 10^{-4} risk level. A description of these RTD options and the approximate soil removal depth for each option at each waste

site follows. For the RTD options that leave residual contamination above risk levels, ICs and ET barriers are incorporated as remedy components to protect HHE.

The process option selected to represent the excavation technology in this alternative is conventional excavation because it is effective for removing contaminated soils, readily implementable without the need for special contractors or equipment, and the least costly of the excavation technologies. Conventional excavation uses standard earth-moving equipment such as excavators, front end loaders, and haul trucks, to remove contaminated soils from the waste sites, place those soils in appropriate waste containers, and haul the waste containers to an appropriate waste disposal facility. Conventional excavation would typically use a side slope angle of 1V:1.5H to maintain stability in the unconsolidated sand and gravel at the waste sites. Benching, a stair-step pattern of side slopes and horizontal working surfaces (benches), would likely be required for the deeper excavations and is typically used in open pit mining, as it is the least costly method of excavation. If an RTD alternative is selected for a waste site where conventional excavation may not be feasible because of the proximity of adjacent waste sites or facilities, other process options from the deep excavation technology may need to be used.
The excavation methods and details of any RTD alternative selected for a waste site would be developed during remedial design.

Conceptually, the RTD process for this alternative consists of the following five steps:

1. Remove and stockpile clean overburden for use in backfilling
2. Remove contaminated soils and debris and place in waste containers
3. Haul waste containers to assay/screening station and then to ERDF or WIPP for disposal
4. Backfill excavation with clean fill and compact
5. Construct ET barrier as necessary and replant surface with native vegetation

Although the contamination for some of the waste sites is deeper than 4.6 m (15 ft), there exists a possibility that contamination could be shallower than 4.6 m (15 ft) due to standing water accumulation in the waste units partitioning the contamination into the sidewalls of the waste unit and/or residual contamination in the gravels in which the waste distribution pipe is bedded. It would be expected that this contamination would not spread laterally to a significant extent. If a remedy were selected that required excavation below 4.6 m (15 ft), the sidewall contamination would be removed during layback excavation of the sidewall soils (1V:1.5H) to reach the deeper contaminated soils. Thus, the potential for direct contact human health risk or for ecological risk would be eliminated.

Because the 200-PW-1 and 200-PW-6 waste sites contain large quantities of plutonium and americium (which emit alpha radiation) and the 200-PW-3 waste sites contain large quantities of cesium-137 (which emits beta-gamma radiation) special conditions apply when disturbing or handling these contaminated soils. Control of airborne contamination will require engineering controls such as water misting and appropriate personal protective equipment for remedial action workers. For the 200-PW-1 and 200-PW-6 waste sites, this FS assumes the excavation and waste container packaging will be performed inside a portable enclosure. In addition, radiation rates to workers from the contaminated soils in the excavation and from the full waste containers will limit the excavation rate and the amount of contaminated soil that can be placed in each waste container. For example, the estimated rates from excavation at the 216-A-8 Crib would require mixing two parts of clean soil with one part of contaminated soil using shielded, long-reach excavators to maintain safe radiation rates to workers. Appendix D includes a discussion of the details of these considerations and others that were used to develop the cost estimates for the RTD alternative.

Excavated soils containing greater than 100 nCi/g of transuranic radionuclides will be loaded into SWBs assuming 1.5 yd^3 (1.14 ft^3) per SWB due to weight limits. Nondestructive analysis (NDA) of soil and sludge in SWBs has been accomplished at other DOE sites and could be performed at the Hanford Site. The FS assumes that NDA of soil placed in SWBs would use the Super High Efficiency Neutron Coincidence counters at a waste management facility on the Central Plateau with eventual shipment of the SWBs to WIPP for disposal. Depending on the specific NDA counter used and the volume/density of soil placed in each SWB, some surrogate testing or calibration may be needed for WIPP certification.

Five RTD options were developed to satisfy and permit evaluation of different removal objectives (in Chapter 6):

1. Option 3A—Remove the highest concentrations of contaminated soils to 0.6 m (2 ft) below the base of a waste site.
2. Option 3B—Remove contaminated soils that could be a direct contact risk to industrial workers and that are less than 4.6 m (15 ft) below the current ground surface.
3. Option 3C—Remove a significant portion of plutonium contamination based on an evaluation of soil contaminant concentration with depth. A significant portion of cesium-137 contamination would be removed at the cesium-137 waste sites based on a similar evaluation.
4. Option 3D—Remove contaminated soils containing greater than 100 nCi/g of transuranic radionuclides.
5. Option 3E—Remove contaminated soils with greater than a 10^{-4} risk level so long-term ICs at a waste site are not necessary.

The five RTD options are not all applicable to every waste site. The waste site construction information, soil sample results, borehole geophysical logging results, and contaminant distribution model details summarized in the RI report (DOE/RL-2006-51) and shown in Figures 2-3 through 2-18 were used to develop removal depths for each waste site. The Option 3A removal depth of 0.6 m (2 ft) beneath the base of a waste site is based on the 1976 to 1977 mining results at the 216-Z-9 Trench (Chapter 2). The mining removed the upper 0.3 m (1 ft) of soil from the floor of the trench and an estimated 58 kg (128 lb) of plutonium. Removing 0.6 m (2 ft) would likely remove the highest contaminant concentrations at a waste site. Plots of soil contaminant concentration with depth were prepared for the plutonium concentrations in the 200-PW-1 OU High-Salt waste sites (represented by the 216-Z-1A Tile Field [Figure 5-4]) and the 200-PW-1 OU Low-Salt waste sites (represented by the 216-Z-12 Crib [Figure 5-5]). These plots are the basis of the depth for removal of a significant portion of plutonium contamination at these waste site groups. The evaluation of risk reduction with removal depth at three waste sites, 216-Z-1A, 216-Z-9, and 216-Z-12, is presented in Appendix F. That evaluation indicated that in order to reduce the risk to future populations under the unrestricted land use scenario from contaminated soils to less than 10^{-4} would require removal of all soils down to 27.4 m (90 ft) bgs at the 216-Z-1A Tile Field (e.g., High-Salt waste sites) and down to 7.6 m (25 ft) bgs at the 216-Z-12 Crib (e.g., Low-Salt waste sites). Using the information described previously, the summary of removal depths for the applicable RTD options for each waste site is shown in Table 5-3. Figure 5-6 shows the conceptual design of RTD Option 3A for one of the 216-Z-18 Cribs.

Two of the waste sites contain sludge primarily contaminated with plutonium and americium. The 241-Z-8 Settling Tank contains approximately 1,890 L (500 gal) of sludge and the 241-Z-361 Settling Tank contains approximately 800 L (200 gal) of liquid and 75 m^3 (98 yd^3) of sludge. A previous engineering evaluation, DOE/RL-2003-52, identified potential remedial technologies for the 241-Z-361 Settling Tank, developed and evaluated the reasonable alternatives (based on effectiveness, implementability, and cost), and recommended a specific removal alternative. The alternative recommended in that study is carried forward in this FS as the removal alternative for the sludge in the two settling tanks.

Sludge removal in the two tanks would employ a Power Fluidics system to loosen and homogenize the sludge, and transfer it to SWBs. WaterWorks SP-400 Superabsorbent Crystals, a polymer absorbent, would be added to the SWBs to absorb residual liquids and stabilize the sludge. The SWBs would then be transported to the CWC for storage, pending waste disposition. Based on the available data, the retrieved sludge will likely designate as transuranic waste or mixed transuranic waste. If so, these SWBs would then be transported to WIPP for disposal. Once the sludge has been removed from these two tanks, the empty tanks would be backfilled with CDF to eliminate any future settlement or collapse issues.

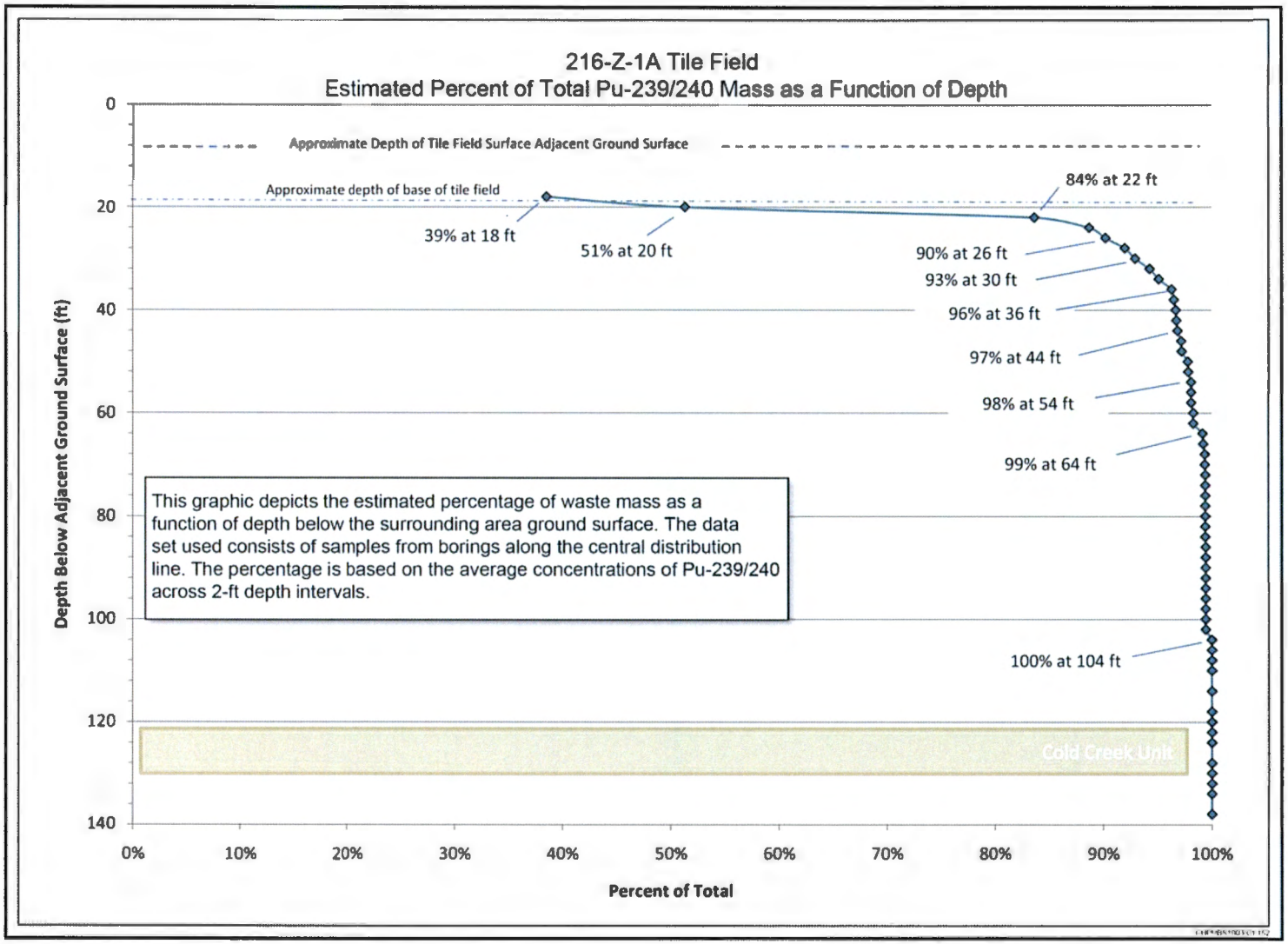


Figure 5-4. Plutonium Mass with Depth Beneath the 216-Z-1A Tile Field (High-Salt Waste Group)

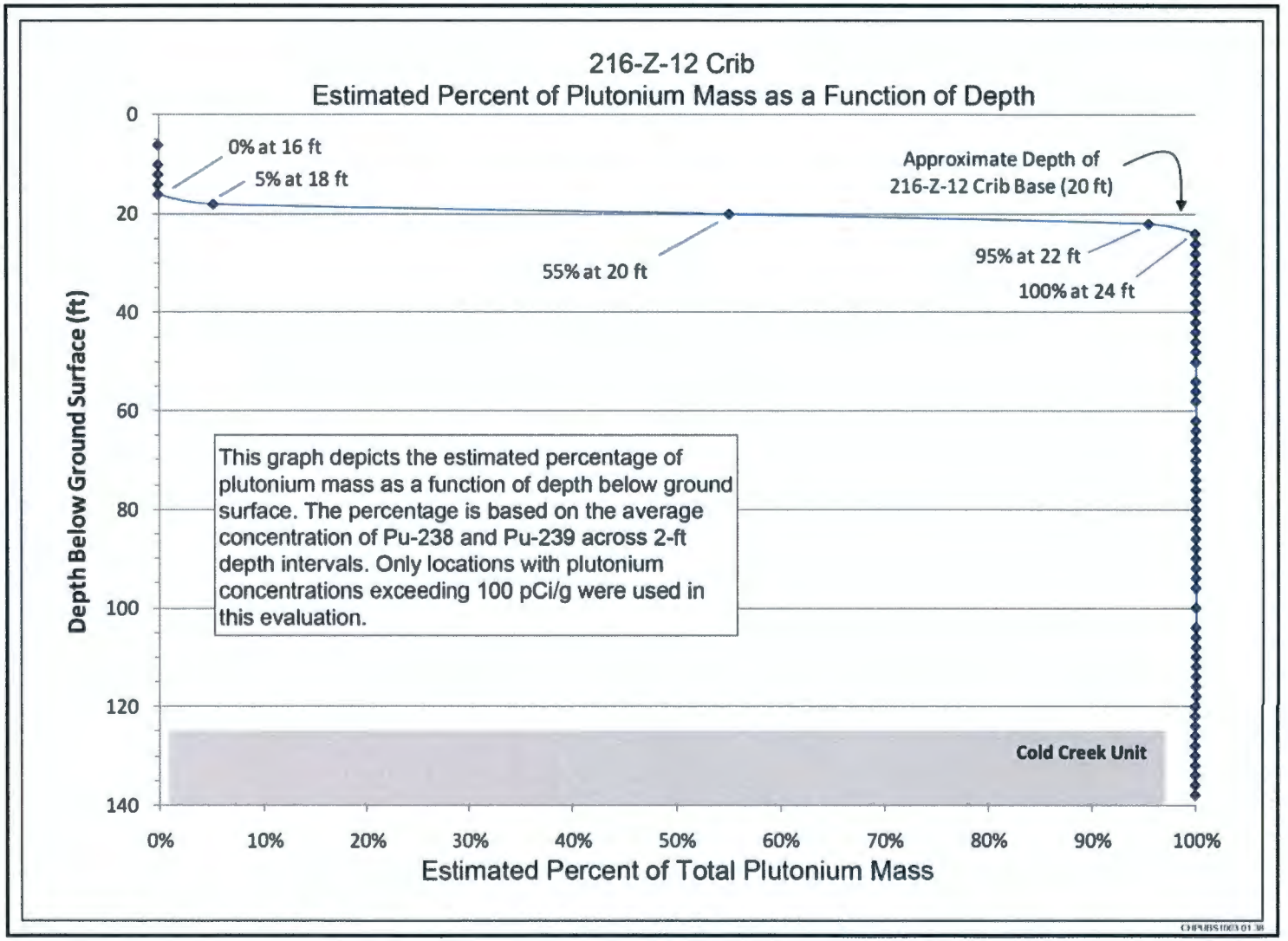


Figure 5-5. Plutonium Mass with Depth Beneath the 216-Z-12 Crib (Low-Salt Waste Group)

Table 5-3. Summary of Material Removal Depths for the RTD Options at the 200-PW-1, 200-PW-3, 200-PW-6 OU Waste Sites

Waste Site	Removal Depth for RTD Options, m (ft) Below Current Ground Surface				
	3A	3B	3C	3D	3E
200-PW-1 Operable Unit					
216-Z-1A	6.1 (20)	7 (23)	11 (36)	31.4 (103)	27.4 (90)
216-Z-1&2	7 (23)	NA1	7.6 (25)	7.6 (25)	7.6 (25)
216-Z-3	9.5 (31)	NA1	10.1 (33)	10.1 (33)	10.1 (33)
216-Z-9	7 (23)	NA1	11 (36)	36.6 (120)	27.4 (90)
216-Z-12	6.7 (22)	NA1	7.3 (24)	7.3 (24)	7.3 (24)
216-Z-18	6.1 (20)	NA1	11 (36)	31.4 (103)	27.4 (90)
241-Z-361	Remove sludge from settling tank and backfill.				
200-PW-3 Operable Unit					
216-A-7	NA2	4.6 (15)	6.1 (20)	NA2	NA2
216-A-8	NA2	4.6 (15)	7 (23)	NA2	NA2
216-A-24	NA2	NA2	6.1 (20)	NA2	NA2
UPR-200-E-56	NA2	4.6 (15)	6.1 (20)	NA2	NA2
216-A-31	NA2	NA2	8.5 (28)	NA2	NA2
200-PW-6 Operable Unit					
216-Z-5	6.1 (20)	NA1	6.7 (22)	6.7 (22)	6.7 (22)
216-Z-8	NA3	NA3	NA3	NA3	NA3
216-Z-10	NA3	NA3	NA3	NA3	NA3
241-Z-8	Remove sludge from settling tank and backfill.				

Notes:

Option 3A—Remove the highest concentrations of contaminated soils to 0.6 m (2 ft) below the base of a waste site.

Option 3B—Remove contaminated soils that could be a direct contact risk to industrial workers and that are less than 4.6 m (15 ft) below the current ground surface.

Option 3C—Remove a significant portion of plutonium contamination based on an evaluation of soil contaminant concentration with depth. A significant portion of cesium-137 contamination would be removed at the cesium-137 waste sites based on a similar evaluation.

Option 3D—Remove contaminated soils containing greater than 100 nCi/g of transuranic radionuclides.

Option 3E—Remove contaminated soils with greater than a 10^{-4} risk level so that long-term institutional controls at a waste site are not necessary.

NA1 = Not applicable to particular waste site. Five RTD options were developed for the plutonium waste sites. For those plutonium waste sites, RTD Option B was not evaluated where the contamination is deeper than 4.5 mbgs (15 ft bgs).

NA2 = Not applicable to particular waste site. RTD Options 3B and 3C were evaluated for the cesium-137 waste sites, to address cases where contamination is located shallower than 4.5 mbgs (15 ft bgs) and to evaluate removal of the mass of the cesium contamination. Option 3A and 3D were not evaluated because they are only applicable to sites with plutonium waste. Option 3E was not evaluated because minimizing the risk associated with cesium-137 was captured in either Option 3B or 3C.

NA3 = Not applicable for particular waste site. For the 216-Z-8 and 216-Z-10 sites, baseline risks are below the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* risk range; therefore, the RTD options were not evaluated (i.e. NA) at these sites.

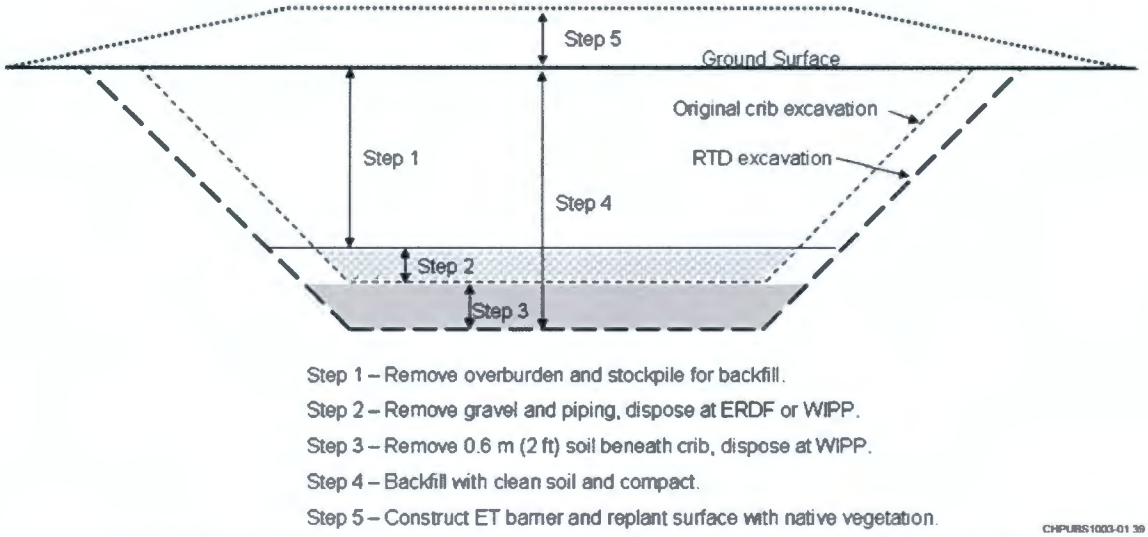


Figure 5-6. Conceptual Design of Alternative 3 Option 3A Removal, Treatment, and Disposal for the 216-Z-18 Crib

6 Detailed Analysis of Alternatives

Each of the remedial alternatives described in Chapter 5 is evaluated in this chapter with respect to specific CERCLA evaluation criteria, as required by 40 CFR 300.430(e)(9). The CERCLA criteria are first identified and defined in Section 6.1. Subsequent sections discuss the detailed analysis of each remedial alternative.

6.1 Description of Evaluation Criteria

The NCP and EPA guidance for conducting the RI/FS (EPA/540/G-89/004) define the nine CERCLA evaluation criteria to address the statutory requirements and the technical and policy considerations important to selecting remedial alternatives. These criteria serve as the basis for conducting the detailed and comparative analyses and, subsequently, for selection of appropriate remedial actions in a ROD.

The nine CERCLA evaluation criteria are grouped into three categories as follows:

- Threshold criteria
  - Overall protection of HHE
  - Compliance with ARARs
- Balancing criteria
  - Long-term effectiveness and permanence
  - Reduction of toxicity, mobility, or volume through treatment
  - Short-term effectiveness
  - Implementability
  - Cost
- Modifying criteria
  - State acceptance
  - Community acceptance.

Threshold criteria constitute the statutory requirements for the remedial action. Only alternatives that meet both threshold criteria are eligible for selection as a remedy.

Each alternative is then evaluated with respect to the five balancing criteria. The evaluation process is consistent and to a similar level of detail for each alternative to allow meaningful comparison of the alternatives during the comparative analysis (discussed in Chapter 7).

The two modifying criteria are not formally addressed in the FS. Although there is interaction with the stakeholders during the RI/FS process, the modifying criteria are formally addressed through the preparation of two post-FS documents. State acceptance is achieved through the process that generates the Proposed Plan, which identifies the Preferred Remedy (or remedies). Community acceptance is formally addressed by the responsiveness summary in the ROD, which documents and addresses public comments submitted on the Proposed Plan and the Preferred Remedy.

In addition to the CERCLA criteria, NEPA values (e.g., analysis of cumulative offsite ecological and socioeconomic impacts of the remedial alternatives) also are considered. Specific consideration of NEPA values is driven by Section 5(a)(13) of DOE O 451.1B Chg 1, *National Environmental Policy Act*

Compliance Program; and Cook, 2002, "DOE Policies on Application of NEPA to CERCLA and RCRA Cleanup Actions," is discussed in Section 6.6.

6.1.1 Overall Protection of Human Health and the Environment

This evaluation criterion provides a final check to assess whether each alternative provides adequate protection of HHE. The overall assessment of protection draws on the assessments conducted under other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

Evaluation of the overall protectiveness of an alternative focuses on whether a specific alternative achieves adequate protection and should describe how site risks posed through each pathway being addressed by the FS are eliminated, reduced, or controlled through treatment, engineering, or institutional controls. This evaluation also allows for consideration of whether an alternative poses any unacceptable short-term or cross-media impacts (e.g., soil cleanup actions that could impact air quality or groundwater quality).

6.1.2 Compliance with Applicable or Relevant and Appropriate Requirements

This evaluation criterion is used to determine whether each alternative will meet all of its federal and state ARARs (as defined in CERCLA Section 121) that have been identified during the RI/FS process. The detailed analysis summarizes which requirements are applicable or relevant and appropriate to an alternative and describes how the alternative meets these requirements. When an ARAR is not met, the basis for justifying one of the six waivers allowed under CERCLA and the NCP (40 CFR 300.430[f][1][ii][C]) should be discussed.

Appendix C discusses the ARARs identified for the 200-PW-1, 200-PW-3, and 200-PW-6 OUs.

6.1.3 Long-Term Effectiveness and Permanence

This criterion addresses the expected results of a remedial action in terms of the risk remaining at the site after the response objectives have been met. The primary focus of this evaluation is the extent and effectiveness of the controls that may be required to manage the risk posed by treatment residuals and/or untreated wastes. The following components of the criterion should be addressed for each alternative:

- Magnitude of residual risk—This factor assesses the residual risk remaining from untreated waste or treatment residuals at the conclusion of remedial activities. The potential for this risk may be measured by numerical standards such as cancer risk levels or the volume or concentration of contaminants in waste, media, or treatment residuals remaining on the site. The characteristics of the residuals should be considered to the degree that they remain hazardous, taking into account their volume, toxicity, mobility, and propensity to bioaccumulate.

- Adequacy and reliability of controls—This factor assesses the adequacy and suitability of controls, if any, that are used to manage treatment residuals or untreated wastes that remain at the site. It may include an assessment of containment systems and institutional controls to determine if they are sufficient to ensure any exposure to human and environmental receptors is within protective levels. This factor also addresses the long-term reliability of management controls for providing continued protection from residuals. It includes the assessment of the potential need to replace technical components of the alternative, such as a cap, a slurry wall, or a treatment system; and the potential exposure pathway and the risks posed, should the remedial action need replacement.

6.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

This evaluation criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce toxicity, mobility, or volume of the hazardous substances as their principal element. This preference is satisfied when treatment is used to reduce the principal threats at a site through destruction of toxic contaminants, reduction of the total mass of toxic contaminants, irreversible reduction in contaminant mobility, or reduction of total volume of contaminated media.

This evaluation would focus on the following specific factors for a particular remedial alternative:

- The treatment processes the remedy will employ, and the materials they will treat
- The amount of hazardous materials that will be destroyed or treated, including how the principal threat(s) will be addressed
- The degree of expected reduction in toxicity, mobility, or volume measured as a percentage of reduction (or order of magnitude)
- The degree to which the treatment will be irreversible
- The type and quantity of treatment residuals that will remain following treatment
- Whether the alternative would satisfy the statutory preference for treatment as a principal element

In evaluating this criterion, an assessment should be made as to whether treatment is used to reduce principal threats, including the extent to which toxicity, mobility, or volume is reduced either alone or in combination.

6.1.5 Short-Term Effectiveness

This evaluation criterion addresses the effects of the alternative during the construction and implementation phase until remedial response objectives are met (e.g., a cleanup target has been met). Under this criterion, alternatives should be evaluated with respect to their effects on HHE during implementation of the remedial action. The following factors should be addressed as appropriate for each alternative:

- Protection of the community during remedial actions—This aspect of short-term effectiveness addresses any risk that results from implementation of the proposed remedial action, such as dust from excavation, transportation of hazardous materials, or air quality impacts from a stripping tower operation that may affect human health.
- Protection of workers during remedial actions—This factor assesses threats that may be posed to workers and the effectiveness and reliability of protective measures that would be taken.
- Environmental impacts—This factor addresses the potential adverse environmental impacts that may result from the construction and implementation of an alternative and evaluates the reliability of the available mitigation measures in preventing or reducing the potential impacts.
- Time until remedial response objectives are achieved—This factor includes an estimate of time required to achieve protection for either the entire site or the individual elements associated with specific site areas or threats.

6.1.6 Implementability

The implementability criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during its implementation. This criterion involves analysis of the following factors:

- Technical feasibility:
  - Construction and operation—This relates to the technical difficulties and unknowns associated with a technology.
  - Reliability of technology—This focuses on the likelihood that technical problems associated with implementation will lead to schedule delays.
  - Ease of undertaking additional remedial action—This includes a discussion of what, if any, future remedial actions may need to be undertaken and how difficult it would be to implement such additional actions.
  - Monitoring considerations—This addresses the ability to monitor the effectiveness of the remedy and includes an evaluation of the risks of exposure, should monitoring be insufficient to detect a system failure.
- Administrative feasibility:
  - Activities needed to coordinate with other offices and agencies (e.g., obtaining permits for offsite activities or rights-of-way for construction)
  - Availability of services and materials
  - Availability of adequate offsite treatment, storage capacity, and disposal services
  - Availability of necessary equipment and specialists, and provisions to ensure any necessary additional resources
  - Availability of services and materials, plus the potential for obtaining competitive bids, which may be particularly important for innovative technologies
  - Availability of prospective technologies

6.1.7 Cost

This criterion evaluates the cost of implementing a remedial alternative and includes capital costs, annual and periodic O&M costs, and the present worth of the capital and O&M costs.

Capital costs consist of direct (construction) and indirect (non-construction and overhead) costs. Direct costs include expenditures for the equipment, labor, and materials necessary to install remedial actions. Indirect costs include expenditures for engineering, financial, and other services that are not part of actual installation activities but are required to complete the installation of remedial alternatives. Capital costs also include project management and contingency estimates.

Operation and maintenance costs are post-construction costs necessary to ensure the continued effectiveness of a remedial action and may be either annual or periodic. Periodic costs include CERCLA 5-year reviews for sites where contamination remains above risk-based levels.

The cost estimates are presented in Appendix D and were developed in accordance with guidance specified in EPA 540-R-00-002, *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*, OSWER 9355.0-75. This guidance requires the development of two cost estimates for each remedial alternative to support the FS: a nondiscounted estimate called the "constant dollar" estimate, and a discounted estimate known as the "present worth" estimate. The present worth estimate is used by EPA to support decisions in the Superfund remedy selection process. The constant dollar estimate is used for comparison purposes and demonstrates the impact of the discount rate on the total present worth cost and the relative amounts of future annual expenditures over the duration of the remedial alternative. The period of analysis for the present worth cost is 1,000 years for the 200-PW-1 and 200-PW-6 OU waste sites with long-lived radionuclides (plutonium and americium) and 350 years for the 200-PW-3 OU waste sites with short-lived Cs-137.

6.1.8 State Acceptance

This assessment evaluates the technical and administrative issues and concerns the state may have regarding each of the remedial alternatives. This criterion will be addressed in the ROD once comments on the RI/FS report and Proposed Plan have been received.

6.1.9 Community Acceptance

This assessment evaluates the issues and concerns the public may have regarding each of the remedial alternatives. As with state acceptance, this criterion will be addressed in the ROD once comments on the RI/FS report and Proposed Plan have been received.

6.2 Detailed Analysis of No Action Alternative

The NCP requires consideration of a No Action Alternative. This alternative would leave a waste site "as-is" in its current state, with no additional remedial activities or access restrictions. This alternative is only acceptable if current waste site conditions are protective of HHE.

6.2.1 Overall Protection of Human Health and the Environment

The protection of human health and the environment evaluated in the BRA (Appendix A) and the evaluation of groundwater impacts from vadose zone contaminants (Appendix E) indicate that No Action is a viable alternative at only a few of the waste sites. The BRA indicates that the radionuclide concentrations at the 216-Z-10 Injection/ Reverse Well are not likely to pose significant risks due to their depth and limited extent near the well. Similarly, the BRA concluded in Appendix A that the risks from exposure to soils at the 216-Z-8 French Drain are below levels that are a health concern for all three populations evaluated (industrial worker, driller, and subsistence farmer). The evaluation of potential groundwater impacts from vadose zone contamination, in Appendix E, indicates that there are potential groundwater impacts from carbon tetrachloride and other VOCs. Uncertainty due to limited data has identified the need for further evaluation of the nature and extent of mobile contaminants (i.e., Tc-99 and nitrate). Assuming long-term recharge rates comparable to those for fully recovered vegetation conditions (e.g., $\leq$4 mm/yr), these sites do not pose a threat to groundwater; therefore, the No Action Alternative is considered protective of HHE at these two waste sites.

For the other 14 waste sites, this alternative does not eliminate, reduce, or control potential risks, so it is not protective of HHE and, thus, fails to meet this threshold criterion. For this reason, the discussion of the remaining evaluation criteria for this alternative is limited to its application at the 216-Z-8 French Drain and the 216-Z-10 Injection/Reverse Well.

6.2.2 Compliance with ARARs

The only chemical-specific ARARs for the No Action Alternative are the requirements to protect the environment via the migration to groundwater pathway. The No Action Alternative at the 216-Z-8 French Drain and the 216-Z-10 Injection/Reverse Well would comply with federal MCLs from 40 CFR 141 because no groundwater impacts were identified from radionuclides at these sites (Appendix E). At 216-A-8, the fate and transport modeling indicate that Tc-99 could potentially have groundwater impacts for some scenarios (elevated recharge rates).

An action-specific ARAR for the No Action Alternative is WAC 173-160-381. This alternative at the 216-Z-10 Injection/Reverse Well would not comply with this ARAR because the well construction does not meet the minimum standards. A limited action at this site is needed to decommission the well to comply with this ARAR. This ARAR does not apply to the 216-Z-8 French Drain.

No location-specific ARARs exist for the No Action Alternative.

6.2.3 Long-Term Effectiveness and Permanence

Although the No Action Alternative would leave untreated wastes at the 216-Z-8 French Drain and the 216-Z-10 Injection/Reverse Well, the baseline risk assessment showed that these concentrations are below levels that are a direct contact risk for the industrial worker. No controls (other than decommissioning of the 216-Z-10 Injection/Reverse Well) are required to manage the untreated wastes at these sites to ensure long-term protection of HHE; therefore, the No Action Alternative provides long-term effectiveness and permanence at these two waste sites.

6.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

The No Action Alternative does not employ treatment technology.

6.2.5 Short-Term Effectiveness

Because no actions are associated with this alternative, it poses no additional short-term risks to human health or the environment and the response objectives are achieved immediately. A limited action to decommission the 216-Z-10 Injection/Reverse Well would entail short-term risks to remedial action workers that can be reliably mitigated with standard radiation and industrial safety practices.

6.2.6 Implementability

No technical or administrative issues exist that would affect the implementability of the No Action Alternative at the 216-Z-8 French Drain and the 216 -Z-10 Injection/Reverse Well.

6.2.7 Cost

Costs associated with the No Action Alternative are estimated at $0. The cost of the limited action to decommission the 216-Z-10 Injection/Reverse Well is estimated to be $162,000 (Appendix D).

6.3 Detailed Analysis of Alternative 1—Barrier

Alternative 1—Barrier provides no treatment, but prevents and controls exposure to hazardous substances through engineering controls and institutional controls to protect HHE. Two process options are considered for this alternative—an ET barrier and a physical barrier.

The key features of the ET barrier are a thick, fine-grained soil layer with a vegetated surface. ET barriers are designed to manage the water balance of the capped area such that deep recharge through the barrier to underlying contaminated soil is limited to about 3 mm/yr (0.12 in./yr). Figure 5-1 shows the conceptual design of a monofill ET barrier. The ET barrier would include a biobarrier at waste sites where residual

contamination above risk levels is within 4.6 m (15 ft) of the ground surface (e.g., 216-A-7 and 216-A-8 Cribs and UPR-200-E-56).

The results of the fate and transport modeling indicate that recharge reduction from an ET barrier would reduce potential impacts to groundwater for all contaminants; however, barrier reduction in recharge does not eliminate potential impacts to groundwater from non-organic contaminants (nitrogen in nitrate+nitrite, and/or Tc-99) at the 216-Z-1A, 216-Z-18, and 216-Z-9 waste sites. Alternative 1 would provide further groundwater protection for 216-A-8, where fate and transport modeling indicate that for the contaminant levels modeled, recharge rates of 4 mm/yr are already protective of groundwater.

For waste sites with long-lived plutonium and americium contamination, a physical barrier component is incorporated into the ET barrier. The purpose of the physical barrier component is to impede and warn future workers (driller or excavator) with durable materials that are significantly different than the surrounding native soils. Figure 5-2 shows the conceptual design of an ET barrier with a physical barrier component.

Four of the waste sites (216-Z-1&2, 216-Z-3, 216-Z-5, and 216-Z-9) contain voids as part of their construction. As part of the barrier alternative at these waste sites, the voids would be backfilled with CDF, a flowable cement product. Optimal formulation(s) and placement of the CDF would be determined during remedial design. For the 216-Z-1&2 and 216-Z-9 sites, the CDF backfill would form a physical barrier 4.3 to 6.4 m (14 to 21 ft) thick. This thick CDF layer would replace the basalt layer in the barrier alternative at these sites.

The 216-Z-9 Trench also includes abovegrade and belowgrade structures and equipment that were constructed to support the soil mining conducted in 1976 to 1977. Alternative 1 at this site includes the removal and disposal of the abovegrade structures, but the belowgrade structures and equipment would be left in place and encased by the CDF backfill.

In addition, Alternative 1 includes several common components, as discussed in Section 5.2.1. These components include institutional controls for sites with residual risks above acceptable levels (1,000 years for sites with long-lived radionuclides and 350 years for sites with Cs-137), expanded SVE system for approximately 10 years at the three High-Salt waste sites, well decommissioning of vadose zone and groundwater monitoring wells that would be impacted by Alternative 1, environmental surveillance and groundwater monitoring, nuclear safety, and MNA for the Cs-137 waste sites.

A modification to the full barrier comprising the ET and physical barrier (Alternative 1) that was considered for the Cs-137 sites was to maintain and enhance the existing soil cover (MEESC). Based on current site conditions, the contamination at the Cs-137 sites do not pose a threat to the groundwater as the contaminants are not mobile under current or anticipated future conditions. The MEESC barrier alternative breaks the exposure pathway under the reasonably anticipated future land use, which is for an industrial worker and is therefore protective of human health. A minimum of 4.5 m (15 ft) of soil cover is used as the basis for evaluating this alternative. Approximately 0.3 m (1 ft) of fill will be constructed over two sites, 216-A-24 and 216-A-31, to grade the site for adequate drainage. The fill will also be used as topsoil for planting vegetation to stabilize the soil. For 216-A-7, 1.2 m (4 ft) of clean fill dirt will be added, and a final 0.3 m (1 ft) of topsoil placed over that. For 216-A-8, 1.4 m (4.5 ft) of fill dirt and 0.3 m (1 ft) of topsoil would be added. For UPR-200-E-56, 2 m (6.5 ft) of fill dirt and 0.3 m (1 ft) of topsoil will be added.

The MEESC barrier alternative is further described Appendix D.2.2 and Table D-4. The cost estimates are presented in Table D-12 and D-13.

6.3.1 Overall Protection of Human Health and the Environment

Alternative 1 achieves adequate protection of HHE by eliminating, reducing, or controlling potential risks associated with the direct contact pathway. The evaluation of potential groundwater impacts from vadose zone contamination in Appendix E indicates that there are potential groundwater impacts from carbon tetrachloride and other VOCs. Uncertainty due to limited data has identified the need for further evaluation of the nature and extent of mobile contaminants (i.e., Tc-99 and nitrate). Assuming long-term recharge rates comparable to those for fully recovered vegetation conditions (e.g., ≤4 mm/yr), these sites do not pose a threat to groundwater; therefore, the Barrier is considered protective of HHE. A summary of compliance with this criterion by waste site group follows:

- High-Salt waste sites—Alternative 1 eliminates potential direct contact risk to the industrial worker at the 216-Z-1A Tile Field and 216-Z-9 Trench by creating more than 4.6 m (15 ft) of separation between wastes and the land surface. There is no direct contact risk at the 216-Z-18 Crib. Alternative 1 also reduces potential groundwater protection risks because the ET barrier reduces recharge. Potential risks to a well driller, currently are already below health-based levels. The physical barrier component reduces the potential risks associated with the future subsistence farmer scenario, which relies on bringing contaminated soils to the surface in drill cuttings. Lastly, the institutional controls component will help control potential risks by controlling site access and preventing land use that is not compatible with this alternative.

- Low-Salt waste sites—Compliance is the same as for the High-Salt waste sites, except there are no direct contact risks at these waste sites due to the current depth of the wastes and there is no carbon tetrachloride, so the SVE system is not part of Alternative 1 for these sites.

- Cs-137 waste sites—Compliance is the same as for the High-Salt waste sites, except the direct contact risks would be eliminated at the 216-A-7 and 216-A-8 Cribs and UPR-200-E-56. There are no organics, so the SVE system is not part of Alternative 1 for these sites and the ET barrier further reduces recharge for an additional level of groundwater protection. The physical barrier component is not necessary at these waste sites because of the relatively short half-life of Cs-137. The institutional control period of 350 years for these sites is considered more reliable than the 1,000-year period used in evaluating the High-Salt and Low-Salt waste sites.

- Settling tanks—Alternative 1 is not applicable to these sites.

- 216-Z-8 French Drain and 216-Z-10 Injection/Reverse Well (hereafter, the no action waste sites)—Alternative 1 is not applicable to these sites.

6.3.2 Compliance with ARARs

The only chemical-specific ARARs for Alternative 1 are the requirements to protect the environment via the migration to groundwater pathway. Because the ongoing SVE remedial activity is a component of all alternatives and addresses carbon tetrachloride and other VOCs, this alternative is expected to comply with ARARs. Uncertainty due to limited data has identified the need for further evaluation of the nature and extent of mobile contaminants (i.e., Tc-99 and nitrate).

Alternative 1 will comply with potential location-specific ARARs *Archeological and Historic Preservation Act of 1974* (16 USC 469a-1–469a-2[d]), *National Historic Preservation Act of 1966* (16 USC 470, Section 106), *Native American Graves Protection and Repatriation Act of 1990* (25 USC 3001), and *Endangered Species Act of 1973* (16 USC 1531-1536[c]) because this alternative includes only limited subsurface activities within the previously disturbed waste site areas and no

archeological, historic, cultural, Native American, or threatened or endangered species have been identified at any of the waste site areas in previous characterization activities.

The action-specific ARAR WAC 173-160-381 will be met by following the well construction standards for the new SVE wells and the well decommissioning standards for decommissioning the vadose zone and groundwater monitoring wells that would be impacted by Alternative 1. Alternative 1 will also comply with potential action-specific ARARs WAC 173-400, WAC 173-460, WAC 173-480, and WAC 246-247 since the SVE system will treat extracted vapors prior to release.

6.3.3 Long-Term Effectiveness and Permanence

Compliance with this criterion, considering the magnitude of residual risk and the adequacy and reliability of controls, is discussed as follows by waste site group:

- High-Salt waste sites—The SVE component of Alternative 1 would reduce the levels of carbon tetrachloride and other VOCs in the vadose zone; however, uncertainty due to limited data has identified the need for further evaluation of the nature and extent of mobile contaminants (i.e., Tc-99 and nitrate). Alternative 1 does not reduce the volume or concentration of the long-lived radionuclides plutonium and americium (except through natural radioactive decay). Alternative 1 eliminates potential direct contact risk to the industrial worker by creating more than 4.6 m (15 ft) of separation between wastes and the land surface where wastes are currently within that depth range. Potential risks to a well driller currently are already below health-based levels. The physical barrier component reduces the potential risks associated with the future subsistence farmer scenario, which relies on bringing contaminated soils to the surface in drill cuttings. Lastly, the institutional controls component will also control potential risks by controlling site access and preventing land use that is not compatible with this alternative. The ET barrier and physical barrier components of Alternative 1 use natural geologic materials, which are adequate and reliable over long time periods to shield humans and the environment from the radioactive contamination at these waste sites. Long-term monitoring, maintenance, and enforcement of institutional controls are required to ensure Alternative 1 remains effective and permanent. Although there is some uncertainty about the reliability of maintaining institutional controls for 1,000 years, the required CERCLA reviews every 5 years will review and ensure this alternative remains effective and permanent in the long term.

- Low-Salt waste sites—Compliance and long-term reliability are the same as for the High-Salt waste sites, except there are no direct contact risks at these waste sites due to the current depth of the wastes and there is no carbon tetrachloride, so the SVE system is not part of Alternative 1 for these sites.

- Cs-137 waste sites—Compliance is the same as for the High-Salt waste sites, except the direct contact risks would be eliminated at the 216-A-7 and 216-A-8 Cribs and UPR-200-E-56. There are no organics, so the SVE system is not part of Alternative 1 for these sites. The physical barrier component is not necessary at these waste sites to mitigate the risk associated with Cs-137 because of the relatively short half-life of Cs-137. Maintaining the institutional control period for 350 years at these sites is facilitated by the required CERCLA reviews every 5 years, which will review and ensure that this alternative remains effective and permanent in the long-term.

6.3.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 1 uses SVE and a treatment technology such as granulated activated carbon or thermal oxidation to reduce the toxicity, mobility, and volume of carbon tetrachloride in the vadose zone at the High-Salt waste sites. The treatment of carbon tetrachloride and other VOCs is irreversible and should reduce concentrations of halogenated hydrocarbons and other VOCs to levels that are protective of

groundwater (Section 3.8.2.2). This component of Alternative 1 will reduce the levels of these principal threat contaminants in the vadose zone.

Alternative 1 does not reduce the toxicity, mobility, and volume of the other final COPCs through treatment at the High-Salt, Low-Salt, and Cs-137 waste sites. Natural radioactive decay will also reduce the toxicity and volume of Cs-137 at the Cs-137 waste sites.

6.3.5 Short-Term Effectiveness

Implementation of Alternative 1 will not result in risk to the community because the location of the waste sites is within the center of the Hanford Site, about 13 km (8 mi) from the nearest site boundary. Remedial action workers will have limited risks from exposure to final COPCs from implementing the SVE component of Alternative 1, these risks can be reliably mitigated with standard radiation and industrial safety practices. Workers will also have limited construction safety risks from implementing the ET barrier and physical barrier components because only clean soil and rock will be used in these actions. Fugitive dust during barrier construction will be controlled using standard dust suppression measures. No significant adverse environmental impacts are related to implementation of Alternative 1 (Section 6.6). Alternative 1 is estimated to achieve the RAOs at the High-Salt waste sites in 11 years (assuming 10 years for the SVE component for cost estimating purposes) and within 1 to 2 years at the Low-Salt and Cs-137 waste sites from the start of the remedial action.

6.3.6 Implementability

No technical, administrative, or availability of services and materials issues would affect the implementability of Alternative 1. Barrier construction and SVE are mature, reliable, and well known technologies that are relatively easy to implement. Monitoring of barrier infiltration recharge reduction and soil vapor concentrations to assess effectiveness of the remedy are readily implemented and the risks of exposure are limited, should monitoring be insufficient to detect a system failure, which would most likely result in groundwater impacts that would be detected by groundwater monitoring.

6.3.7 Cost

The estimated costs for Alternative 1 at the High-Salt, Low-Salt, and Cs-137 waste sites are summarized in Table 6-1 and the cost details are presented in Appendix D. The period of analysis for the present worth cost is 1,000 years for the High-Salt and Low-Salt waste sites with long-lived radionuclides (plutonium and americium) and 350 years for the Cs-137 waste sites.

Table 6-1. Summary of Detailed Analysis of Alternatives

Criteria	No Action Alternative	Alternative 1—Barrier	Alternative 2—In Situ Vitrification	Alternative 3—Removal, Treatment, and Disposal
Overall Protection of Human Health and the Environment	The No Action Alternative is only evaluated for the two waste sites where this alternative meets both threshold criteria.	Alternative 1 is not evaluated for the two settling tanks and the two waste sites evaluated under the No Action Alternative.	Alternative 2 is not evaluated for the five Cs-137 sites, the two settling tanks, and the two waste sites evaluated under the No Action Alternative.	Alternative 3 is evaluated for all of the waste sites except the two waste sites evaluated under the No Action Alternative.
Industrial Worker	Final COPCs are below risk levels at the 216-Z-10 Injection/Reverse Well and 216-Z-8 French Drain so this alternative is protective and the remaining criteria are only evaluated for these two sites. At the other 15 waste sites, there is no elimination, reduction, or control of potential risks, so this alternative fails this threshold criterion.	Barrier eliminates direct contact risk at 216-Z-1A, 216-Z-9, 216-A-7, 216-A-8, and UPR-200-E-56 sites. No direct contact risks at other sites.	ISV immobilizes radionuclides in vitrified glass eliminating the direct contact risk at 216-Z-1A and 216-Z-9. No direct contact risks at other sites.	RTD all options eliminate direct contact risk at 216-Z-1A and at 216-Z-9, and RTD Option 3B eliminates direct contact risk at 216-A-7, 216-A-8, and UPR-200-E-56. No direct contact risks at other sites. RTD eliminates potential risks at settling tanks.
Well Driller		Current risks below health concerns.	Current risks below health concerns.	Current risks below health concerns.
Future Subsistence Farmer		Barrier and institutional controls reduce potential for well driller to bring contaminated soils to the surface, which would reduce risks to future subsistence farmers.	ISV and institutional controls reduce potential for well driller to bring contaminated soils to the surface, which would reduce risks to future subsistence farmers. No untreated radionuclides remain at Low-Salt sites so institutional controls are not needed.	At High-Salt sites RTD Option 3C reduces direct contact risk to just under 10^{-3}, RTD Option 3E reduces risk to $<10^{-4}$, and RTD Option 3D reduces risk to $<10^{-6}$. At Low-Salt sites RTD Option 3A reduces direct contact risk to about 2×10^{-3}. RTD Options 3C, 3D, and 3E reduce risk to $<10^{-6}$ at the same depth. At Cs-137 sites RTD Option 3C reduces direct contact risk but it is still likely $>10^{-4}$. RTD eliminates potential direct contact risks at settling tanks. Institutional controls at sites with residual risks reduce potential for well driller to bring contaminated soils to the surface, which would reduce risks to future subsistence farmers.
Protection of Groundwater		SVE component reduce impacts from carbon tetrachloride at High-Salt sites. Uncertainty exists for certain contaminants (Tc-99, nitrate) regarding groundwater protection.	SVE component reduce impacts from carbon tetrachloride at High-Salt sites. Uncertainty exists for certain contaminants (Tc-99, nitrate) regarding groundwater protection.	SVE component reduce impacts from carbon tetrachloride at High-Salt sites. Uncertainty exists for certain contaminants (Tc-99, nitrate) regarding groundwater protection.
Environmental Protection		No current ecological risks at any waste sites-barrier further reduces risk.	No current ecological risks at any waste sites—ISV further reduces risk.	No current ecological risks at any waste sites–all RTD options further reduce risk.
Compliance with ARARs				
Chemical-specific ARARs	Uncertainty exists for certain contaminants (Tc-99, nitrate) regarding compliance with MCLs to protect groundwater.	Uncertainty exists for certain contaminants (Tc-99, nitrate) regarding compliance with MCLs to protect groundwater.	Uncertainty exists for certain contaminants (Tc-99, nitrate) regarding compliance with MCLs to protect groundwater.	Uncertainty exists for certain contaminants (Tc-99, nitrate) regarding compliance with MCLs to protect groundwater.
Location-specific ARARs	There are no location-specific ARARs.	Limited subsurface activities would comply with archeological, historic, cultural, Native American, and threatened and endangered species ARARs.	Subsurface activities would comply with archeological, historic, cultural, Native American, and threatened and endangered species ARARs.	Excavation activities would comply with archeological, historic, cultural, Native American, and threatened and endangered species ARARs. After excavation, waste soil and debris would be handled and disposed of to comply with ARARs regarding transuranic waste, dangerous waste, solid waste, and disposal criteria at ERDF and WIPP.
Action-specific ARARs	Limited action is required at the 216-Z-10 Injection/Reverse Well site to comply with well decommissioning ARAR.	Would comply with well construction and decommissioning ARARs and air pollution ARARs.	Would comply with well construction and decommissioning ARARs and air pollution ARARs.	Would comply with well construction and decommissioning ARARs and air pollution ARARs.
Long-term Effectiveness and Permanence				
Magnitude of Residual Risk	Residual risks are below health concerns with no groundwater impacts.	SVE component decreases carbon tetrachloride and other VOC concentrations at High-Salt sites to reduce risk and radioactive decay reduces risk at Cs-137 sites–magnitude of residual risk is unchanged at other sites.	SVE component decreases carbon tetrachloride and other VOC concentrations at High-Salt sites to reduce risk. ISV reduces risk at High-Salt and Low-Salt sites.	SVE component decreases carbon tetrachloride and other VOC concentrations at High-Salt sites to reduce risk. RTD reduces risk at High-Salt, Low-Salt, and Cs-137 sites as described above for the overall protection criterion.

Table 6-1. Summary of Detailed Analysis of Alternatives

Criteria	No Action Alternative	Alternative 1—Barrier	Alternative 2—In Situ Vitrification	Alternative 3—Removal, Treatment, and Disposal
Adequacy and Reliability of Controls	No controls needed other than decommissioning of 216-Z-10 well.	ET and physical barriers adequately mitigate direct contact exposure pathways. Institutional controls required for 1,000 years and longer at High-Salt and Low-Salt sites and for 350 years at Cs-137 sites.	ISV adequately mitigates direct contact exposure pathways. Institutional controls required for 1,000 years and longer at High-Salt sites. No untreated radionuclides remain at Low-Salt sites so institutional controls not needed.	RTD and ET barriers adequately mitigate direct contact exposure pathways. Institutional controls required for 1,000 years and longer at High-Salt (except for RTD Options 3D and 3E) and Low-Salt sites (except for RTD Options 3C, 3D, and 3E) and for 350 years at Cs-137 sites.
Need for five year Reviews	Not needed.	Required at High-Salt, Low-Salt, and Cs-137 sites to ensure alternative remains protective as long as risks exceed acceptable levels.	Required at High-Salt sites to ensure alternative remains protective as long as risks exceed acceptable levels.	Required at High-Salt (except for RTD Options 3D and 3E), Low-Salt (except for RTD Options 3C, 3D, and 3E), and Cs-137 sites to ensure alternative remains protective as long as risks exceed acceptable levels.
Reduction of Toxicity, Mobility, or Volume Through Treatment				
Treatment Process Used	None.	Vapor extraction for carbon tetrachloride and VOCs at High-Salt sites.	Vapor extraction for carbon tetrachloride and VOCs at High-Salt sites. ISV for radionuclides at High-Salt and Low-Salt sites.	Vapor extraction for carbon tetrachloride and VOCs at High-Salt sites.
Amount Destroyed or Treated	None.	Carbon tetrachloride vapor concentrations will be reduced to 16 ppmv to integrate with the 200-ZP-1 OU groundwater remedy.	Carbon tetrachloride vapor concentrations will be reduced to 16 ppmv to integrate with the 200-ZP-1 OU groundwater remedy. ISV treats approximately 90 percent of the radionuclides at High-Salt sites and 100 percent of the radionuclides at Low-Salt sites.	Carbon tetrachloride vapor concentrations will be reduced to 16 ppmv to integrate with the 200-ZP-1 OU groundwater remedy.
Expected Reduction in Toxicity, Mobility, or Volume	None.	Reduced toxicity and volume of carbon tetrachloride and VOCs at High-Salt sites.	Reduced toxicity and volume of carbon tetrachloride and VOCs at High-Salt sites. Reduced mobility of radionuclides at High-Salt and Low-Salt sites.	Reduced toxicity and volume of carbon tetrachloride and VOCs at High-Salt sites.
Irreversible Treatment	None.	Vapor extraction is irreversible.	Vapor extraction and ISV are irreversible.	Vapor extraction is irreversible.
Type and Quantity of Residuals Following Treatment	None.	Carbon from vapor extraction (if used) requires regeneration.	Carbon from vapor extraction (if used) requires regeneration. Air filters from last ISV melt require disposal.	Carbon from vapor extraction (if used) requires regeneration.
Statutory Preference for Treatment	Does not satisfy.	Satisfies, but only for carbon tetrachloride and VOCs at High-Salt sites.	Satisfies.	Satisfies, but only for carbon tetrachloride and VOCs at High-Salt sites.
Short-term Effectiveness				
Community Protection	No risk to community.	No risk to community.	No risk to community.	The various RTD options at High-Salt and Low-Salt waste sites could result in between 422 and 1,761 truckloads of transuranic waste transported to WIPP in New Mexico–potential risks are mitigated by costly shipping requirements.
Worker Protection	No significant risk to workers.	Protection required from dust during barrier construction and from dermal contact, dust, and vapors during SVE construction and operation.	Protection required from dermal contact, dust, and vapors during SVE and ISV construction and operation.	Protection required from dermal contact, dust, and vapors during SVE and RTD construction and SVE operation. Engineering and radiological controls needed for worker protection at significant cost.
Environmental Impacts	No environmental impacts.	Dust and SVE emissions will meet air pollution ARARs.	Dust, SVE, and ISV emissions will meet air pollution ARARs.	Dust and SVE emissions will meet air pollution ARARs.
Time Until Action is Complete	Less than 1 week to decommission 216-Z-10 Injection/Reverse Well.	11 years at High-Salt sites and one to two years at low -salt and Cs-137 sites after start of remedial action.	14 years at High-Salt sites and four years at Low-Salt sites after start of remedial action.	11 to 15 years at High-Salt sites and one to two years at Low-Salt, Cs-137, and settling tank sites after start of remedial action.
Implementability				
Technical Feasibility	No technical issues.	No technical issues.	No technical issues.	Deeper excavation RTD options may have technical difficulties caused by proximity of several waste sites to facilities and infrastructure.
Administrative Feasibility	No administrative issues.	No administrative issues.	Coordinate electrical power requirements of ISV with other Hanford Site power needs.	Coordinate RTD of High-Salt, Low-Salt, and settling tanks with PFP D&D.
Availability of Services and Materials	No availability issues.	No availability issues.	No availability issues.	No availability issues.

Table 6-1. Summary of Detailed Analysis of Alternatives

Criteria	No Action Alternative	Alternative 1—Barrier	Alternative 2—In Situ Vitrification	Alternative 3—Removal, Treatment, and Disposal
		Cost		
Capital Cost	$0.16 to decommission 216-Z-10 Injection/Reverse Well; $0 for 216-Z-8 French Drain.	High-Salt sites $12.3 Low-Salt sites $4.2 Cs-137 sites $5.0	High-Salt sites $115.1 Low-Salt sites $17.8	High-Salt sites 3A $57.5 3B $32.2 3C $278.5 3D $441.8 3E $422.5 Low-Salt sites 3A $31.2 Settling tanks $33.4 Cs-137 sites 3B $11.7 3C $22.7
Annual and Periodic Costs	$0	High-Salt sites $107.5 Low-Salt sites $171.0 Cs-137 sites $71.8	High-Salt sites $107.4 Low-Salt sites $171.0	High-Salt sites 3A $107.5 3B $35.8 3C $107.4 3D $6.6 3E $6.6 Low-Salt sites 3A $171.0 3C/D/E $0 Settling tanks $0 Cs-137 sites 3B $37.1 3C $63.9
Total Nondiscounted Costs	$0.16	High-Salt sites $119.8 Low-Salt sites $175.3 Cs -137 sites $76.8	High-Salt sites $222.5 Low-Salt sites $188.8	High-Salt sites 3A $165.0 3B $68.0 3C $385.9 3D $448.4 3E $429.0 Low-Salt sites 3A $202.2 3C/D/E $38.9 Settling tanks $33.4 Cs -137 sites 3B $48.8 3C $86.7
Present Worth	$0.16	High-Salt sites $19.1 Low-Salt sites $10.1 Cs-137 sites $12.2	High-Salt sites $94.0 Low-Salt sites $23.7	High-Salt sites 3A $52.4 3B $27.1 3C $213.0 3D $325.8 3E $313.3 Low-Salt sites 3A $37.1 3C/D/E $38.9 Settling tanks $33.4 Cs-137 sites 3B $15.3 3C $29.1

$ = millions

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6.4 Detailed Analysis of Alternative 2—In Situ Vitrification

Alternative 2 utilizes ISV to reduce the mobility of hazardous substances affected by the ISV. ISV uses an electric current to melt soil or other media at extremely high temperatures (1,600 to 2,000°C [2,900 to 3,650°F]). Radionuclides and other pollutants are immobilized within the vitrified glass, a chemically stable, leach-resistant material similar to obsidian or basalt rock. However, the mobility of radionuclides such as plutonium or americium would not be reduced, as they are currently not mobile under existing or anticipated conditions.

A vacuum hood is placed over the treated area to collect offgases, which are treated before release. Institutional controls are also a component of this alternative at waste sites where the ISV process leaves residual contamination at a waste site that will require long-term controls.

The depth of the ISV melt at each waste site would target the highest radionuclide concentrations, which are estimated to range from 1.5 to 4.6 m (5 to 15 ft) below the base of each waste site. The actual configuration, depth, and number of melts needed at each waste site would be determined during remedial design. For the purposes of the FS, it is assumed each melt would be advanced to a minimum of 4.6 m (15 ft) below the surface of the clean compacted sand fill. Previous ISV projects have achieved melt depths in excess of 7.6 m (25 ft). The mobility and potential groundwater impacts of contaminants at depths below the ISV melt zone would not be affected, except for the attendant effects of recharge reduction from the ISV.

Several waste sites would require site-specific preparation prior to implementing ISV and these are included as part of this alternative. The concrete cover and support columns at the 216-Z-9 Trench, as well as the abovegrade and belowgrade structures and equipment used for the 1976 to 1977 soil mining would need to be removed prior to ISV. At waste sites constructed of timbers and other flammable materials (216 Z-1&2 and 216-Z-5) partial excavation to remove these materials would be conducted prior to ISV. Partial excavation at the 216-Z-3 Crib would also be conducted to collapse the culverts and remove these voids prior to ISV.

After any site-specific preparations as noted previously, the waste site would be covered by approximately 1.5 m (5 ft) of compacted clean sand to accomplish the following:

- Cover the waste site to enhance radiological safety.
- Provide overburden material to compensate for the volume reduction of the treated soil due to vitrification (site soils have up to 30 percent void space; glass has none).
- Enhance radionuclide retention in the glass due to the sand filter effect (described in Section 5.2.3).

After the melt operations are complete at each waste site, the result would be a durable glass monolith, roughly 4 to 5 m (12 to 16 ft) thick (because of loss of pore space), with the approximate lateral dimensions of the base of the waste site. The subsidence area at each ISV site would be backfilled with clean fill to match the surrounding grade and the surface plus any disturbed areas would be replanted with native vegetation.

In addition, Alternative 2 includes several common components as discussed in Section 5.2.1. These components include institutional controls for 1,000 years at sites where residual risks would remain above acceptable levels, expanded SVE system for approximately 10 years at the three High-Salt waste sites, well decommissioning of vadose zone and groundwater monitoring

wells that would be impacted by Alternative 2, environmental surveillance and groundwater monitoring, and nuclear safety.

6.4.1 Overall Protection of Human Health and the Environment

Alternative 2 achieves adequate direct contact protection of HHE by eliminating, reducing, or controlling potential risks for those contaminants at depths affected by ISV. The evaluation of potential groundwater impacts from vadose zone contamination, in Appendix E, indicates that there are potential groundwater impacts from carbon tetrachloride and other VOCs. Uncertainty due to limited data has identified the need for further evaluation of the nature and extent of mobile contaminants (i.e., Tc-99 and nitrate). Assuming long-term recharge rates comparable to those for fully recovered vegetation conditions (e.g., ≤4 mm/yr), these sites do not pose a threat to groundwater; therefore, the ISV Alternative is considered protective of HHE. Compliance with this criterion, by waste site group, is summarized as follows:

- High-Salt waste sites—Alternative 2 eliminates potential direct contact risk to the industrial worker at the 216-Z-1A Tile Field and 216-Z-9 Trench by immobilizing the radionuclides in the vitrified glass. There is no direct contact risk at the 216-Z-18 Crib. Alternative 2 can also reduce the potential migration to groundwater pathway through reduction of carbon tetrachloride and other VOCs using an SVE system and also due to the effects of the glass monolith on reduction of subsurface recharge. The glass monolith further reduces the likelihood of potential risks to a well driller, which currently are already below health-based levels, thereby also reducing the potential risks associated with the future subsistence farmer scenario, which relies on bringing contaminated soils to the surface in drill cuttings. In the unlikely possible situation that a well was drilled through the vitrified glass, the risks to a future subsistence farmer would be reduced because the plutonium and americium immobilized in the glass would not contribute to the direct contact, inhalation, or ingestion exposure pathways. Lastly, the institutional controls component will help control potential residual risks by controlling site access and preventing land use that is not compatible with this alternative.

- Low-Salt waste sites—Compliance is the same as for the High-Salt waste sites, except there are no direct contact risks at these waste sites due to the current depth of the wastes and there is no carbon tetrachloride, so the SVE component is not part of Alternative 2 for these sites. Because all of the radionuclide contamination above risk levels is within 1.2 m (4 ft) of the base of these waste sites and will be immobilized in the vitrified glass, no untreated radionuclide wastes will remain, so institutional controls are not necessary for these waste sites as part of Alternative 2.

- Cs-137 waste sites—Alternative 2 is not applicable to these sites.

- Settling tanks—Alternative 2 is not applicable to these sites.

- No action waste sites—Alternative 2 is not applicable to these sites.

6.4.2 Compliance with ARARs

The only chemical-specific ARARs for Alternative 2 are the requirements to protect the environment via the migration to groundwater pathway. Because the ongoing SVE remedial activity is a component of all alternatives and addresses carbon tetrachloride and other VOCs, this alternative is expected to comply with ARARs. Uncertainty due to limited data has identified the

need for further evaluation of the nature and extent of mobile contaminants (i.e., Tc-99 and nitrate).

Alternative 2 will comply with potential location-specific ARARs *Archeological and Historic Preservation Act of 1974* (16 USC 469a-1–469a-2[d]), *National Historic Preservation Act of 1966* (16 USC 470, Section 106), *Native American Graves Protection and Repatriation Act of 1990* (25 USC 3001), and *Endangered Species Act of 1973* (16 USC 1531-1536[c]) because this alternative includes only limited subsurface activities within the previously disturbed waste site areas and no archeological, historic, cultural, Native American, or threatened or endangered species have been identified at any of the waste site areas in previous characterization activities.

The action-specific ARAR WAC 173-160-381 will be met by following the well decommissioning standards for decommissioning the vadose zone and groundwater monitoring wells that would be impacted by Alternative 2. Alternative 2 will also comply with potential action-specific ARARs WAC 173-400, WAC 173-460, WAC 173-480, and WAC 246-247 since the SVE system will treat extracted vapors prior to release and the ISV system uses a vacuum hood over the treated area to collect offgases, which are treated before release.

6.4.3 Long-Term Effectiveness and Permanence

Compliance with this criterion, considering the magnitude of residual risk and the adequacy and reliability of controls, is discussed by waste site group as follows:

- High-Salt waste sites—The SVE component of Alternative 2 would reduce the levels of carbon tetrachloride and VOCs in the vadose zone; however, uncertainty due to limited data has identified the need for further evaluation of the nature and extent of mobile contaminants (i.e., Tc-99 and nitrate).

- Although Alternative 2 does not reduce the radioactivity at these waste sites, it does reduce the mobility of contaminated soil affected by the ISV by immobilizing the radionuclides in the vitrified glass. Alternative 2 eliminates the potential direct contact risk to the industrial worker at the 216-Z-1A Tile Field and 216-Z-9 Trench, and there is no current direct contact risk at the 216-Z-18 Crib. The glass monolith further reduces the likelihood of potential risks to a well driller, which currently are already below health-based levels, thereby also reducing the potential risks associated with the future subsistence farmer scenario, which relies on bringing contaminated soils to the surface in drill cuttings. In the unlikely possible situation that a well was drilled through the vitrified glass, the risks to a future subsistence farmer would be reduced because the radionuclides immobilized in the glass would not contribute to the direct contact, inhalation, or ingestion exposure pathways. Lastly, the institutional controls component will help control potential residual risks by controlling site access and preventing land use that is not compatible with this alternative.

- The vitrified glass monolith created by Alternative 2 would be similar to the natural geologic materials, obsidian or basalt, which are adequate and reliable over long time periods to shield humans and the environment from the radioactive contamination at these waste sites. Long-term monitoring, maintenance, and enforcement of institutional controls are required to ensure that Alternative 2 remains effective and permanent. Although there is some uncertainty in the reliability of maintaining institutional controls for 1,000 years, the required CERCLA reviews every 5 years will review and ensure this alternative remains effective and permanent in the long-term.

- Low-Salt waste sites—Compliance and long-term reliability are the same as for the High-Salt waste sites, except there are no direct contact risks at these waste sites due to the current depth of the wastes and there are is no carbon tetrachloride, so the SVE system is not part of Alternative 2 for these sites. Because all of the radionuclide contamination above risk levels is within 1.2 m (4 ft) of the base of these waste sites and will be immobilized in the vitrified glass, no untreated radionuclide wastes will remain, so institutional controls are not necessary for these waste sites as part of Alternative 2.

6.4.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 2 uses SVE and a treatment technology such as granulated activated carbon or thermal oxidation to reduce the toxicity, mobility, and volume of carbon tetrachloride in the vadose zone at the High-Salt waste sites. The treatment of carbon tetrachloride and other VOCs is irreversible and should reduce concentrations of halogenated hydrocarbons and other VOCs to levels that are protective of groundwater (Section 3.8.2.2). This component of Alternative 1 will reduce the levels of these principal threat contaminants in the vadose zone.

Alternative 2 also uses ISV to reduce the mobility of the highest concentration of radionuclides present near the base of the High-Salt and Low-Salt waste sites. The ISV process will be irreversible and reduces the mobility of the radionculides immobilized in the vitrified glass so they will not contribute to the direct contact, inhalation, or ingestion exposure pathways if the glass monolith is inadvertently disturbed. Alternative 2 would satisfy the statutory preference for treatment as a principal element of the principal threat final COPCs plutonium and americium.

6.4.5 Short-Term Effectiveness

Implementation of Alternative 2 will not result in risk to the community because the location of the waste sites is within the center of the Hanford Site about 13 km (8 mi) from the nearest site boundary. Remedial action workers will have limited risks from exposure to final COPCs from implementing the SVE component and the ISV component of Alternative 2, these risks can be reliably mitigated with standard radiation and industrial safety practices. The clean sand fill, vacuum hood, and the offgas treatment train are effective and reliable elements of this alternative that will prevent and mitigate potential risks to workers and any environmental impacts from Alternative 2. Fugitive dust during placement of the clean sand fill or the post-melt backfill will be controlled using standard dust suppression measures. No significant adverse environmental impacts are related to implementation of Alternative 2 (Section 6.6). Alternative 2 is estimated to achieve the RAOs at the High-Salt waste sites in 14 years (assuming 10 years for the SVE component for cost estimating purposes) and within 4 years at the Low-Salt waste sites from the start of the remedial action.

6.4.6 Implementability

No technical or availability of services and materials issues exist that would affect the implementability of Alternative 2. The ISV and SVE technologies are proven and commercially available. An electrical distribution system, offgas treatment system, and process control system are required for implementation. Since the ISV treatment is entirely in situ, no offsite activity is necessary to manage, treat, or store waste. Monitoring of post-ISV recharge and soil vapor concentrations to assess effectiveness of the remedy are readily implemented and the risks of exposure are limited, should monitoring be insufficient to detect a system failure, which would most likely result in groundwater impacts that would be detected by groundwater monitoring.

The electrical power requirements of ISV may create the need for administrative coordination between Alternative 2 and other Hanford Site electrical power needs, especially those of the Waste Treatment Plant project. This coordination is not expected to affect the implementability of Alternative 2.

6.4.7 Cost

Table 6-1 summarizes the estimated costs for Alternative 2 at the High-Salt and Low-Salt waste sites, and Appendix D presents the cost details. The period of analysis for the present worth cost is 1,000 years for the High-Salt waste sites with untreated long-lived radionuclides (plutonium and americium).

6.5 Detailed Analysis of Alternative 3—Removal, Treatment, and Disposal

Alternative 3 removes waste site soil, sludge, and/or debris, treating it as necessary to meet ARARs, and then disposing of it in an onsite (ERDF) or offsite (WIPP) disposal facility as appropriate. Five RTD options are evaluated for their ability to achieve different removal objectives, from partial removal of the highest contaminant concentrations to removal of contamination that poses greater than a 10^{-4} risk level for any exposure scenarios to evaluate unrestricted future land use at a waste site. For the RTD options that leave residual contamination above risk levels, institutional controls and ET barriers are incorporated as remedy components to protect HHE.

The evaluation of Alternative 3 includes conventional excavation as the excavation technology because it is effective for removing contaminated soils, readily implementable without the need for special contractors or equipment, and the least costly of the excavation technologies. Conventional excavation uses standard earth-moving equipment such as excavators, front-end loaders, and haul trucks, to remove contaminated soils from the waste sites, place those soils in appropriate waste containers, and haul the waste containers to an appropriate waste disposal facility. Conventional excavation would typically use a side slope angle of 1V:1.5H to maintain stability in the unconsolidated sand and gravel at the waste sites. Benching, a stair-step pattern of side slopes and horizontal working surfaces (benches), is also included as part of this alternative for the deeper excavation options and a 3 m (10 ft) wide bench is used for every 7.6 m (25 ft) of vertical depth. If an RTD alternative is selected for a waste site where conventional excavation may not be feasible because of the proximity of adjacent waste sites or facilities, other process options from the deep excavation technology may need to be used, but they are not included in the evaluation of this alternative and are expected to result in increased costs from those evaluated in this section. The excavation methods and details of any RTD alternative selected for a waste site would be developed during remedial design.

Conceptually, the RTD process for this alternative consists of five steps:

- Remove and stockpile clean overburden for backfilling.
- Remove contaminated soils and debris and place in waste containers.
- Haul waste containers to assay/screening station and then to ERDF or WIPP for disposal (containers destined for WIPP are temporarily stored at the Hanford Site's CWC until shipped to WIPP).

- Backfill excavation with clean fill and compact.
- Construct ET barrier as necessary and replant surface with native vegetation.

Because the High-Salt and Low-Salt waste sites contain large quantities of plutonium and americium (which emit alpha radiation) and the Cs-137 waste sites contain large quantities of Cs-137 (which emits beta-gamma radiation) special conditions apply when disturbing or handling these contaminated soils. Control of airborne contamination will require engineering controls such as water misting or other dust suppression methods and appropriate personal protective equipment for remedial action workers. For the High-Salt and Low-Salt waste sites, the excavation and waste container packaging could be performed inside a portable enclosure. In addition, radiation rates to workers from the contaminated soils in the excavation and from the full waste containers will limit the excavation rate and the amount of contaminated soil that can be placed in each waste container. For example, the estimated radiation rates from excavation of the Cs-137 contamination at the 216-A-8 Crib is estimated to require mixing two parts of clean soil with one part of contaminated soil using shielded, long-reach excavators to maintain safe radiation rates to workers. Appendix D includes a discussion of the details of these considerations and others that were used to develop the cost estimates for the RTD alternative.

Five RTD options were developed to satisfy and permit evaluation of different removal objectives:

1. Option 3A—Remove the highest concentrations of contaminated soils to 0.6 m (2 ft) below the base of a waste site.
2. Option 3B—Remove contaminated soils that could be a direct contact risk to industrial workers and that are less than 4.6 m (15 ft) below the current ground surface.
3. Option 3C—Remove a significant portion of plutonium contamination based on an evaluation of soil contaminant concentration with depth. A significant portion of Cs-137 contamination would be removed at the Cs-137 waste sites based on a similar evaluation.
4. Option 3D—Remove contaminated soils containing greater than 100 nCi/g of transuranic radionuclides.
5. Option 3E—Remove contaminated soils with greater than a 10^{-4} risk level so that long-term institutional controls at a waste site are not necessary.

Each of the five RTD options is not applicable to every waste site. Using the waste site information described in Section 5.2.4, Table 5-3 provides a summary of the removal depths for the applicable RTD options for each waste site.

Two of the waste sites contain sludge that is primarily contaminated with plutonium and americium. The 241-Z-8 Settling Tank contains approximately 1,890 L (500 gal) of sludge and the 241-Z-361 Settling Tank contains about 800 L (200 gal) of liquid and 75 m^3 (98 yd^3) of sludge. A previous engineering evaluation, DOE/RL-2003-52, identified potential remedial technologies for the 241-Z-361 Settling Tank, developed and evaluated the reasonable alternatives (based on effectiveness, implementability, and cost), and recommended a specific removal alternative. The alternative recommended in that study is carried forward in this FS as the removal alternative for the sludge in the two settling tanks.

Sludge removal in the two settling tanks would employ a Power Fluidics system to loosen and homogenize the sludge, and transfer it to SWBs. WaterWorks SP-400 Superabsorbent Crystals, a

polymer absorbent, would be added to the SWBs to absorb residual liquids and stabilize the sludge. The SWBs would then be transported to the CWC for storage, pending proper waste disposition. Based on the available data, the retrieved sludge will likely designate as transuranic waste or mixed transuranic waste. If so, these SWBs would then be transported to WIPP for disposal. Once the sludge has been removed from these two tanks, the empty tanks would be backfilled with CDF to eliminate any future settlement or collapse issues.

In addition, Alternative 3 includes several common components as discussed in Section 5.2.1. These components include institutional controls for 1,000 years at the High-Salt and Low-Salt waste sites and 350 years at the Cs-137 waste sites where residual risks would remain above acceptable levels, expanded SVE system for approximately 10 years at the three High-Salt waste sites, well decommissioning of vadose zone and groundwater monitoring wells that would be impacted by Alternative 3, environmental surveillance and groundwater monitoring, and nuclear safety.

6.5.1 Overall Protection of Human Health and the Environment

Alternative 3 achieves adequate protection of HHE by eliminating, reducing, or controlling potential direct contact risks to different degrees depending on the contaminated soil removal depth. It can also potentially mitigate some groundwater impacts to different degrees depending on the contaminated soil removal depth. Alternative 3 poses the greatest short-term risks to remedial action workers and the environment, which can be mitigated by engineering and radiological controls but at significant cost. The evaluation of potential groundwater impacts from vadose zone contamination, in Appendix E, indicates that there are potential groundwater impacts from carbon tetrachloride and other VOCs. Uncertainty due to limited data has identified the need for further evaluation of the nature and extent of mobile contaminants (i.e., Tc-99 and nitrate). Assuming long-term recharge rates comparable to those for fully recovered vegetation conditions (e.g., ≤4mm/yr), these sites do not pose a threat to groundwater; therefore, the RTD Alternative is considered protective of HHE. Compliance with this criterion, by waste site group, is summarized as follows:

- High-Salt waste sites—The potential direct contact risk to the industrial worker at the 216-Z-1A Tile Field would be eliminated by all options of Alternative 3. The current direct contact risks at the 216-Z-9 Trench are prevented by the concrete cover, and any potential future direct contact risks to the industrial worker due to collapse of the cover would be eliminated by all options of Alternative 3. There is no current direct contact risk at the 216-Z-18 Crib. Alternative 3 can also reduce the potential migration to groundwater pathway through reduction of carbon tetrachloride and other VOCs using an SVE system.
  The potential risks to a well driller currently are already below health-based levels.
  The potential risks associated with the future subsistence farmer scenario, which relies on bringing contaminated soils to the surface in drill cuttings is addressed to different degrees by RTD Options 3C, 3D, and 3E. In the unlikely possible situation that a well was drilled through these waste sites after RTD to the various depths considered in these options, the risks to a future subsistence farmer would be reduced because only the generally lower concentrations of plutonium and americium remaining below the RTD depths would contribute to the direct contact, inhalation, or ingestion exposure pathways. The risk evaluation, presented in Appendix F, indicates excavation to 27.4 m (90 ft) depth bgs is needed at these waste sites to reduce the risk to the future subsistence farmer to below 10^{-4}, the upper bound of the CERCLA risk range of 10^{-4} to 10^{-6}; therefore, RTD Option 3C (removal of significant contaminant mass) would only reduce the future subsistence farmer

risk to just below 10^{-3} and RTD Options 3D and 3E would reduce the future subsistence farmer risk to below 10^{-4}. The RTD Option 3D (removal of transuranic radionuclides greater than 100 nCi/g) requires excavation depths of 31.4 to 36.6 m (103 to 120 ft) at these waste sites, but is estimated to reduce the future subsistence farmer risk to near 10^{-6}, the lower end of the CERCLA risk range. Lastly, the institutional controls component will help control potential residual risks by controlling site access and preventing land use that is not compatible with this alternative.

- Low-Salt waste sites—No direct contact risks exist at these waste sites due to the current depth of the wastes and there is no carbon tetrachloride, so the SVE component is not part of Alternative 3 for these sites. The potential risks to a well driller, currently are already below health-based levels. RTD Option 3A would reduce the potential for direct contact risk but would only reduce the future subsistence farmer risk to about 2×10^{-3}. Because all of the radionuclide contamination above risk levels is within 1.2 m (4 ft) of the base of these waste sites, RTD Options 3C, 3D, and 3E achieve their different remedial objectives at the same excavation depth, which is less than 1 m (3 ft) deeper than the RTD Option 3A depth. RTD options 3C, 3D, and 3E would reduce the future subsistence farmer risk to below 10^{-6}, the lower end of the CERCLA risk range. Lastly, the institutional controls component will help control potential residual risks by controlling site access and preventing land use that is not compatible with this alternative.

- Cs-137 waste sites—The potential direct contact risk to the industrial worker at the 216-A-7 and 216-A-8 Cribs and UPR-200-E-56 would be eliminated by Alternative 3, Option 3B. No current direct contact risks exist at the other Cs-137 waste sites because of the depth of the contamination or because the Cs-137 concentrations are less than the RBC throughout for protection of the industrial worker (Table 3-1). The SVE system is not part of Alternative 3 for these waste sites, because there are no organics. The potential risks to a well driller, currently are already below health-based levels. RTD Option 3C (removal of significant contaminant mass) would reduce the future subsistence farmer risk at these waste sites but it is likely that the residual risks 150 years in the future would still be greater than 10^{-4}, the upper bound of the CERCLA risk range. Because of its relatively short half-life, Cs-137 will decay to levels that are protective of human health within about 350 years. Maintaining the institutional control period for 350 years at these sites is facilitated by the required CERCLA reviews every 5 years, which will review and ensure this alternative remains effective and permanent in the long-term.

- Settling tanks—Alternative 3 will eliminate potential risks to HHE from the radioactively contaminated sludge and remaining liquids in these tanks by removing and stabilizing the sludge so that it can be disposed at WIPP. After sludge removal, the empty tanks would be backfilled with CDF to eliminate any future settlement or collapse issues.

- No action waste sites—Alternative 3 is not applicable to these sites.

6.5.2 Compliance with ARARs

The only chemical-specific ARARs for Alternative 3 are the requirements to protect the environment via the migration to groundwater pathway. Because the ongoing SVE remedial activity is a component of all alternatives and addresses carbon tetrachloride and other VOCs, this alternative is expected to comply with ARARs. Uncertainty due to limited data has identified the need for further evaluation of the nature and extent of mobile contaminants (i.e., Tc-99 and nitrate).

Alternative 3 will comply with potential location-specific ARARs *Archeological and Historic Preservation Act of 1974* (16 USC 469a-1–469a-2[d]), *National Historic Preservation Act of 1966* (16 USC 470, Section 106), *Native American Graves Protection and Repatriation Act of 1990* (25 USC 3001), and *Endangered Species Act of 1973* (16 USC 1531-1536[c]) because this alternative includes only limited subsurface activities within the previously disturbed waste site areas and no archeological, historic, cultural, Native American, or threatened or endangered species have been identified at any of the waste site areas in previous characterization activities.

Alternative 3 will comply with potential action-specific ARARs regarding the identification, designation, and management of excavated soils that may designate as transuranic waste per the *Atomic Energy Act of 1954* (42 USC 2011); DOE/WIPP-02-3122, *Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant*; WCH-191, *Environmental Restoration Disposal Facility Waste Acceptance Criteria*; and 0000X-DC-W0001, *Supplemental Waste Acceptance Criteria for Bulk Shipments to the Environmental Restoration Disposal Facility*. Designation, handling, and disposal of the excavated soils and debris will also comply with WAC 173-303; WAC 173-304, "Minimum Functional Standards for Solid Waste Handling;" and WAC 173-350, "Solid Waste Handling Standards."

The action-specific ARAR WAC 173-160-381 will be met by following the well decommissioning standards for decommissioning the vadose zone and groundwater monitoring wells that would be impacted by Alternative 3. Alternative 3 will also comply with potential action-specific ARARs WAC 173-400, WAC 173-460, WAC 173-480, and WAC 246-247 since the SVE system will treat extracted vapors prior to release and since engineering controls will be used to reduce and control airborne dust during the RTD process.

6.5.3 Long-Term Effectiveness and Permanence

Compliance with this criterion, considering the magnitude of residual risk and the adequacy and reliability of controls, is discussed by waste site group as follows:

- High-Salt waste sites—The SVE component of Alternative 2 would remove carbon tetrachloride from the vadose zone so residual concentrations will not migrate and impact the groundwater.

- Alternative 3 reduces the radioactive contamination at these waste sites to different degrees depending on the contaminated soil removal depth. The potential direct contact risk to the industrial worker at the 216-Z-1A Tile Field would be eliminated in all options by Alternative 3. The current direct contact risks at the 216-Z-9 Trench are prevented by the concrete cover, but potential future direct contact risks to the industrial worker due to collapse of the cover would be eliminated in all options by Alternative 3. There is no current direct contact risk at the 216-Z-18 Crib. The potential risks to a well driller currently are already below health-based levels. The potential risks associated with the future subsistence farmer scenario, which relies on bringing contaminated soils to the surface in drill cuttings is addressed to different degrees by RTD Options 3C, 3D, and 3E. In the unlikely possible situation that a well was drilled through these waste sites after RTD to the various depths considered in these options, the risks to a future subsistence farmer would be reduced because only the generally lower concentrations of plutonium and americium remaining below the RTD depths would contribute to the direct contact, inhalation, or ingestion exposure pathways. The risk evaluation presented in Appendix F indicates excavation to 27.4 m (90 ft) depth bgs is needed at these waste sites to reduce the risk to the future subsistence farmer to below 10^{-4}, the upper bound of the CERCLA risk range; therefore, RTD Option 3C

(removal of significant contaminant mass) would only reduce the future subsistence farmer risk to just below 10^{-3} and RTD Options 3D and 3E would reduce the future subsistence farmer risk to below 10^{-4}. RTD Option 3D (removal of transuranic radionuclides greater than 100 nCi/g) requires excavation depths of 31.4 to 36.6 m (103 to 120 ft) at these waste sites, but is estimated to reduce the future subsistence farmer risk to near 10^{-6}, the lower end of the CERCLA risk range. Long-term monitoring, maintenance, and enforcement of institutional controls are required to ensure Alternative 3 remains effective and permanent. Although there is some uncertainty in the reliability of maintaining institutional controls for 1,000 years, the required CERCLA reviews every 5 years will review and ensure this alternative remains effective and permanent in the long-term.

- Low-Salt waste sites—No direct contact risks exist at these waste sites due to the current depth of the wastes and there is no carbon tetrachloride, so the SVE component is not part of Alternative 3 for these sites. The potential risks to a well driller currently are already below health-based levels. RTD Option 3A would further reduce the potential for direct contact risk but would only reduce the future subsistence farmer risk to about 2×10^{-3}. Because all of the radionuclide contamination above risk levels is within 1.2 m (4 ft) of the base of these waste sites, RTD Options 3C, 3D, and 3E achieve their different remedial objectives at the same excavation depth, which is less than 1 m (3 ft) deeper than the RTD Option 3A depth. RTD options 3C, 3D, and 3E would reduce the future subsistence farmer risk to below 10^{-6}, the lower end of the CERCLA risk range. Long-term monitoring, maintenance, and enforcement of institutional controls are required to ensure Alternative 3 remains effective and permanent. Although there is some uncertainty in the reliability of maintaining institutional controls for 1,000 years, the required CERCLA reviews every 5 years will review and ensure that RTD Option 3A, if selected, remains effective and permanent in the long-term.

- Cs-137 waste sites—The potential direct contact risk to the industrial worker at the 216-A-7 and 216-A-8 Cribs and UPR-200-E-56 would be eliminated by Alternative 3, Option 3B. No current direct contact risks exist at the other Cs-137 waste sites because of the depth of the contamination or because the Cs-137 concentrations are less than the RBC for protection of the industrial worker (Table 3-1). The SVE system is not part of Alternative 3 for these waste sites because there are no organics. The potential risks to a well driller, currently are already below health-based levels. RTD Option 3C (removal of significant contaminant mass) would reduce the future subsistence farmer risk at these waste sites but it is likely the residual risks 150 years in the future would still be greater than 10^{-4}, the upper bound of the CERCLA risk range. Because of its relatively short half-life, Cs-137 will decay to levels that are protective of human health within about 350 years, which is greater than 10 half-lives. Maintaining the institutional control period for 350 years at these sites is facilitated by the required CERCLA reviews every 5 years, which will review and ensure this alternative remains effective and permanent in the long-term.

- Settling tanks—Alternative 3 will eliminate potential risks to HHE from the radioactively contaminated sludge and remaining liquids in these tanks by removing and stabilizing the sludge so it can be disposed at WIPP. After sludge removal, the empty tanks would be backfilled with CDF to eliminate any future settlement or collapse issues.

6.5.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 3 uses SVE and a treatment technology such as granulated activated carbon or thermal oxidation to reduce the toxicity, mobility, and volume of carbon tetrachloride in the

vadose zone at the High-Salt waste sites. The treatment of carbon tetrachloride and other VOCs is irreversible and should reduce concentrations of halogenated hydrocarbons and other VOCs to levels that are protective of groundwater (Section 3.8.2.2). This component of Alternative 1 will reduce the levels of these principal threat contaminants in the vadose zone.

Alternative 3 reduces the radioactive contamination at the High-Salt, Low-Salt, and Cs-137 waste sites by the physical removal of contaminated soil and at the settling tanks by the physical removal of contaminated sludge; however, the RTD component of Alternative 3 does not satisfy the statutory preference for treatment as a principal element.

6.5.5 Short-Term Effectiveness

Alternative 3 poses the greatest short-term risks to remedial action workers and the environment, which can be mitigated by engineering and radiological controls but at significant costs. Alternative 3 will have potential risks to the community and the environment because although the location of the waste sites is within the center of the Hanford Site about 13 km (8 mi) from the nearest site boundary, a significant volume of soil contaminated with transuranic radionuclides would be transported offsite for disposal at the WIPP facility in New Mexico. Depending on the RTD option that may be selected for the High-Salt and Low-Salt waste sites, the contaminated soil that is expected to designate as transuranic waste could result in between 433 and 2,504 truckloads that would be transported through Richland, Washington, and along major highways in Washington, Oregon, Idaho, Utah, Wyoming, Colorado, and New Mexico before arriving at WIPP for disposal. This estimate assumes certified assays of the contaminated soils in SWBs can be completed at the Hanford Site (Section 5.2.4); however, these potential risks can be reliably mitigated by DOE requirements and protocols for shipping transuranic waste to WIPP, which include the following:

- Approved shipping containers must meet radiation limits for public safety.
- Drivers must meet stringent qualifications and training requirements.
- Trucks are inspected prior to departure and periodically en route and use designated transportation routes.
- Trucks are continuously tracked via satellite and have redundant two-way communication systems with WIPP.
- DOE has trained emergency response personnel along the designated routes to respond to emergencies.

The remedial action workers will have risks from potential exposure to final COPCs from implementing the SVE component of Alternative 3, and more significantly from potential exposure to radionuclides during the RTD process. These risks can be reliably mitigated with standard and site-specific radiation and industrial safety practices. For instance, the High-Salt and Low-Salt waste sites and the settling tanks RTD options would be conducted inside a portable enclosure to mitigate the potential for airborne contamination, dust suppression controls would be used, and workers would likely also use respiratory protection. In addition, radiation rates to workers from the soils in the Cs-137 waste sites and from the full waste containers will limit the excavation rate and the amount of contaminated soil that can be placed in each waste container. The RTD of these waste sites is estimated to require mixing two parts of clean soil with one part of contaminated soil using shielded, long-reach excavators to maintain safe radiation rates to

workers. All of these controls can effectively mitigate the short-term risks to workers, but they also limit RTD productivity and significantly increase costs.

Fugitive dust during RTD excavation and backfilling with clean soil will be controlled using standard dust suppression measures. Alternative 3 disturbs an area about twice the size of the excavated waste site because of soil stockpiles and RTD operations areas, in addition to the borrow source areas needed for backfill and ET barrier materials; however, no significant adverse environmental impacts are related to implementation of Alternative 3 (Section 6.6). Alternative 3 is estimated to achieve the RAOs at the High-Salt waste sites in 11 to 16 years (assuming 10 years for the SVE component for cost estimating purposes) and within 1 to 2 years at the Low-Salt waste sites, the Cs-137 waste sites, and the settling tanks from the start of the remedial action.

6.5.6 Implementability

Although the technical feasibility of RTD and SVE are proven and these are commercially available technologies, several site-specific issues may affect the implementability of Alternative 3. The nature and extent of contamination is generally bounded by the available data at these waste sites but it is very likely RTD may encounter previously unknown "hot spots" or lateral spreading areas, which would affect the estimated RTD dimensions, costs, and schedules used in the FS. Additional RTD could be undertaken to manage these uncertainties relatively easily. Monitoring of ET barrier recharge and soil vapor concentrations to assess effectiveness of the remedy are readily implemented and the risks of exposure are limited, should monitoring be insufficient to detect a system failure, which would most likely result in groundwater impacts that would be detected by groundwater monitoring.

The technical and administrative feasibility of Alternative 3 is the result of the proximity of several waste sites to facilities and infrastructure. The High-Salt and Low-Salt waste sites and settling tanks are located adjacent to the PFP. Decontamination and decommissioning (D&D) of the PFP is currently ongoing and coordination of Alternative 3 with that project will be necessary. The deeper excavation RTD options for some of these waste sites overlap and affect other waste sites if these options were selected for implementation. Because the 216-Z-1&2, 216-Z-3, and 216-Z-1A waste sites are co-located and near the 241-Z-361 Settling Tank, the selection and implementation of the remedies for these waste sites will require careful planning and coordination. Because of the shallower excavations for the RTD options at the Cs-137 waste sites, fewer infrastructure impacts are anticipated but should also be reviewed after remedy selection.

The conventional excavation technology considered as part of Alternative 3 is readily available through many contractors. Alternative 3 will require onsite disposal services and capacity at ERDF, as well as certified assay services for the expected transuranic waste soils placed in SWBs and offsite disposal capacity at WIPP. All of these services and disposal capacities are assumed to be available.

6.5.7 Cost

Table 6-1 provides a summary of the estimated costs for Alternative 3 at the High-Salt, Low-Salt, and Cs-137 waste sites and the settling tanks and Appendix D presents the cost details.
The period of analysis for the present worth cost is 1,000 years for the High-Salt and Low-Salt waste sites with untreated long-lived radionuclides (plutonium and americium) and 350 years for the Cs-137 waste sites with residual Cs-137 risks.

6.6 National Environmental Policy Act of 1969 Values Evaluation

The NEPA process is intended to help federal agencies make decisions based on understanding environmental consequences and to take actions that protect, restore, and enhance the environment. Under DOE's CERCLA/NEPA Policy, established in 1994, DOE relies on the CERCLA process for review of actions to be taken under CERCLA; i.e., a separate NEPA document or NEPA process ordinarily is not required (Cook 2002). NEPA values are incorporated into DOE's CERCLA documentation (DOE O 451.1b Chg 1) and include (but are not limited to) consideration of the cumulative, ecological, cultural, historical, and socioeconomic impacts of the proposed remedial action. This integration of NEPA values provides a more comprehensive analysis of potential impacts resulting from the various 200-PW-1, 200-PW-3, and 200-PW-6 OU remedial alternatives. To support the CERCLA decision-making process, the NEPA value analysis is addressed in the following sections.

6.6.1 Description of National Environmental Policy Act of 1969 Values

Several of the CERCLA evaluation criteria involve consideration of environmental resources, but the emphasis frequently is directed at the potential effects of chemical contaminants on living organisms. The NEPA regulations (40 CFR 1502.16, "Environmental Impact Statement," "Environmental Consequences") specify evaluation of the environmental consequences of proposed alternatives including potential effects on transportation resources, air quality, and cultural and historical resources; noise, visual, and aesthetic effects; environmental justice; and the socioeconomic aspects of implementation. The NEPA process also involves consideration of several issues such as cumulative impacts (direct and indirect), mitigation of adversely impacted resources, and the irreversible and irretrievable commitment of resources. The NEPA-related resources and values DOE has considered in this evaluation include the following:

- **Transportation Impacts.** This value considers impacts of the proposed remedial alternatives on local traffic (i.e., traffic at the Hanford Site) and traffic in the surrounding region. Transportation impacts are considered in part under the CERCLA criteria of short-term effectiveness and implementability.

- **Air Quality.** This value considers potential air quality concerns associated with emissions generated during the proposed remedial alternatives.

- **Natural, Cultural, and Historical Resources.** This value considers impacts of the proposed remedial alternatives on wildlife, wildlife habitat, archeological sites and artifacts, and historically significant properties in the Central Plateau.

- **Noise, Visual, and Aesthetic Effects.** This value considers increases in noise levels or impaired visual or aesthetic values in the Central Plateau during or following the proposed remedial alternatives.

- **Socioeconomic Impacts.** This value considers impacts pertaining to employment, income, other services (e.g., water and power utilities), and the effect of implementation of the proposed remedial alternatives on the availability of services and materials.

- **Environmental Justice.** Environmental justice, as mandated by Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations*, refers to fair treatment of humans of all races, cultures, and income levels with respect to laws, policies, and government actions. This value considers whether the proposed

remedial alternatives would have inappropriately or disproportionately high and adverse human health or environmental effects on minority or low income populations.

- **Cumulative Impacts (Direct and Indirect).** This value considers whether the proposed remedial alternatives could have cumulative impacts on human health or the environment when considered together with other activities in the Central Plateau, at the Hanford Site, or in the region.
- **Mitigation.** If adverse impacts cannot be avoided, remedial action planning should minimize them to the extent practicable. This value identifies required mitigation activities.
- **Irreversible and Irretrievable Commitment of Resources.** This value evaluates the use of nonrenewable resources for the proposed remedial alternatives 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.

6.6.2 Detailed Evaluation of the National Environmental Policy Act of 1969

The following sections describe the NEPA considerations previously mentioned above.

6.6.2.1 Transportation Impacts

No transportation impacts are associated with the No Action Alternative. Alternative 2 is considered to have the fewest transportation impacts since ISV is an in situ process. Alternative 1 would have short-term impacts on local traffic and traffic in the surrounding region from the hauling of soil materials to construct the ET barriers and physical barriers. The cost estimate (Appendix D) is based on obtaining general fill from Pit 30 (located between the 200 East and 200 West Areas), silt from Area C (west of the Rattlesnake gate area), and basalt from an offsite commercial source. Alternative 3 is considered to have the most short-term impacts on both local traffic and traffic in the surrounding region because it would require hauling contaminated soils to both onsite and offsite disposal facilities, hauling clean soil to backfill the RTD excavations, and hauling soil materials to construct the ET barriers.

Depending on the RTD option in Alternative 3 that may be selected for the High-Salt and Low-Salt waste sites, the contaminated soil that is expected to designate as transuranic waste could result in between 433 and 2,504 truckloads that would be transported through Richland, Washington, and along major highways in Washington, Oregon, Idaho, Utah, Wyoming, Colorado, and New Mexico before arriving at WIPP for disposal. This estimate assumes certified assays of the contaminated soils in SWBs can be completed at the Hanford Site, if not; the number of truckloads would increase.

6.6.2.2 Air Quality

No air quality impacts are associated with the No Action Alternative. Alternatives 1, 2, and 3 each have potential air quality impacts that can be reliably mitigated. All alternatives include an SVE component for the High-Salt waste sites and the treatment train will treat the extracted vapors so emissions meet ARARs. Fugitive dust during barrier construction (Alternatives 1 and 3), offgas vapors and dust during ISV (Alternative 2), and airborne contamination and dust during RTD (Alternative 3) will be controlled using various engineering controls discussed for each alternative and standard dust suppression measures so emissions meet ARARs. Routine emissions from vehicles and equipment would also occur for Alternatives 1, 2, and 3.

6.6.2.3 Natural, Cultural, and Historical Resources

No natural, cultural, or historical resource impacts are associated with the No Action Alternative. Under each of the alternatives, remediation will be implemented at waste sites that are highly disturbed by industrial activities as discussed in Chapter 2. The three alternatives include only limited subsurface activities within the previously disturbed waste site areas and no archeological, historic, cultural, Native American, or threatened or endangered species have been identified at any of the waste site areas in previous characterization activities. The deeper excavation RTD options in Alternative 3 have the potential to impact areas on the order of 4 hectares (10 acres) around the High-Salt waste sites, which may increase the potential for natural, cultural, or historical resource impacts at the waste sites and at the Hanford Site borrow sources; however, all of the alternatives will be implemented to comply with ARARs regarding natural, cultural, and historical resources.

6.6.2.4 Noise, Visual, and Aesthetic Effects

No noise, visual, or aesthetic impacts are associated with the No Action Alternative. During construction of Alternatives 1, 2, and 3 there will be a short-term increase in noise that will go unnoticed by the community because the location of the waste sites is within the center of the Hanford Site about 13 km (8 mi) from the nearest site boundary. Visually and aesthetically, given the past disturbance and industrial activities in the 200 Area and on the Central Plateau, no further impacts to these values are expected from Alternatives 1, 2, and 3. Following completion of Alternatives 1, 2, and 3, the visual and aesthetic qualities of the waste site areas will be improved, as all disturbed areas will be replanted with native vegetation after the ET barriers or backfilled waste sites are contoured to blend into the surrounding land surface. The deeper excavation RTD options and the associated haul roads in Alternative 3 have the potential to impact areas on the order of 4 hectares (10 acres) around the High-Salt waste sites, which would increase the short-term impacts to these effects.

6.6.2.5 Socioeconomic Impacts

The No Action Alternative would have no socioeconomic impacts. The other remedial alternatives would have some positive socioeconomic impacts related to the employment opportunities that would occur during the life of the remedial action project. The labor force required to implement remedial action would likely come from current Hanford Site contractors and the local labor force, so the socioeconomic impacts would be expected to be positive but minimal.

6.6.2.6 Environmental Justice

None of the remedial alternatives would have inappropriately or disproportionately high and adverse human health or environmental effects on minority or low income populations.

6.6.2.7 Irreversible and Irretrievable Commitment of Resources

All of the remedial alternatives, with the exception of the No Action Alternative, would require some irreversible or irretrievable commitment of resources (primarily energy and soil materials). Alternative 2 would utilize significant electricity, which is generated primarily by hydropower in this area and is a renewable resource. Alternative 2 would also use less soil materials to backfill subsided areas than the other alternatives and is considered to have the least impact on resource consumption. Alternative 1 uses more nonrenewable energy (fossil fuels) and more soil materials to construct ET barriers and physical barriers than Alternative 2 and is considered to have the second greatest impact on resource consumption. Alternative 3 is considered to have the greatest

impact on resource consumption. Alternative 3 requires even more nonrenewable energy (fossil fuels) to excavate contaminated soils, transport the contaminated soils to ERDF and WIPP, and excavate backfill and soils for the ET barriers. Alternative 3 would also use more soil materials than Alternative 1. The effect that this resource consumption would have on future generations would be to provide adequate protection of HHE, as discussed in the previous sections for each remedial alternative.

6.6.2.8 Cumulative Impacts

The remedial action alternatives could have cumulative impacts when considered together with impacts from past and foreseeable future actions at and near the Hanford Site. Authorized current and future activities include soil and groundwater remediation on the Central Plateau and within the Hanford Site; waste management and treatment (e.g., tank farms, the Waste Treatment Plant); and surveillance, maintenance, decontamination, and decommissioning of facilities. Other Hanford Site activities that might be ongoing during remedial action at the Central Plateau waste sites include deactivation and decontamination of reprocessing facilities and operation of the Energy Northwest reactor. Activities near the Hanford Site include a privately owned radioactive and mixed-waste treatment facility, a commercial nuclear fuel manufacturer, a commercial low-level radioactive waste disposal facility, and a titanium reprocessing plant.

The remedial alternatives would have short-term impacts on transportation; air quality; noise, visual, and aesthetic effects; and natural, cultural, and historical resources; therefore, cumulative impacts with respect to these values are expected to be insignificant. The most notable area for cumulative impacts is with respect to the irretrievable and irreversible commitment of resources. All of the remedial alternatives except for the No Action Alternative would require different levels of resource consumption, but the net benefit to future generations from this resource consumption would be to provide adequate protection of HHE, as discussed in previous sections for each remedial alternative.

The 200-PW-1, 200-PW-3, and 200-PW-6 OU waste sites constitute only a small portion of the remedial actions at waste sites and facilities in the Central Plateau that may require soil and rock materials for barriers and backfill. The total quantity of geologic materials required for other Hanford Site actions currently is being identified and has been addressed adequately in DOE/EA-1403, *Environmental Assessment: Use of Existing Borrow Areas, Hanford Site, Richland, Washington.*

6.6.2.9 Mitigation

The No Action Alternative will not require any mitigation. The potential short-term impacts on transportation will not require mitigation for any of the alternatives. The potential short-term impacts on air quality; noise, visual, and aesthetic effects; and natural, cultural, and historical resources will be mitigated for each alternative by complying with ARARs.

6.6.2.10 Summary of National Environmental Policy Act of 1969 Evaluation

The No Action Alternative will have no impact on any of the NEPA values considered in this evaluation. Alternatives 1, 2, and 3 each have different potential short-term impacts on transportation; air quality; noise, visual, and aesthetic effects; and natural, cultural, and historical resources that can be mitigated for each alternative by complying with ARARs. The most significant impact is with respect to the irretrievable and irreversible commitment of resources. All of the remedial alternatives except for the No Action Alternative would require different levels of resource consumption, with Alternative 3 requiring the greatest resource consumption of

nonrenewable energy (fossil fuels) and soil materials; however, the net benefit to future generations from this resource consumption would be to provide adequate protection of HHE as discussed in the previous sections for each remedial alternative.

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7 Comparative Analysis of Alternatives

The remedial action alternatives for the 200-PW-1, 200-PW-3, and 200-PW-6 OU waste sites (which were developed in Chapter 5 and analyzed in detail in Chapter 6) are compared in this chapter. The comparative analysis identifies the relative advantages and disadvantages of each alternative with respect to the CERCLA evaluation criteria and how reasonable variations of key uncertainties may change the expectations of their relative performance.

Under each individual criterion, the alternative(s) that performs the best overall in that category is discussed first with the other alternatives discussed in the relative order in which they best perform. The following is a list of alternatives.

- No Action Alternative
- Alternative 1—Barrier
- Alternative 2—In Situ Vitrification
- Alternative 3—Removal, Treatment, and Disposal
  - Option 3A—Remove the highest concentrations of contaminated soils to 0.6 m (2 ft) below the base of a waste site.
  - Option 3B—Remove contaminated soils that could be a direct contact risk to industrial workers and that are less than 4.6 m (15 ft) below the current ground surface.
  - Option 3C—Remove a significant portion of plutonium contamination based on an evaluation of soil contaminant concentration with depth. A significant portion of cesium-137 contamination would be removed at the cesium-137 waste sites based on a similar evaluation.
  - Option 3D—Remove contaminated soils containing greater than 100 nCi/g of transuranic radionuclides.
  - Option 3E—Remove contaminated soils with greater than a 10^{-4} risk level so that long-term institutional controls at a waste site are not necessary.

Figures 7-1 through 7-10 (located at the end of the chapter) summarize the key features of the remedial alternatives. Each figure contains the following:

- A description of the remedy
- A risk mitigation summary
- A map depicting the land impact (footprint) and possible layout of the remedy
- Estimated quantities of wastes generated, backfill soil needed, barrier materials needed, and duration of the remedial action

7.1 Summary of Alternatives

Figures 7-1 through 7-7 address alternatives for the 200-PW-1 and 200-PW-6 OUs; both OUs are presented in each figure. Figures 7-8 through 7-10 address alternatives for the 200 PW-3 OU. These figures contain the capital costs, nondiscounted costs, and total present worth costs associated with the remedial action alternative. Not included in these costs are settling tank costs or future sampling costs. Note the depiction of soil stockpiles for the RTD alternatives is provided to illustrate the land area required to manage imported backfill soil and the overburden soil excavated from waste sites. The actual location and configuration of the stockpiles would be determined during remedial design.

7.2 Overall Protection of Human Health and the Environment

Alternatives 1, 2, and 3 provide adequate protection of HHE. The No Action Alternative provides adequate protection of HHE at the 216-Z-8 French Drain and 216-Z-10 Injection/Reverse Well because current risk levels at those sites are within or below the CERCLA risk range of 10^{-4} to 10^{-6}. Alternatives 1, 2, and 3 control, reduce, or eliminate direct contact risks to the industrial worker so that these risks are below 10^{-4}. These alternatives also control, reduce, or eliminate risks to a future subsistence farmer so that risks are within the 10^{-4} to 10^{-6} range or below. These alternatives all use SVE to eliminate groundwater impacts from carbon tetrachloride at the High-Salt waste sites.

Alternative 1 achieves protection by preventing exposure with ET and physical barriers, and uses institutional controls to maintain long-term protection. Alternative 2 uses ISV to treat and immobilize radionuclides in a vitrified glass monolith to prevent exposure and uses institutional controls to maintain long-term protection from any untreated residuals above risk levels. Alternative 3 achieves protection through RTD and ET barriers to prevent exposure and uses institutional controls to maintain long-term protection from any untreated residuals above risk levels.

7.3 Compliance with ARARs

The evaluation of the ability of the alternatives to comply with ARARs included a review of chemical-specific, location-specific, and action-specific ARARs that was presented for each alternative in Chapter 6. All of the alternatives will meet their respective ARARs, except for the No Action Alternative. A limited action at the 216-Z-10 Injection/Reverse Well is required to comply with the state well decommissioning ARAR.

7.4 Long-Term Effectiveness and Permanence

Alternatives 2, 3A, 3B, and 3C provide long-term effectiveness and permanence. Alternative 2 would use ISV to treat approximately 90 percent of the radionuclides at the High-Salt sites and 100 percent of the radionuclides at the Low-Salt sites, while Alternatives 3A, 3B, and 3C would remove similar percentages of radionuclides at these sites using RTD. These alternatives would significantly reduce risks at the Low-Salt sites and eliminate the need for long-term institutional controls but both would require institutional controls for 1,000 years and longer to maintain effectiveness at the High-Salt waste sites.

Alternative 3, Options 3D and 3E provide long-term effectiveness and permanence at the High-Salt waste sites because they reduce risks to less than 10^{-4} and eliminate the need for long-term institutional controls, but they require excavations between 27 and 36 m (90 and 120 ft) deep that are costly and disturb significant land areas (Figure7-6 [Option 3D] and Figure 7-7 [Option 3E]).

Alternative 1, like the other action alternatives, uses SVE to eliminate groundwater impacts from carbon tetrachloride at the High-Salt waste sites, but all other contamination at the waste sites remains untreated. Alternative 1 provides long-term protection by preventing exposure with ET and physical barriers, and uses institutional controls to maintain long-term protection.

For all of the action alternatives that leave untreated contamination above risk levels at the waste sites, institutional controls are required to help maintain long-term effectiveness and permanence at the High-Salt and Low-Salt sites for 1,000 years and longer, and for 350 years at the cesium-137 sites. Long-term monitoring will continue at sites where residual contamination remains above the CERCLA risk levels and 5-year reviews would be necessary for these sites to verify the remedy remains protective. Although there is some uncertainty regarding the reliability of maintaining institutional controls for these durations, the required CERCLA reviews every 5 years helps ensure all of the components of the remedy (including institutional controls) remain effective and permanent in the long-term.

The No Action Alternative provides long-term effectiveness and permanence at the 216-Z-8 French Drain and 216-Z-10 Injection/Reverse Well because current risk levels at those sites are within or below the CERCLA risk range of 10^{-4} to 10^{-6}.

7.5 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 2 uses ISV to treat and immobilize radionuclides in a vitrified glass monolith to prevent exposure and for any untreated contamination above risk levels, uses institutional controls to maintain long-term protection. However, the mobility of plutonium or americium will not be reduced, as they are currently not mobile under existing or anticipated conditions. Alternative 2, like the other action alternatives, also uses SVE to remove carbon tetrachloride from the vadose zone at the High-Salt waste sites and treat the contaminated soil vapor with granulated activated carbon or another treatment technology such as thermal oxidation. The thermal oxidation or regeneration of the granulated activated carbon would ultimately destroy the carbon tetrachloride. The ISV and SVE technologies are irreversible and Alternative 2 would satisfy the statutory preference for treatment as a principal element.

Alternatives 1 and 3 also use SVE to remove carbon tetrachloride from the vadose zone at the High-Salt waste sites and treat the contaminated soil vapor with a treatment technology such as thermal oxidation; however, the alternative does not reduce the toxicity, mobility, or volume of the other final COPCs through treatment. The Barrier, ISV, and RTD alternatives do not reduce the mobility of Pu and Am as they are currently not mobile under existing or anticipated conditions; however, the SVE system would be continued under each alternative. Therefore, each alternative ranks as performing moderately well for reduction in toxicity, mobility, and volume through treatment. Under Alternative 1, the toxicity and volume of cesium-137 will be reduced to below risk levels by natural radioactive decay in about 150 years for the construction worker and in about 350 years for the subsistence farmer scenario.

7.6 Short-Term Effectiveness

Alternatives 1 and 2 are anticipated to have equal short-term effectiveness. These alternatives have some risk to the community, remedial action workers, and the environment. Workers will need to be protected from dust during barrier construction (Alternative 1) and from dust, dermal contact, and vapors during SVE (Alternatives 1 and 2) and ISV (Alternative 2) construction and operation. Alternative 1 will have environmental impacts at borrow sources for the barrier materials. Alternative 2 will need borrow for pre-melt fill and post-melt subsidence backfill. The time required to achieve short-term effectiveness is estimated as 11 years (Alternative 1) and 16 years (Alternative 2) at the High-Salt sites, 1 to 2 years (Alternative 1) and 4 years (Alternative 2) at the Low-Salt sites, and 1 to 2 years (Alternative 1) at the cesium-137 sites from the start of the remedial action. For this reason, the barrier was ranked higher.

All RTD options in Alternative 3 are expected to have equal short-term risks to the community, remedial action workers, and the environment. Figures 7-3 through 7-7 summarize the potential land area impacts, wastes generated, soil and rock quantities needed for backfill, and ET barriers are summarized for the various RTD options in Figures 7-3 through 7-7. The various RTD options at the High-Salt and Low-Salt waste sites could result in between 433 and 2,504 truckloads of transuranic waste transported to WIPP in New Mexico. These potential risks to the community are mitigated by costly shipping requirements. Workers must be protected from dermal contact, dust, and vapors during SVE and RTD construction and SVE operation. Protecting workers from airborne radiological contamination during excavation at the High-Salt and Low-Salt sites and from external radiation at the cesium-137 sites will require engineering and radiological controls at significant cost. Alternative 3 will also have the greatest environmental impacts at both the waste sites being excavated and the borrow areas and will disturb significant land areas. The time required to achieve short-term effectiveness is estimated as 11 to 16 years at the High-Salt sites and 1 to 2 years at the Low-Salt, settling tanks, and cesium-137 sites from the start of the remedial action.

The durations of all of the remedial alternatives for the High-Salt waste sites assume the SVE component takes 10 years (for cost estimating purposes). The sequencing and duration of remedy components will be refined during the remedial design.

7.7 Implementability

Alternative 1 would be the simplest to construct and operate. The ET and physical barrier soil and rock materials are available in the local area. Subsurface voids at several waste sites (216-Z-1&2, 216-Z-3, 216-Z-5, and 216-Z-9) would be backfilled with CDF prior to barrier construction and the abovegrade structures at the 216-Z-9 Trench would be removed. The barriers at each waste site could easily be expanded if contamination is discovered beyond the waste site footprint during a post-ROD design investigation. Periodic maintenance of the barriers would maintain their reliability in the future. The SVE component, which is common to all action alternatives, can be readily constructed by installing new SVE wells at the High-Salt waste sites and connecting these wells to an SVE blower and treatment train.

Construction of Alternative 2 would require extending or upgrading electrical power to the High-Salt and Low-Salt waste sites, partially excavating to remove flammable timbers at the 216-Z-1&2 and 216-Z-5 Cribs, partially excavating to collapse the culvert at the 216-Z-3 Crib, removing the abovegrade and belowgrade structures and the concrete cover at the 216-Z-9 Trench, and placing clean sand fill over the waste sites prior to ISV melt operations. No anticipated technical or service and material issues are associated with Alternative 2, although there may be a need to administratively coordinate the electrical power requirements of ISV with other Hanford Site power needs (especially operation of the Waste Treatment Plant project).

Alternative 3 is also a complicated alternative to implement and construct. The RTD excavations and sludge removal from the settling tanks will require significant contaminated material handling requirements for worker safety and environmental protection. Because the High-Salt and Low-Salt sites contain plutonium and americium (which emit alpha radiation) and the cesium-137 sites contain cesium-137 (which emits beta-gamma radiation), special conditions apply when disturbing, handling, and transporting these contaminated soils. Control of airborne contamination will require engineering controls such as water misting and appropriate personal protective equipment for remedial action workers. For the High-Salt, Low-Salt, and settling tank sites, the excavation, sludge removal, and waste container packaging will be performed inside a portable enclosure. The waste containers (SWBs) would then be assayed and transported to the CWC for storage pending proper waste disposition. The SWBs designated as transuranic waste or mixed transuranic waste would then be transported to WIPP for disposal. All other contaminated soil and debris are expected to meet the criteria for disposal at Hanford (ERDF).

In addition, radiation dose rates to workers from the contaminated soils in the excavation and from the full waste containers will limit the excavation rate and the amount of contaminated soil that can be placed in each waste container. Based on the soil concentrations found at the cesium-137 sites and the FY08 field experience from the excavation treatability test at the 216-B-26 Trench in the 200 East Area, the contaminated soils at the cesium-137 sites are expected to be mixed, on average, with two parts clean soil to one part contaminated soil in order to maintain safe radiation dose rates.

A key uncertainty that impacts the cost and duration of Alternative 3 is the estimated quantity of contaminated soil at the High-Salt and Low-Salt waste sites that will require disposal at WIPP or ERDF. The RTD at each waste site could easily be expanded if contamination is discovered beyond the waste site footprint during a post-ROD design investigation or during excavation.

Because of the land area required for waste site excavation, remedial operations, and clean soil stockpiling, Alternative 3 at the High-Salt, Low-Salt, and settling tank sites will need to be administratively coordinated with the PFP D&D project. Because the 216-Z-1&2, 216-Z-3, and 216-Z-1A

waste sites are co-located and near the 241-Z-361 Settling Tank, the selection and implementation of the remedy(s) for these waste sites will require careful planning and coordination.

The deeper excavation RTD options (Alternative 3, Options 3D and 3E) at the High-Salt waste sites will encounter technical difficulties, as these excavations will be between 27 and 36 m (90 and 120 ft) deep and will overlap with each other and impact other waste sites and adjacent infrastructure (Figures 7-6 and 7-7). Deep excavation technologies could be used at these waste sites to reduce the impacts if these RTD options are selected as the final remedies for these sites but they would incur additional implementability issues and the costs would be significantly higher.

7.8 Cost

Table 7-1 provides a summary of the costs for the alternatives evaluated at the waste site groups for costs directly assumed by DOE-RL, which include the costs for construction, operation and maintenance, and institutional controls. The cost details of all of the alternatives are provided in Appendix D. Present worth costs are used in this section to compare the remedial alternatives. The costs presented in Table 7-2 are estimates for the RTD alternatives for disposal to WIPP. The costs of operation of WIPP are managed by a separate DOE office and no disposal fees are reflected to RL. An average disposal cost was estimated using Carlsbad Field Office facility operations budget and the total volume disposed. The average disposal cost is $44,000 per cubic meter. To provide an estimate of the total project costs for comparison of alternatives, the estimate of the WIPP disposal cost is included in the cost information for the RTD options for the High-Salt, Low-Salt and settling tank waste groups."

The No Action Alternative has no costs for any waste sites. The limited action to decommission the 216-Z-10 Injection/Reverse Well has a present worth cost of about $162,000.

For the High-Salt sites, the present worth costs are approximately $19.1 million for Alternative 1, $94.0 million for Alternative 2, $112 million for Alternative 3A, $642 million for Alternative 3C, $917 million for Alternative 3D, and $896 million for Alternative 3E. Because Alternative 3B would only excavate soils at the 216-Z-1A Tile Field, the costs for maintaining the existing cover at 216-Z-9 and 216-Z-18 must be included to evaluate a complete alternative; therefore, the total cost is $40.2 million.

For the Low-Salt sites, the present worth costs are approximately $10.1 million for Alternative 1, $23.7 million for Alternative 2, $61.8 million for Alternative 3A, and $81.4 million for Alternatives 3C, 3D, and 3E.

For the settling tanks, the present worth costs are approximately $39.6 million for Alternative 3.

For the cesium-137 sites, the present worth costs are approximately $12.2 million for Alternative 1 and $29.1 million for Alternative 3C. Because Alternative 3B would only excavate soils at the 216-A-7 and 216-A-8 Cribs and the UPR-200-E-56 unplanned release, costs for maintaining the existing soil cover at 216-A-24 and 216-A-31 Cribs must be included to evaluate a complete alternative; therefore, the total cost is $19.6 million.

7.9 State Acceptance

State acceptance will be addressed in the ROD.

7.10 Community Acceptance

Community acceptance will be addressed in the ROD. An initial assessment of the alternatives the community supports, has reservations about, or opposes, is based on an early involvement public workshop held on April 15, 2008, that presented the remedial alternatives considered in the Draft A FS for the 200-PW-1 OU waste sites (e.g., the High-Salt and Low-Salt sites). As a result of that workshop,

the HAB issued Consensus Advice #207 on June 6, 2008 (HAB 207), containing considerations that the Board believes are important to development of the Proposed Plan. Both the public comments at the workshop and Consensus Advice #207 indicate the community supports Alternative 3, to the extent practicable, at the High-Salt and Low-Salt sites and opposes Alternative 1, unless there is no other practicable alternative.

As a result, this Draft C FS includes five RTD Options in Alternative 3 to address community input and values, the risk analysis and life-cycle cost estimates for these sites are evaluated for a 1,000-year period, and deep excavation technologies are included in the evaluation of remedial alternatives.

Two Tribal Nations also requested that Tribal risk scenarios be evaluated in the risk assessment of these waste sites. These scenarios, like the unrestricted land use (subsistence farmer) scenario in the BRA, are not consistent with the anticipated future land use but are evaluated to assist interested parties in providing input on the remedial alternatives as part of the CERCLA modifying criteria. Native American scenarios developed specifically by the Yakama Nation and the CTUIR were evaluated and the detailed assessment is included as Appendix G. These scenarios were used by the DOE as received by the two Tribes.

7.11 Summary of Comparative Analysis

Table 7-3 summarizes each of the alternatives and the outcome of the analysis for each waste group. The table includes the threshold and balancing criteria determinations for each alternative and total cost for each alternative, including present worth cost for construction, operation and maintenance, institutional controls, and estimated costs for disposal at WIPP, if appropriate.

Table 7-1. Summary of Costs of Alternatives by Waste Site Group

Waste Site Group	No Action Alternative	Alternative 1—Barrier	Alternative 2—In Situ Vitrification	Alternative 3—Removal, Treatment and Disposal					
216-Z-8 French Drain and 216-Z-10 Injection/ Reverse Well	Cap $0.16 A&P $0 TND $0.16 PW $0.16	Not evaluated	Not evaluated	Not evaluated					
Settling Tanks (241-Z-8, 241-Z-361)	All costs $0	Not evaluated	Not evaluated	Cap $33.4 A&P $0 TND $33.4 TPV $33.4					
					Option 3B				
				Option 3A	Excavation Only	With Barrier	Option 3C	Option 3D	Option 3E
High-Salt Sites (216-Z-1A, 216-Z-9, 216-Z-18)	All costs $0	Cap $12.3 A&P $107.5 TND $119.8 PW $19.1	Cap $115.1 A&P $107.4 TND $222.5 PW $94.0	Cap $57.4 A&P $107.5 TND $165.0 PW $52.4	Cap $32.2[a] A&P $35.8[a] TND $68.0[a] PW $27.1[a]	Cap $40.8[a] A&P $107.5[a] TND $148.4[a] PW $40.2[a]	Cap $278.5 A&P $107.4 TND $385.9 PW $213.0	Cap $441.8 A&P $6.6 TND $448.4 PW $325.8	Cap $422.5 A&P $6.6 TND $429.0 PW $313.3
Low-Salt Sites (216-Z-1&2, 216-Z-3, 216-Z-5, 216-Z-12)	All costs $0	Cap $4.2 A&P $171.0 TND $175.3 PW $10.1	Cap $17.8 A&P $171.0 TND $188.8 PW $23.7	Cap $31.2 A&P $171.0 TND $202.2 PW $37.1	Not evaluated		Cap $38.9 A&P $0 TND $38.9 PW $38.9	Cap $38.9 A&P $0 TND $38.9 PW $38.9	Cap $38.9 A&P $0 TND $38.9 PW $38.9
		ET	MEESC						
Cesium-137 Sites (216-A-7, 216-A-8, 216-A-24, 216-A-31, UPR-200-E-56)	All costs $0	Cap $5.0 A&P $71.8 TND $76.8 PW $12.2	Cap $4.4 A&P $68.0 TND $72.4 PW $11.1	Not evaluated	Not evaluated	Cap $11.7[b] A&P $37.1[b] TND $48.8 [b] PW $15.3[b]	Cap $13.2[b] A&P $63.9[b] TND $76.6[b] PW $19.6[b]	Cap $22.7 A&P $63.9 TND $86.7 PW $29.1	Not evaluated	Not evaluated

a. RTD Option 3B at the High-Salt sites only includes the 216-Z-1A Tile Field. Additional costs are incurred when the barrier is constructed over 216-Z-9 and 216-Z-18.

b. RTD Option 3B at the cesium-137 sites only includes the 216-A-7 and 216-A-8 Cribs and the UPR-200-E-56 unplanned release. Additional costs are incurred when MEESC is constructed over 216-A-24 and 216-A-31.

Cap = Capital cost (in $ millions)

A&P = Annual and periodic cost (in $ millions)

TND = Total nondiscounted cost (in $ millions)

PW = Present worth cost (in $ millions)

Table 7-2. Summary of WIPP Disposal Costs by Alternatives by Waste Site Group

Waste Site	Alternative 3a		Alternative 3b		Alternative 3c		Alternative 3d		Alternative 3e	
	Volume (yd^3)	Disposal Cost ($ millions)	Volume (yd^3)	Disposal Cost ($ millions)	Volume (yd^3)	Disposal Cost ($ millions)	Volume (yd^3)	Disposal Cost ($ millions)	Volume (yd^3)	Disposal Cost ($ millions)
High-Salt Soil Sites (216-Z-1A, 216-Z-9, and 216-Z-18)	1,630	$54.8	1,108	$37.3	10,814	$364	14,118	$475	14,051	$473
Low-Salt Soil Sites (216-Z-1&2, 216-Z-3, 216-Z-5, and 216-Z-12)	911	$30.6	NA	NA	1,263	$42.5	1,263	$42.5	1,263	$42.5
Settling Tanks (241-Z-361 and 216-Z-8)	185	$6.19	185	$6.19	185	$6.19	185	$6.19	185	$6.19

Table 7-3. Comparative Analysis Summary for the 200-PW-1, 200-PW-3, and 200-PW-6 Sites

Alternatives	Threshold Criteria		Balancing Criteria				
	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume	Short-term Effectiveness	Implementability	Cost[a, d] (Present Worth in $ million)
High-Salt Waste Group 216-Z-1A Tile Field, 216-Z-9 Trench, and 216-Z-18 Crib							
No Action	No	No	Not Ranked[b]				$0
Barrier	Yes	Yes	◐	◐[c]	○	○	$19.1
ISV	Yes	Yes	◐	◐[c]	◐	●	$94.0
RTD Option A	Yes	Yes	◐	◐[c]	◐	◐	$112
RTD Option B[e]	Yes	Yes	◐	◐[c]	◐	◐	$77.5
RTD Option C	Yes	Yes	◐	◐[c]	◐	◐	$642
RTD Option D	Yes	Yes	◐	◐[c]	◐	●	$917
RTD Option E	Yes	Yes	○	◐[c]	◐	●	$896
Low-Salt Waste Group 216-Z-1&2 Cribs, 216-Z-3 Crib, 216-Z-12 Crib and 216-Z-5 Crib							
No Action	No	No	Not Ranked[b]				$0
Barrier	Yes	Yes	◐	●	○	○	$10.1
ISV	Yes	Yes	◐	●	◐	●	$23.7
RTD Option A	Yes	Yes	◐	●	◐	◐	$61.8
RTD Option C	Yes	Yes	○	●	◐	◐	$81.4
RTD Option D	Yes	Yes	○	●	◐	◐	$81.4
RTD Option E	Yes	Yes	○	●	◐	◐	$81.4
Cesium-137 Waste Group 216-A-7 Crib, 216-A-8 Crib, 216-A-24 Crib, 216-A-31 Crib and UPR-200-E-56 Unplanned Release							
No Action	No	No	Not Ranked[b]				$0
Barrier (Original)	Yes	Yes	◐	●	○	○	$12.2
Barrier (MEESC)	Yes	Yes	◐	●	○	○	$11.1
RTD Option B[f]	Yes	Yes	◐	●	◐	◐	$19.6
RTD Option C	Yes	Yes	◐	●	◐	◐	$29.1

Table 7-3. Comparative Analysis Summary for the 200-PW-1, 200-PW-3, and 200-PW-6 Sites

Alternatives	Threshold Criteria		Balancing Criteria				
	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume	Short-term Effectiveness	Implementability	Cost[a, d] (Present Worth in $ million)
Settling Tanks 241-Z-361 Settling Tank and 241-Z-8 Settling Tank							
No Action	No	No	Not Ranked[b]				$0
RTD – Remove Tank Contents	Yes	Yes	○	●	◐	◐	$39.6
Other 216-Z-8 French Drain and 216-Z-10 Reverse Well							
No Action	Yes	Yes	Not Ranked				$0.16
Barrier	Not Evaluated						
ISV	Not Evaluated						
RTD	Not Evaluated						

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

b. The No Action Alternative is not ranked because it does not meet the threshold criteria.

c. Carbon tetrachloride and other volatile organic compounds removed by soil vapor extraction are subject to treatment.

d. The costs for confirmatory sampling and pipeline removal costs are not included here.

e. Option B excavates only at 216-Z-1A and includes the barrier for 216-Z-9 and 216-Z-18,

f. Option B excavates only at 216-A-7, 216-A-8, and UPR 200-E-56. The option includes MEESC for 216-A-24 and 216-A-31.

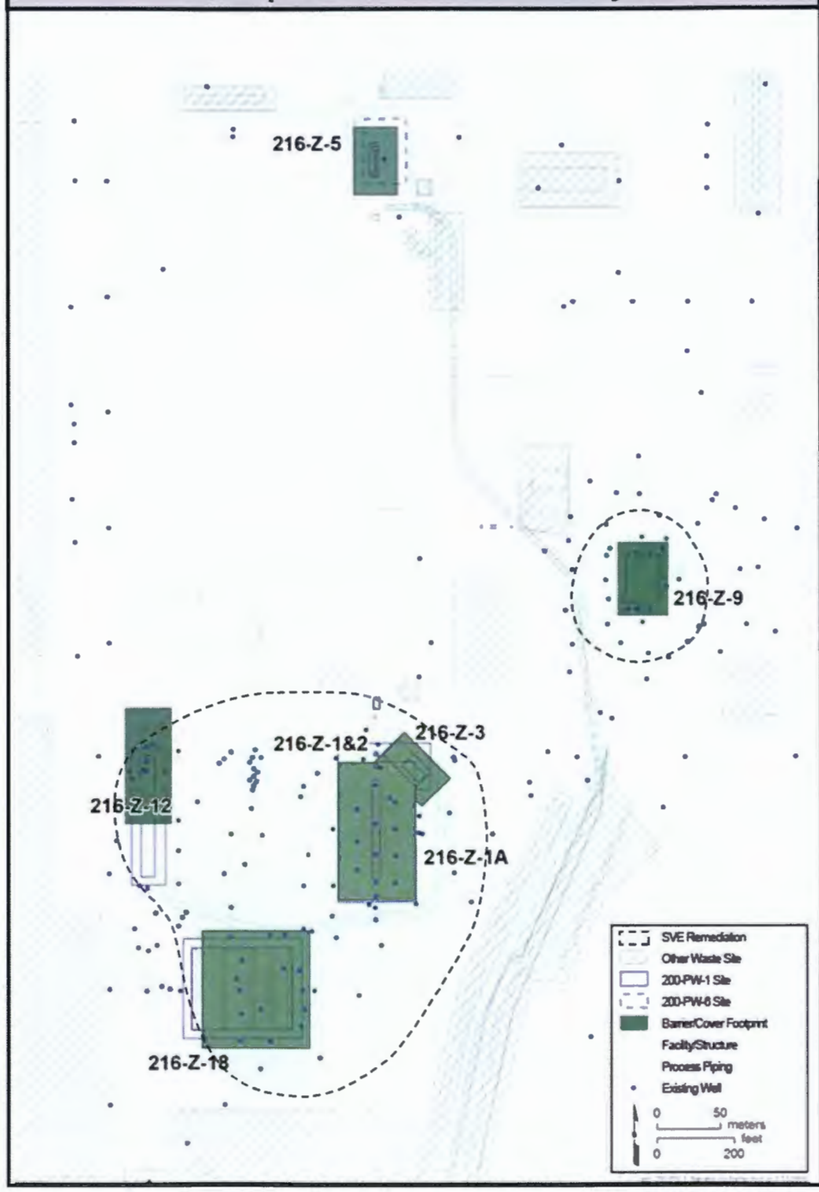
Evaluation Metric

● = 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.

Footprint of Barrier Remedy



Alternative 1 Description

This alternative is to include the following components:

- SVE for 10 years at 216-Z-1A, 216-Z-9 and 216-Z-18
- ET Barrier (with basalt) to cover waste site dimensions, after completion of SVE
- IC for 1,000 years

Duration

Assume 10 year duration for SVE

Active remedy implementation 1 year following completion of SVE.

ICs, including 5 years reviews, extend to 1,000 years

Estimated Cost ($M)

Total Capital Cost	$ 16.5
Non-Discounted Cost	$ 295.1
Total Present Worth	$ 29.2

Estimated Quantities

Waste and Backfill

ERDF	0 cu yd.
WIPP	0 cu yd.
Overburden	0 cu yd.
Void Volume	0 cu yd.
Imported Fill	0 cu yd.

Barrier

Backfill	28,960 cu yd.
Basalt	36,040 cu yd.
Silt	24,750 cu yd.
CDF	270 cu yd.

Exposure Pathway

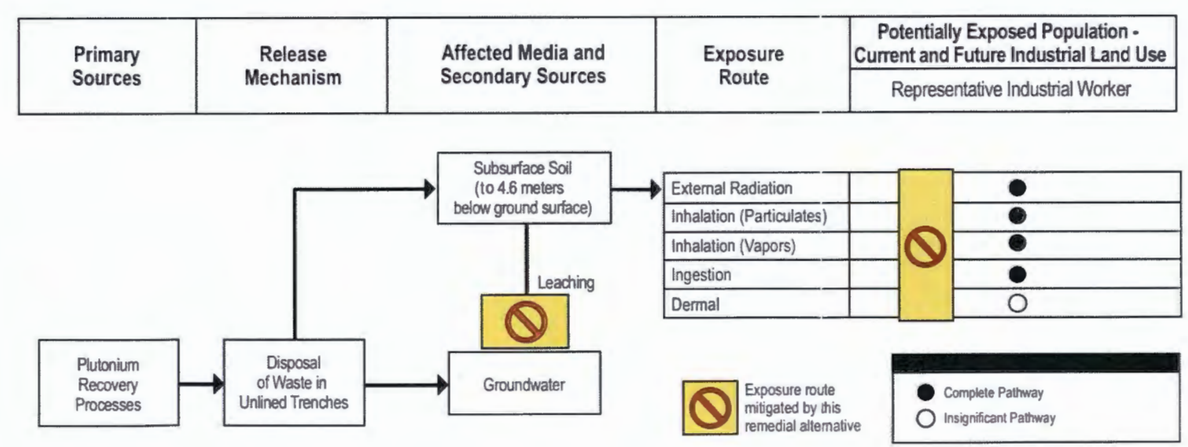


Figure 7-1. Alternative 1 Summary for the 200-PW-1 and 200-PW-6 Operable Units

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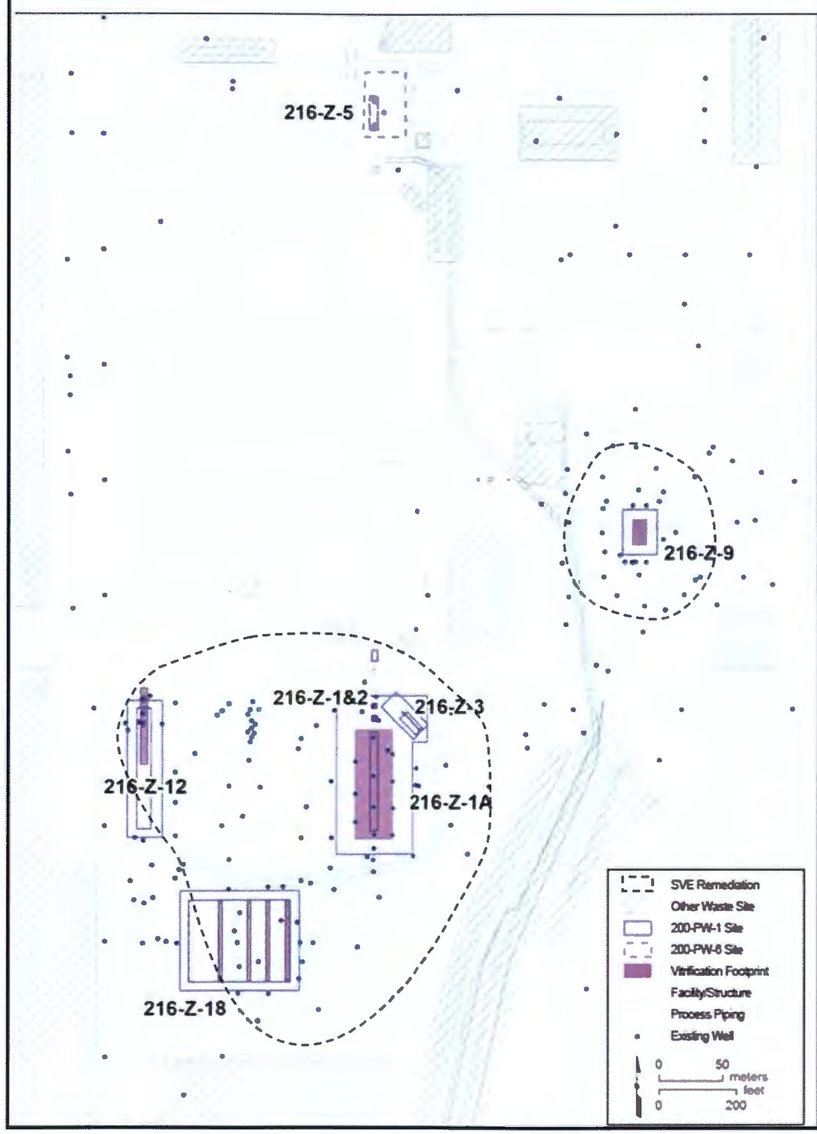
Footprint of Situ Vitrification Remedy



Alternative 2 Description

This alternative is to include the following components:

- SVE for 10 years at 216-Z-1A, 216-Z-9 and 216-Z-18
- In Situ Vitrification after completion of SVE
- IC for 1,000 years at 216-Z-1A, 216-Z-9 and 216-Z-18

Duration

Assume 10 year duration for SVE

Active remedy implementation 2-8 years following completion of SVE.

ICs, including 5 years reviews, extend to 1,000 years

Estimated Cost ($M)

Total Capital Cost	$ 132.9
Non-Discounted Cost	$ 411.3
Total Present Worth	$ 117.7

Estimated Quantities

Waste and Backfill

ERDF	570 cu yd.
WIPP	0 cu yd.
Overburden	31,430 cu yd.
Imported Fill	14,920 cu yd.

Barrier

Engineered Fill	0 cu yd.
Basalt	0 cu yd.
Silt	0 cu yd.

Exposure Pathway

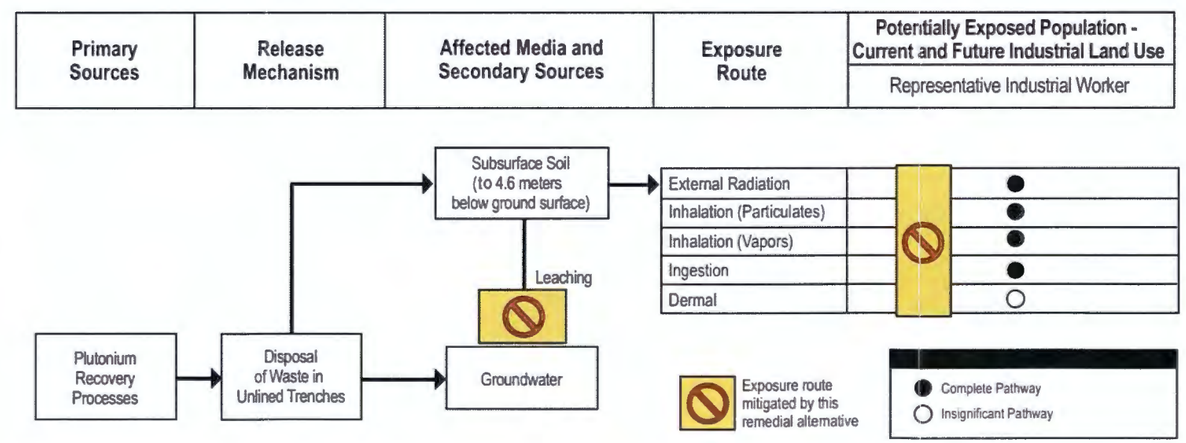


Figure 7-2. Alternative 2 Summary for the 200-PW-1 and 200-PW-6 Operable Units

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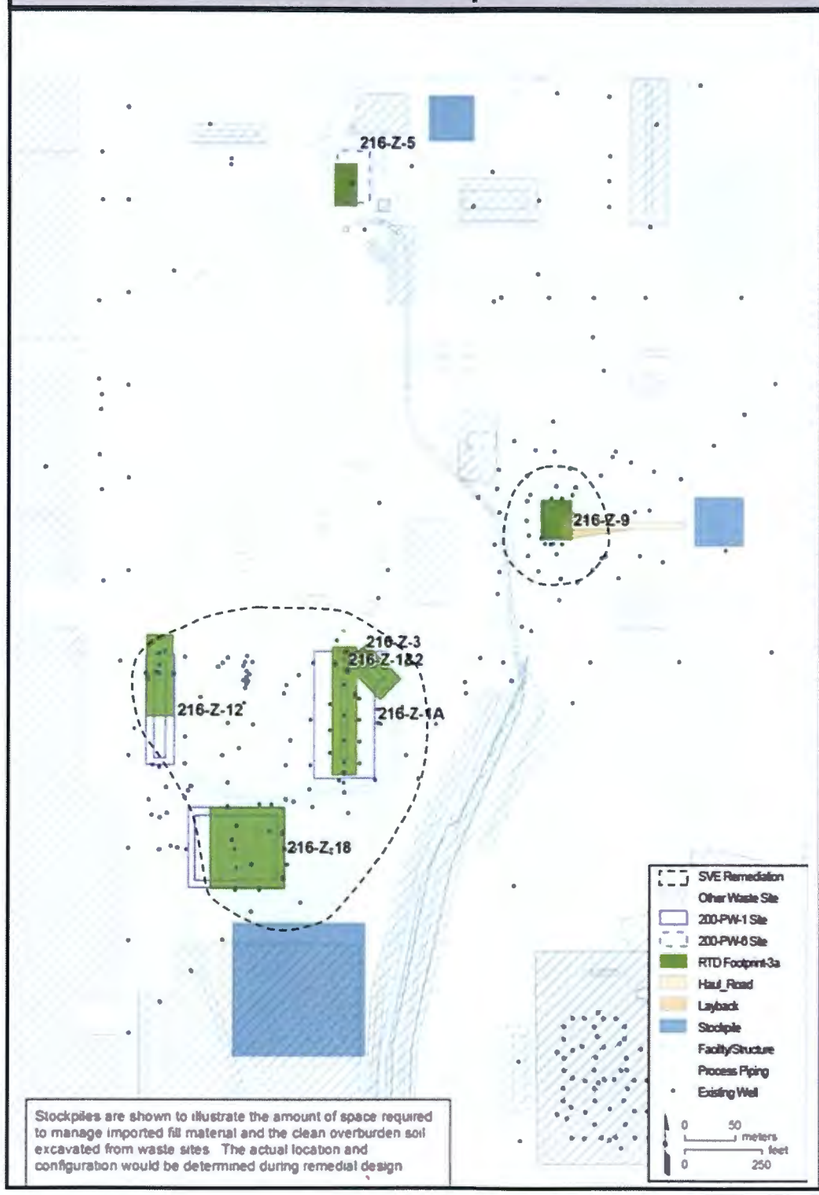
Waste Site and Stockpile Locations



Alternative 3a Description

This alternative is to include the following components:

- SVE for 10 years 216-Z-1A, 216-Z-9, and 216-Z-18
- Remove Highest Pu concentrations (2ft below base of waste site), after completion of SVE
- Backfill to grade, addition of ET barrier
- IC for 1,000 years

Duration

Assume 10 years for SVE

Active remedy implementation 1 year following completion of SVE.

ICs, including 5 year reviews, extend to 1,000 years

Estimated Cost ($M)

Total Capital Cost	$ 88.7
Non-Discounted Cost	$ 367.2
Total Present Worth	$ 89.5
WIPP Disposal	$ 91.6

Estimated Quantities

Waste and Backfill

ERDF	2,100 cu yd.
WIPP	2,730 cu yd.
Overburden	71,350 cu yd.
Void Volume	13,270 cu yd.
Imported Fill	19,160 cu yd.

Barrier

Engineered Fill	20,740 cu yd.
Basalt	1,680 cu yd.
Silt	21,170 cu yd.

Exposure Pathway

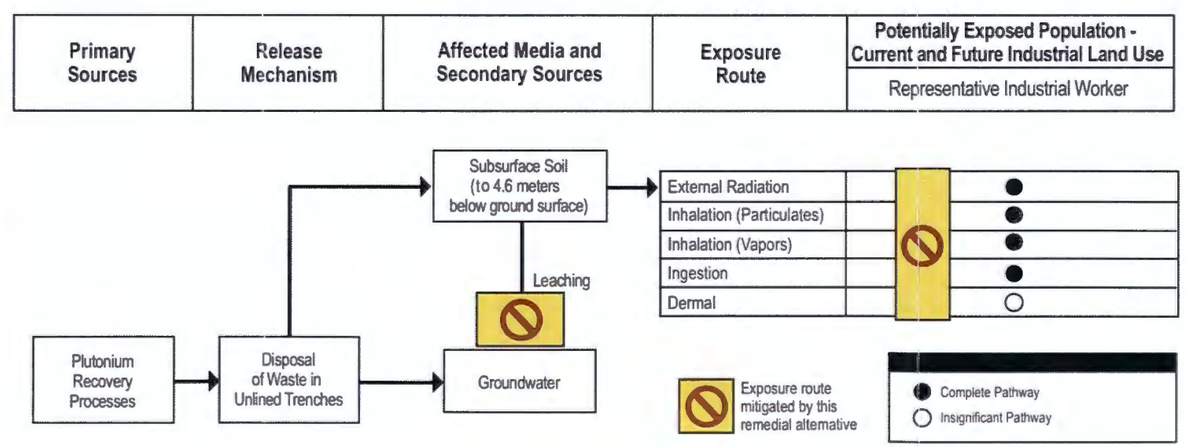


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Figure 7-3. Alternative 3A Summary for the 200-PW-1 and 200-PW-6 Operable Units

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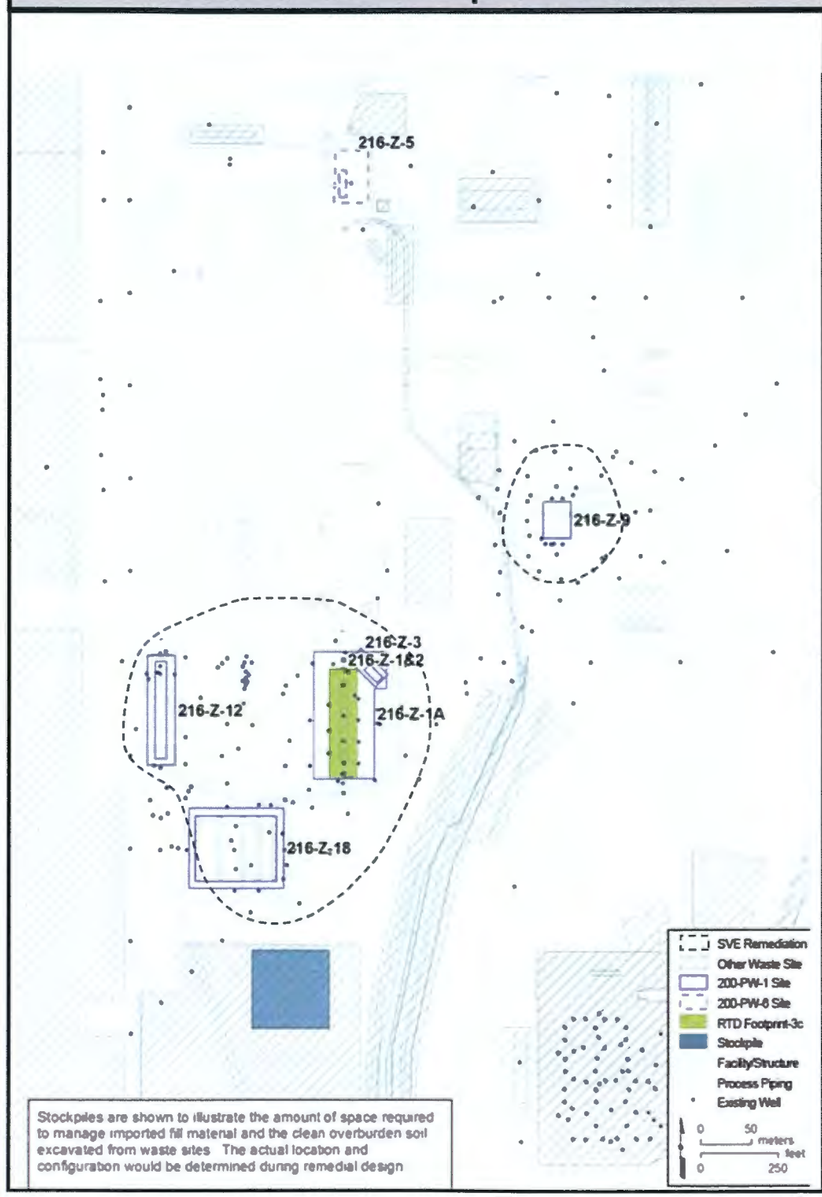
Waste Site and Stockpile Locations



Alternative 3b Description

This alternative is to include the following components:

- SVE for 10 years 216-Z-1A, 216-Z-9, and 216-Z-18
- Remove Pu direct-contact risk < 15 ft bgs (only at 216-Z-1A
- Backfill to grade, addition of ET barrier
- IC for 1,000 years

Duration

Assume 10 years for SVE

Active remedy implementation 1 year following completion of SVE. Final waste shipments could occur during IC period.

ICs, including 5 year reviews, extend to 1,000 years

Estimated Cost ($M)

Total Capital Cost	$ 32.2
Non-Discounted Cost	$ 68.0
Total Present Worth	$ 27.1
WIPP Disposal	$ 43.5

Quantities

Waste and Backfill

ERDF	1,210 cu yd.
WIPP	1,290 cu yd.
Overburden	5,000 cu yd.
Void Volume	8,600 cu yd.
Imported Fill	12,240 cu yd.

Barrier

Engineered Fill	4,570 cu yd.
Basalt	390 cu yd.
Silt	6,480 cu yd.

Exposure Pathway

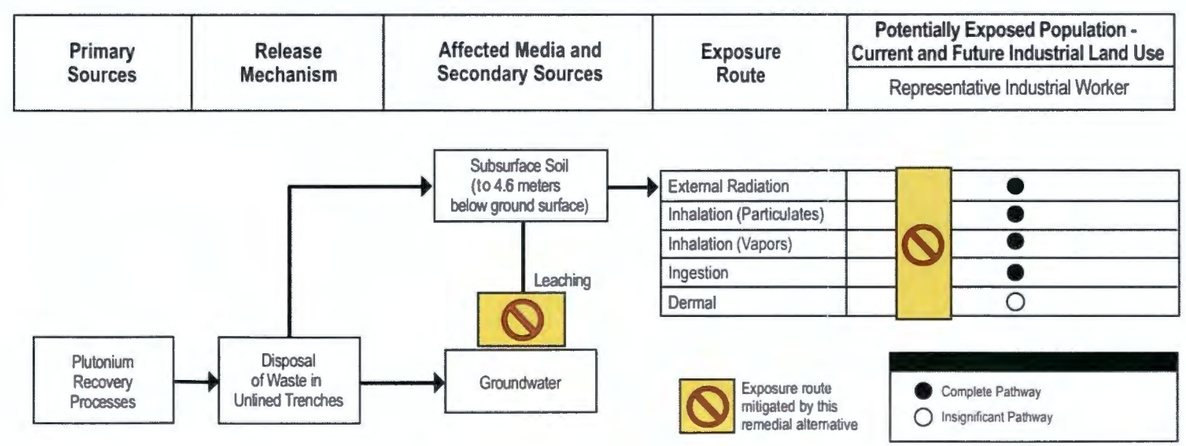


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Figure 7-4. Alternative 3B Summary for the 200-PW-1 and 200-PW-6 Operable Units

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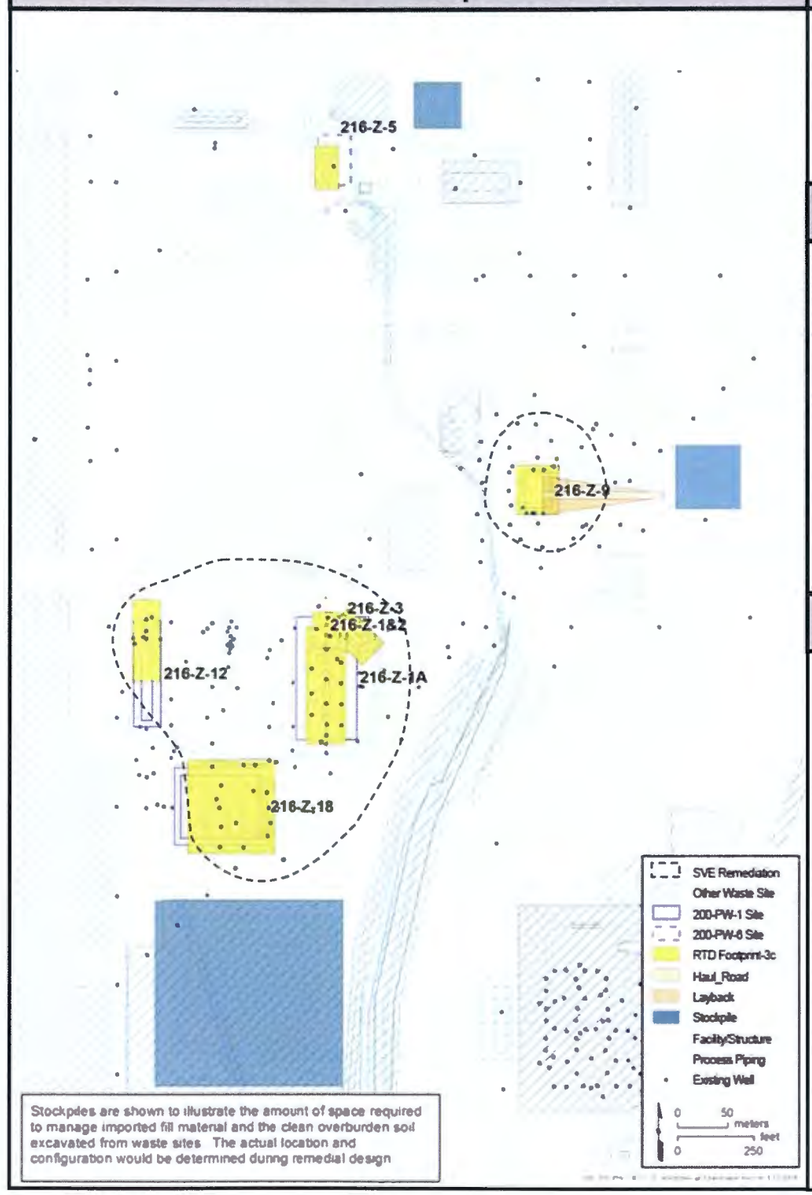
Waste Site and Stockpile Locations



Alternative 3c Description

This alternative is to include the following components:

- SVE remediation of carbon test at 216-Z-1A, 216-Z-9 and 216-Z-18
- Remove significant portion of Pu contamination (maximum 36 ft)
- Backfill to grade, addition of ET barrier
- IC for 1,000 years at 216-Z-1A, 216-Z-9 and 216-Z-18

Duration	Estimated Cost ($M)	
Assume 10 years for SVE	Total Capital Cost	$ 317.4
Active remedy implementation 2-5 years following completion of SVE.	Non-Discounted Cost	$ 424.8
Final Waste shipments could occur during IC period	Total Present Worth	$ 251.9
ICs, including 5 year reviews extend to 1,000 years	WIPP Disposal	$ 412.7

Estimated Quantities

Waste and Backfill

ERDF	14,632 cu yd.
WIPP	19,236 cu yd.
Overburden	163,364 cu yd.
Void Volume	19,917 cu yd.
Imported Fill	53,281 cu yd.

Barrier

Engineered Fill	35,724 cu yd.
Basalt	1,680 cu yd.
Silt	20,842 cu yd.

Exposure Pathway

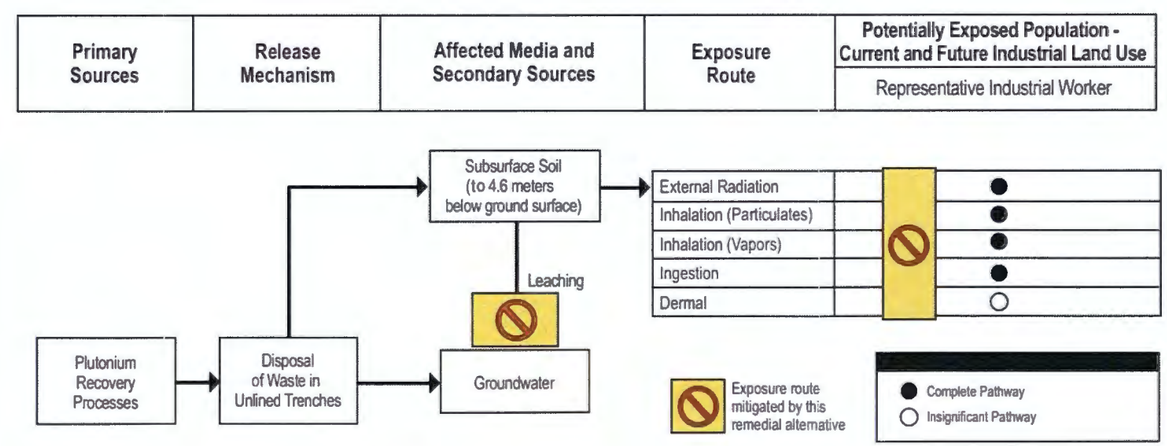


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Figure 7-5. Alternative 3C Summary for the 200-PW-1 and 200-PW-6 Operable Units

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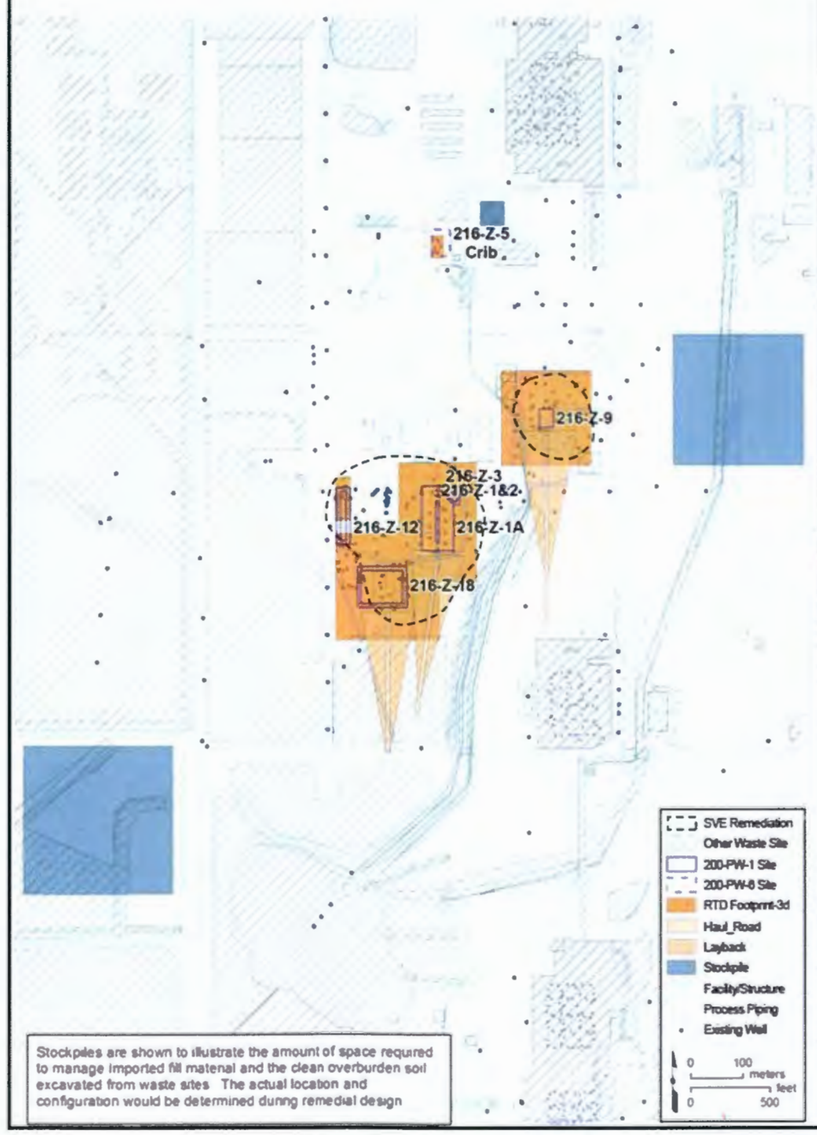
Waste Site and Stockpile Locations



Alternative 3d Description

This alternative is to include the following components:

- SVE for 10 years at 216-Z-1A, 216-Z-9 and 216-Z-18
- Remove > 100 nCi/g concentrations (maximum 120 ft)
- Backfill to grade, addition of ET barrier

Duration

Assume 10 year duration for SVE

Active remedy implementation 3-6 years following completion of SVE.

Estimated Cost ($M)

Total Capital Cost	$ 480.7
Non-Discounted Cost	$ 487.3
Total Present Worth	$ 364.7
WIPP Disposal	$ 523.7

Quantities

Waste and Backfill

ERDF	145,260 cu yd.
WIPP	15,570 cu yd.
Overburden	6,467,500 cu yd.
Void Volume	13,270 cu yd.
Imported Fill	176,120 cu yd.

Barrier

Engineered Fill	15,590 cu yd.
Basalt	1,540 cu yd.
Silt	19,920 cu yd.

Exposure Pathway

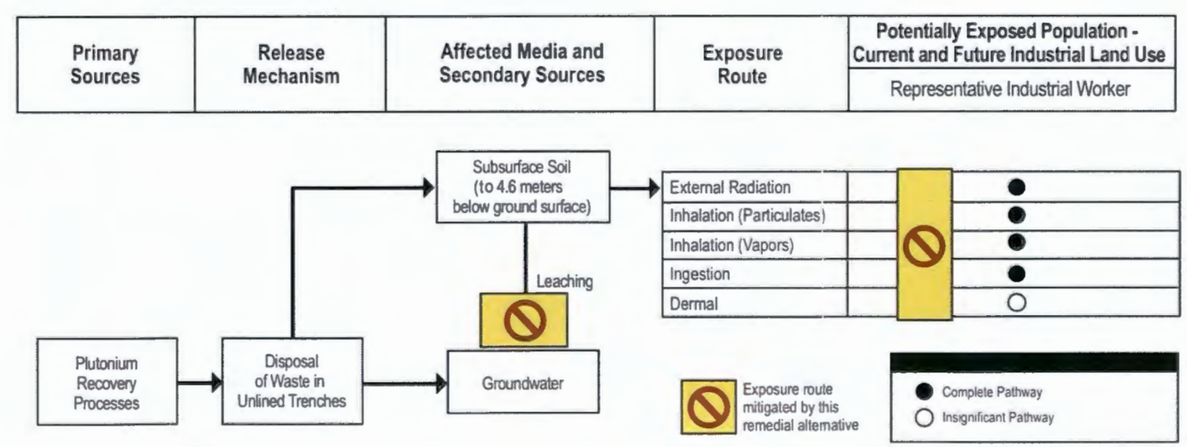


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Figure 7-6. Alternative 3D Summary for the 200-PW-1 and 200-PW-6 Operable Unit

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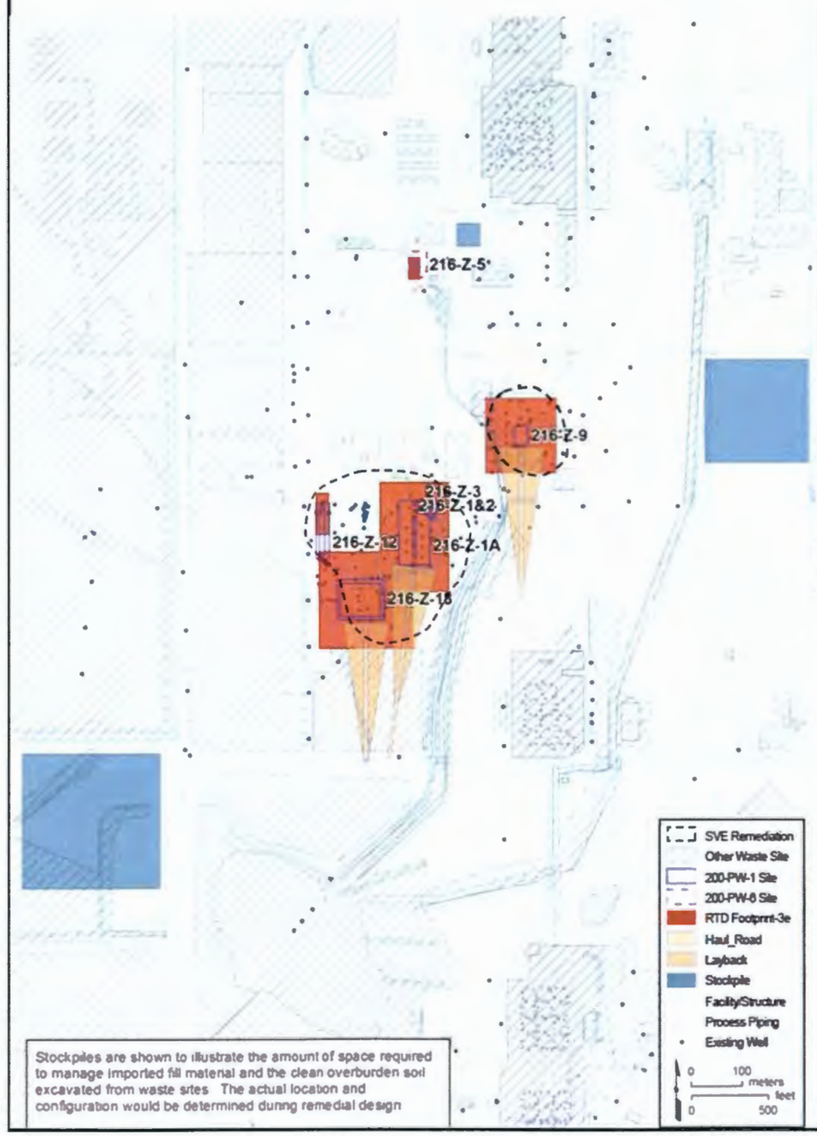
Waste Site and Stockpile Locations



Alternative 3e Description

This alternative is to include the following components:

- SVE for 10 years at 216-Z-1A, 216-Z-9 and 216-Z-18
- Remove > 100 pCi/g concentrations (maximum 120 ft)
- Backfill to grade, addition of ET barrier (not at 216-Z-9)

Duration

Assume 10 year duration for SVE

Active remedy implementation 2-6 years following completion of SVE.

Estimated Cost ($M)

Total Capital Cost	$ 461.4
Non-Discounted Cost	$ 467.9
Total Present Worth	$ 342.2
WIPP Disposal	$ 521.7

Quantities

Waste and Backfill

ERDF	121,740 cu yd.
WIPP	15,790 cu yd.
Overburden	4,836,250 cu yd.
Void Volume	13,270 cu yd.
Imported Fill	152,520 cu yd.

Barrier

Engineered Fill	20,730 cu yd.
Basalt	1,680 cu yd.
Silt	21,170 cu yd.

Exposure Pathway

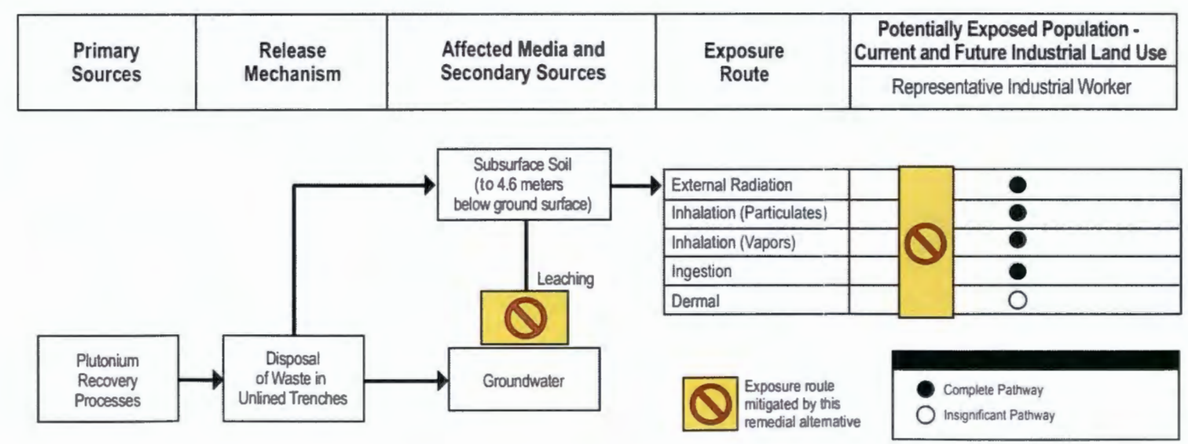


Figure 7-7. Alternative 3E Summary for the 200-PW-1 and 200-PW-6 Operable Units

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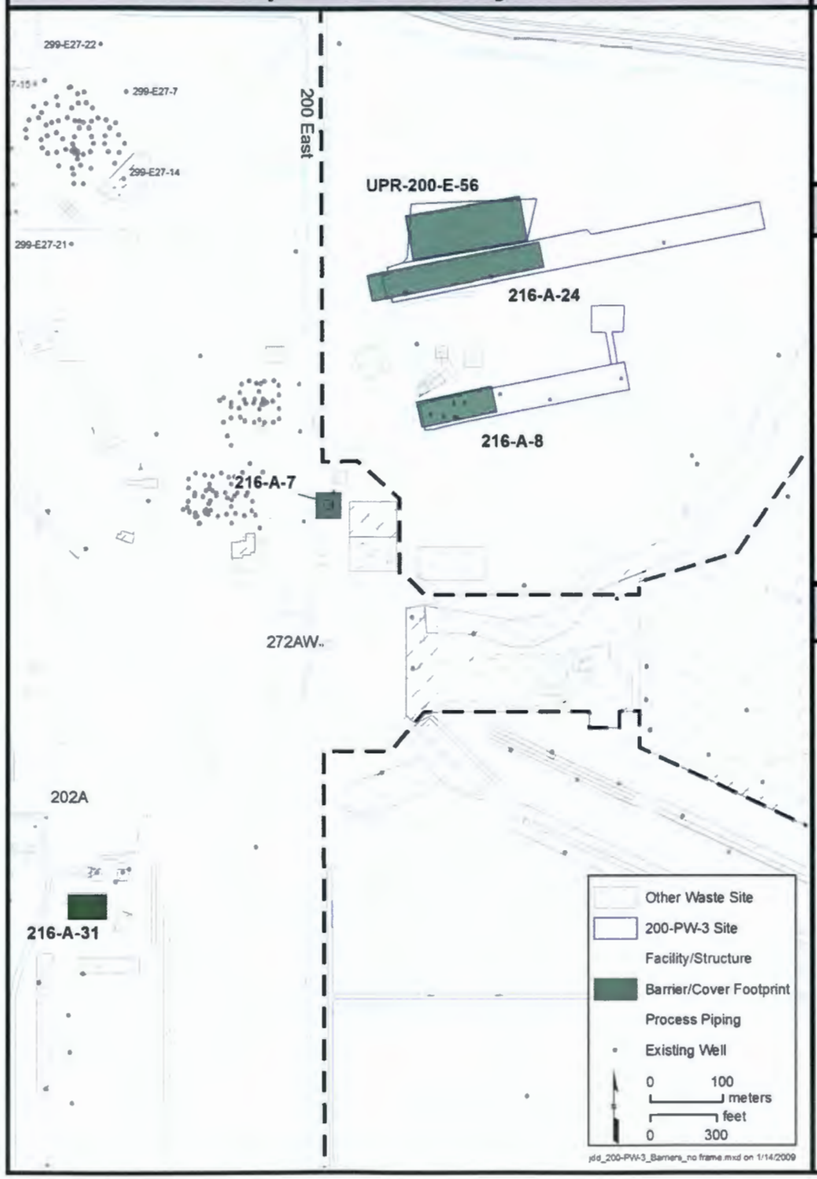
Footprint of Remedy



Alternative 1 Description

This alternative is to include the following components:

- Construct Barrier or MEESC to cover waste site
- IC for 350 years

Duration

Active remedy implementation 50-200 days.

IC's, including 5 year reviews, extend to 350 years

Estimated Cost (millions)

	Original	MEESC
Total Capital Cost	$ 5.0	$ 4.4
Non-Discounted Cost	$ 76.8	$ 72.4
Total Present Worth	$ 12.2	$ 11.1

Estimated Quantities

Waste and Backfill

ERDF	0 cu yd.
WIPP	0 cu yd.
Overburden +non-contaminated	0 cu yd.
Void Volume	0 cu yd.
Imported Fill	0 cu yd.

Barrier (cu yd.)

	Original	MEESC
Engineered Fill	16,140	29,080
Basalt	1,960	N/A
Silt	24,070	N/A
Soil	N/A	6,332

Exposure Pathway

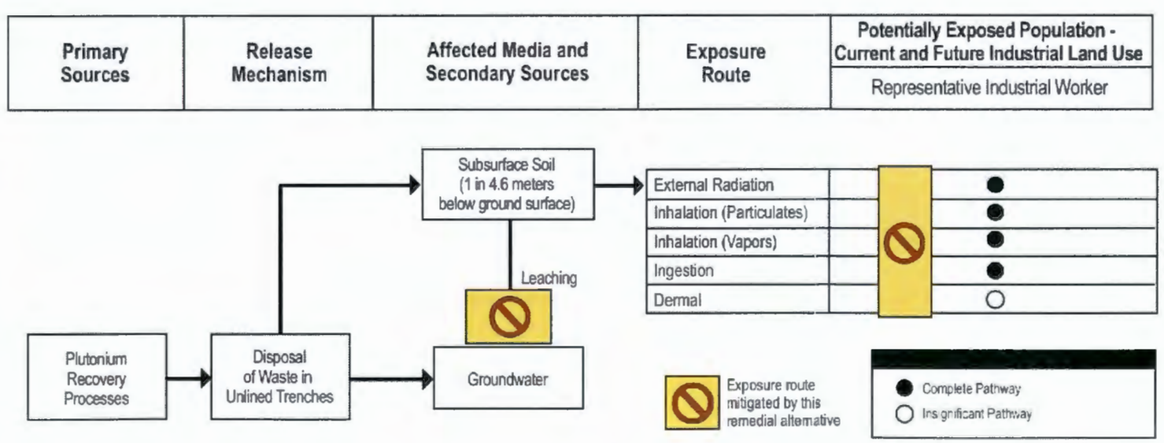


Figure 7-8. Alternative 1 Summary for the 200-PW-3 Operable Unit (Revised April 2011)

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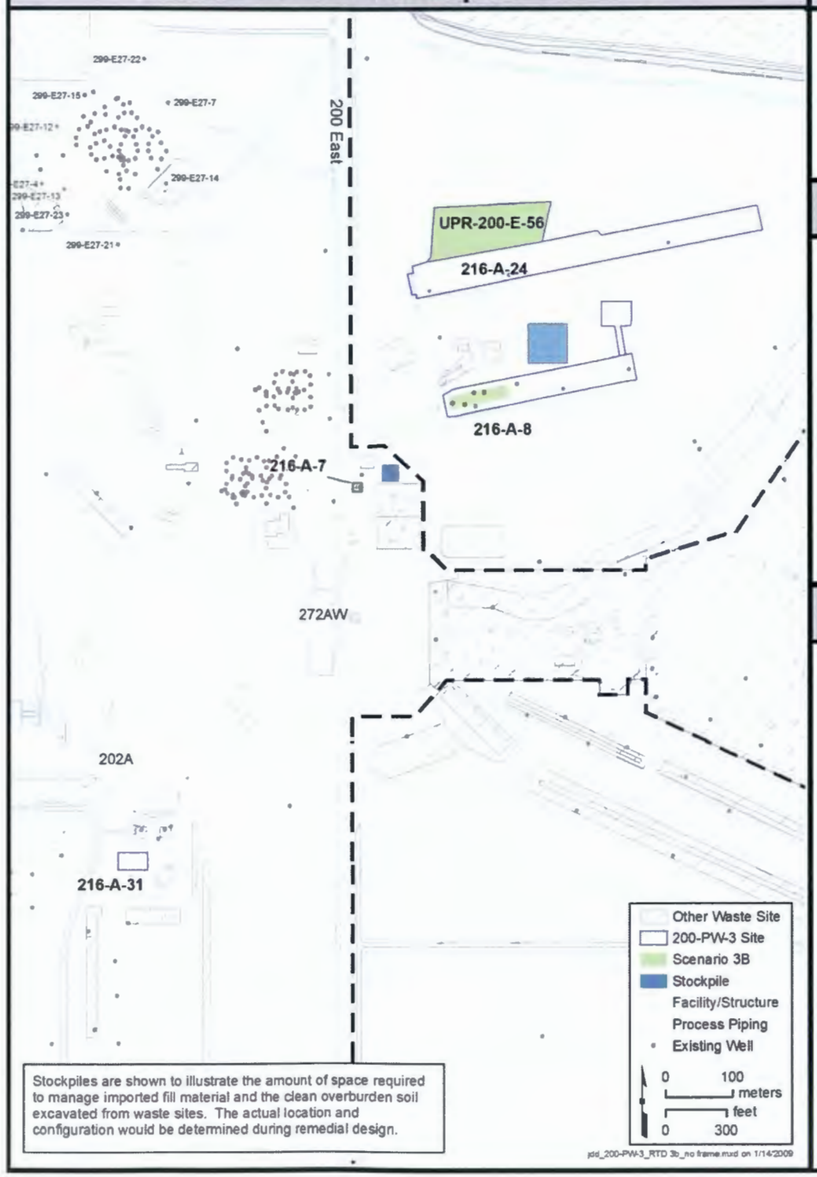
Waste Site and Stockpile Locations



Alternative 3b Description

This alternative is to include the following components:

- Remove Cs-137 direct-contact risk < 15 ft bgs
- Backfill to grade
- IC for 350 years

Duration

Active remedy implementation .5 years following completion of SVE.

IC's, including 5 years reviews, extend to 350 years

Estimated Cost (millions)

Total Capital Cost	$ 11.7
Non-Discounted Cost	$ 48.8
Total Present Worth	$ 15.3

Quantities

Waste and Backfill

ERDF	580 cu yd.
WIPP	0 cu yd.
Overburden	7,010 cu yd.
Imported Fill	580 cu yd.

Barrier

Engineered Fill	1,100 cu yd.
Basalt	340 cu yd.
Silt	3,520 cu yd.

Exposure Pathway

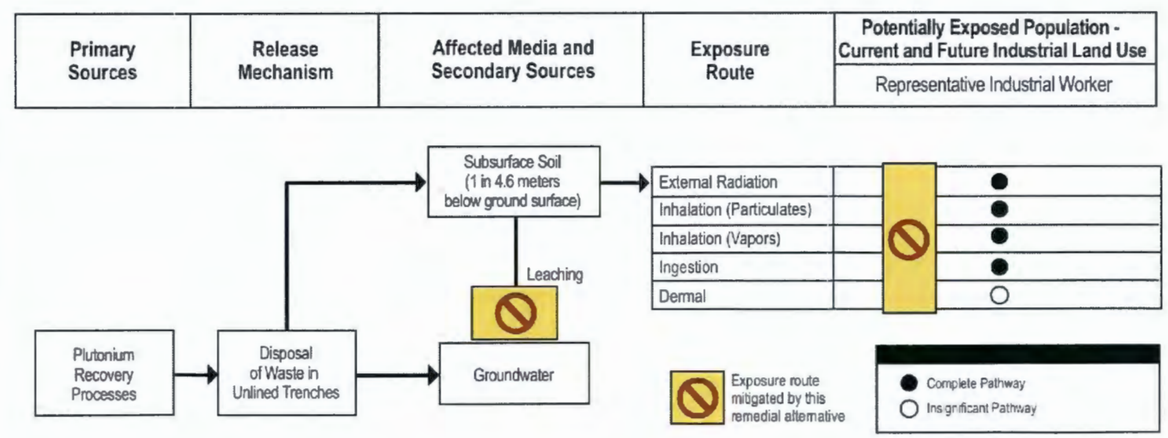


Figure 7-9. Alternative 3B Summary for the 200-PW-3 Operable Unit

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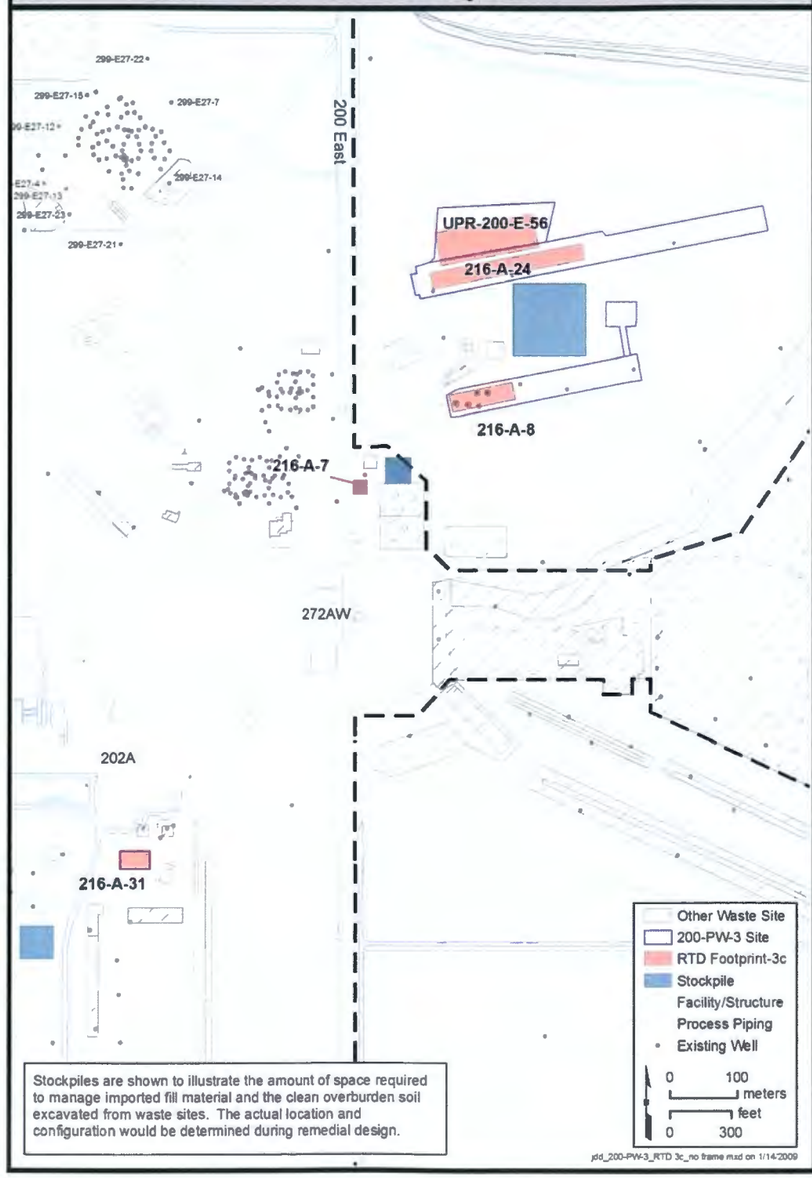
Waste Site and Stockpile Locations



Alternative 3c Description

This alternative is to include the following components:

- Remove Cs-137 mass using best breakpoint
- Backfill to grade
- IC for 350 years

Duration

Active remedy implementation 1-2 years.

IC's, including 5 years reviews, extend to 350 years

Estimated Cost

Total Capital Cost	$ 22.7
Non-Discounted Cost	$ 86.7
Total Present Worth	$ 29.1

Quantities

Waste and Backfill

ERDF	43,530 cu yd.
WIPP	0 cu yd.
Overburden	56,990 cu yd.
Imported Fill	43,530 cu yd.

Barrier

Engineered Fill	3,430 cu yd.
Basalt	860 cu yd.
Silt	11,000 cu yd.

Exposure Pathway

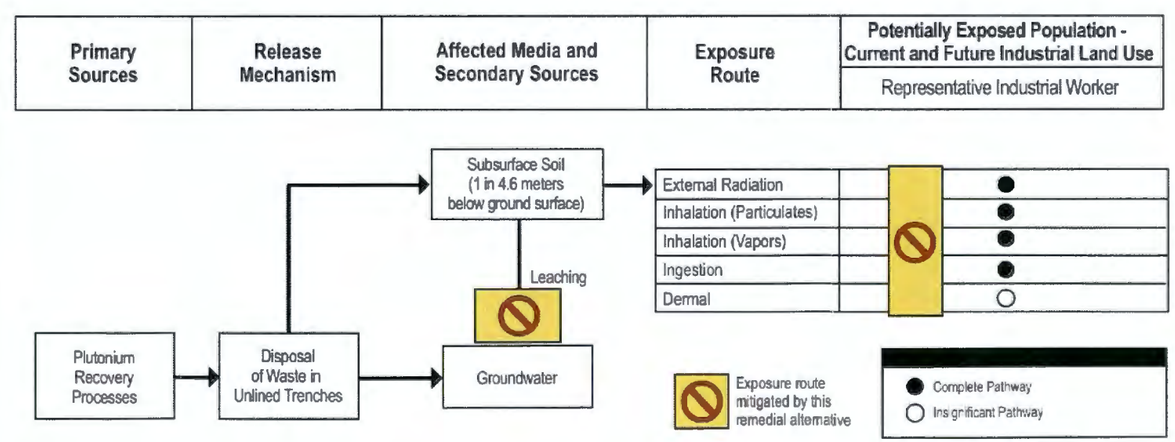


Figure 7-10. Alternative 3C Summary for the 200-PW-3 Operable Unit

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8 Uncertainties Related to Decision Making

The purpose of this chapter is to describe the key uncertainties inherent to the analyses performed as part of the FS. Uncertainties are propagated throughout any evaluation of technical processes that have a scope as complex as environmental restoration. The uncertainty is a reflection of limited knowledge, engineering, and technical assumptions made during the evaluation. Examples of the uncertainties that propagate through the FS evaluations are in the areas of technology, cost, performance, policy, future land use, and human health and ecological risk. Other associated uncertainties include the following:

- Estimating and evaluating health risk posed by contamination
- Estimating the extent of contamination and the expected outcomes of each remedial alternative
- Associated cost of implementing remedial alternatives
- Associated potential impacts

8.1 Uncertainties in Estimating and Evaluating Health Risk Posed by Contamination

Estimating and evaluating health risk from exposure to environmental contaminants is a complex process with inherent uncertainties. Uncertainty reflects limitations in knowledge, and simplifying assumptions that must be made to quantify health risks. In the risk assessment, uncertainties relate to the selection of COPCs and the development of media concentrations to which humans may be exposed, the assumptions about exposure and toxicity, and the characterization of health risks. A list of some key areas of uncertainty evaluated in the human health risk assessment follows. A more detailed discussion regarding uncertainties in the risk assessment process is presented in Section A6 of Appendix A.

A limited number of soil samples were obtained to represent the contaminant characteristics of a larger area. Soil sample locations at waste sites were usually biased, to identify the maximum concentrations. Thus, concentrations of the COPCs were likely biased high, and health risks have not been underestimated. Because of the large amount of information on Hanford's history and past waste disposal practices, the available samples were analyzed for contaminants based on the known sources of constituents at the various waste sites; thus, contaminant classes have not been left out of the COPC selection process.

The measured concentrations of Am-241 are the result of in-growth from decay of Pu-241 released to the Z Plant waste sites from the plutonium production process. Because laboratory analysis for Pu-241 is difficult, Pu-241 has not been analyzed at any of the Z Plant waste sites; therefore, the Am-241 concentrations measured at the sites may not be at their maximum concentration, depending on how much Pu-241 is present and how much has decayed. The half-life of Pu-241 is 14.5 years. Therefore, the percent of maximum Am-241 concentration currently present in soil was estimated using disposal information from the waste sites and the information on the half-life of Pu-241. The final wastes disposed to the waste sites varied in time and therefore some sites are further along the Am-241 in-growth curve than others. Some uncertainty exists at the Z Plant waste sites as to whether the maximum concentrations of Am-241 have been adequately captured; however, analysis indicates 97 percent of the Am-241 maximum concentrations have likely been reached.

For the industrial worker exposures to soil calculations, characterization of the top 4.6 m (15 ft) was limited with few, if any, soil samples representing that depth horizon. Maximum soil concentrations were used, which likely have resulted in risks that are biased high because the majority of the worker's exposure would be to uncontaminated shallower soil.

For subsistence farmer soil concentrations, concentrations are dependent on the size of the garden over which drill cuttings would be spread. The risk calculations assumed a 100 m^2 (1,076 ft^2) garden from the analysis performed for the tank waste performance assessment (HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Dose Factors for the Hanford Tank Waste Performance Assessment*). The value of 100 m^2 (1,076 ft^2) is based on an area that could likely supply at least 25 percent of vegetables and fruit for a family of four. Larger-size gardens or other types of spreading areas would result in a decrease in concentrations.

For the soil-to-plant pathway, risks were estimated using RESRAD (ANL, 2005) based on site soil concentrations. This model is designed to be health protective in an attempt to overestimate, rather than underestimate, the potential concentrations of contaminants in plant tissues irrigated with contaminated groundwater or grown in contaminated soil. It is likely the amount of COPC estimated to be in plant tissue is overestimated by this modeling process.

A second area of uncertainty associated with the plant ingestion pathway is the ingestion rate used in the risk calculations.

Toxicity values have been developed by EPA from the available toxicological data. These values frequently involve high- to low-dose extrapolations and are often derived from animal rather than human data. In addition, few studies may be available for a particular contaminant. As the unknowns increase, the uncertainty of the value increases. Uncertainty is addressed by reducing reference doses (RfDs) using uncertainty factors and by deriving slope factors using a conservative model. The greater the uncertainty, the greater the uncertainty factors and the tendency to overestimate the toxicity to ensure health protective analyses.

8.1.1 Potential Impacts

Every aspect of the risk assessment contains multiple sources of uncertainty. Simplifying assumptions are often made so health risks can be estimated quantitatively. Because the exact amount of uncertainty cannot be quantified, the risk assessment is intended to overestimate rather than underestimate probable risk. The sampling strategies for contaminants in this assessment were, in general, designed to prevent underestimation of media concentrations, thus avoiding an underestimation of the risks to public health. Based on the uncertainty when quantifying exposure and toxicity, the health risks and hazards presented in this risk assessment are more likely to overestimate risk. In the risk assessment, uncertainties were managed conservatively (i.e., health protective choices were preferentially made). This strategy is more likely to produce false positive errors than false negative errors. The results of this assessment, therefore, are likely to be protective of health despite the inherent uncertainties in the process.

8.2 Uncertainty Estimates of the Potential Impacts to Groundwater

The correlation between waste type and waste distribution identified from the waste inventory as well as characterization data was used to group waste sites to facilitate evaluation of remedial alternatives. In addition, some waste sites have more characterization data than others. As presented in Section 2.4, all of the available characterization data have been used in developing the contaminant distribution models for each waste site. This results in different degrees of uncertainty at the various waste sites in estimating the magnitude and extent of contamination.

Although there is some uncertainty in this approach, in general, the contaminant distribution of a waste site group used in the FS evaluation is more likely to be overestimated than underestimated at the waste sites with less characterization data. This is because the waste sites generally considered "worst case" in terms of quantity of liquid wastes disposed or contaminant inventory have the most characterization data. These "worst case" sites were used to evaluate site risks, used to evaluate the soil removal depths

necessary to achieve less than a 10^{-4} risk, and used to evaluate the "best breakpoint" of contaminant mass with depth.

An identified exception to this approach is the lack of technetium-99 data from the vadose zone around the 216-Z-1A and 216-Z-18 Cribs. The waste streams to these cribs presumably did not contain significant quantities of technetium-99; therefore, technetium-99 was not identified or evaluated as a COPC at these waste sites. However, the waste streams to these cribs were similar to the waste stream to the 216-Z-9 Crib, where technetium-99 was identified as a final COPC for the protection of groundwater. Consequently, technetium-99 has not been addressed in the evaluation of risk to the groundwater at the 216-Z-1A and 216-Z-18 Cribs. The inventory of technetium-99 in the vadose zone around these cribs represents an uncertainty in the characterization of the risk at these wastes sites.

Sources of uncertainty in specific risk characterization model evaluations are primarily categorized as (1) model uncertainties, (2) scenario uncertainties, and (3) parameter uncertainties. Documentation is provided in Sections 4.0 and 5.0 of DOE/RL-2007-34 Rev. 0 on (1) dominant model factors, (2) model assumptions and effects on model results, and (3) model limitations. Model uncertainty pertaining to the equations used as numerical representations of the natural processes is expected to be relatively small. The theory and equations incorporated into the STOMP code have widespread acceptance within the scientific community, and several peer-reviewed journal articles that include modeling analyses performed using the STOMP code exist in the scientific literature. As a further demonstration of its adequacy, DOE/RL-2007-34, Rev. 0 provides a summary evaluation of the comparisons of field data and field test results to corresponding model results obtained using the STOMP code, and the evaluation indicates that the equations used in STOMP adequately simulate the cogent natural processes. Based on the results of the uncertainty analysis, the results of the vadose zone modeling for the 216-Z-1A, 216-Z-18, 216-Z-9, and 216-A-8 Cribs should provide conservative estimates of risk in terms of impacts to groundwater from vadose zone contamination.

The technical basis regarding scenario selection and the corresponding evaluation of uncertainty and variability is documented in DOE/RL-2007-34 Rev. 0, and in Appendix E. Scenario uncertainty regarding future use and conditions of the waste sites and surrounding environs is also expected to be relatively small. The waste sites are located within the 200 Area where the DOE-RL is expected to retain control and custodianship and limit access for the foreseeable future. After completion of the remediation and reclamation activities, the former waste site surface is expected to re-acquire a mature shrub-steppe vegetation cover, which is a conclusion reached on the basis of a significant weight of evidence from subject matter experts at the national laboratory and observations made at similar locations throughout the United States.

The results of the assumptions and sensitivity analyses are intended to address parameter uncertainty. An evaluation of the primary assumptions associated with this vadose zone modeling approach at the Hanford Site is summarized in Table 5-3 in DOE/RL-2007-34, Rev. 0. The evaluation of these assumptions indicates that (1) most of the assumptions involve hydrogeologic and geochemical factors, (2) most of the assumptions are either conservative or neutral, (3) source-term uncertainty is potentially nonconservative, and (4) the majority of conservative assumptions range from moderate to high magnitudes in terms of their potential effect on risk and vadose zone model results. Uncertainties in this evaluation primarily relate to the applicability of the following assumptions used in the fate and transport modeling scenarios:

- The simplified representations of the natural system in the model reliably approximate the subsurface environment features, events, and processes at the waste sites evaluated.
- The contaminant concentration measurements and estimated extent of contamination adequately approximate the contamination within the modeled areas.

- Contaminant concentrations are uniformly distributed within distinct layers or at discrete depth intervals in the vadose zone.
- Contamination transport is contained in two-dimensional space.
- Soil properties within each model layer may be approximated by homogenous average values.
- Future site conditions are consistent with current assumptions regarding future land use.

The evaluation of these assumptions indicates that the assumptions associated with model parameterization are largely conservative. The assumptions identified as nonconservative or neutral are associated with the ability to approximate the geology in a finite difference grid, the applicability of the porous media continuum to water flow in the vadose zone, and the hydrogeologic parameterization of the main stratigraphic units. The magnitude of the effect of these assumptions on risk estimates is identified in DOE/RL-2007-34 as neutral or low.

Although source-term uncertainty can be potentially nonconservative, the estimates of contaminant concentration used in the 216-Z-1A, 216-Z-18, 216-Z-9, and 216-A-8 Crib models included biases that result in the overestimation of the impacts to groundwater. The estimates of average concentration in the contaminated soil volumes include a bias toward the highest values within the contaminant plumes. As noted previously, a limited number of soil samples were obtained to represent the contaminant characteristics of a larger area.

The data used to calculate the average concentrations are generally based on samples collected from boreholes that were located with the intent to discover the most contaminated parts of the subsurface. The estimates of contaminant availability for transport and contaminant mobility in the vadose zone also include a conservative bias. The entire contaminant inventory estimated from the concentration in the contaminated soil volumes is assumed to be available for transport; none is assumed to be trapped or restrained in pore space where its movement is impeded or prevented.

The uncertainty in the evaluation of groundwater protection impacts remedy selection for the waste sites. The conclusion of the contaminant fate and transport modeling is that certain contaminants impact groundwater at levels that exceed the MCL. The two contaminants with the largest potential impacts to groundwater that are not addressed by the SVE remedy, i.e., nitrogen as nitrate and nitrite and Tc-99, have the greatest uncertainty in the estimates of their concentrations in the plume. These estimates are based on as few as two data points for some contaminated depth intervals. Reduction of uncertainty in the evaluation of groundwater protection modeling is possible by conducting additional sampling during the remedy implementation. The soil data results could have impacts on the selection and estimated cost and duration of the remedial alternatives.

8.3 Uncertainty on Plutonium Inventory

Estimates of the total amount of plutonium discharged to each of the waste sites in the 200-PW-1 and 200-PW-6 OUs are discussed in the RI report and included in the conceptual site model figures provided in Chapter 2 of this FS. The inventories reported are based on historical documents, as cited. Each of these estimates was based on records kept by the facility and the results of sampling and survey data available when the estimate was prepared. This includes nuclear accountability records, nuclear safety evaluations, soil samples, thermal surveys, and neutron response surveys. Uncertainty in the accuracy of the estimates is due to assumptions, the accuracy of the records, and any sample bias or non-representative sampling design. Where a range is provided for the estimated inventory, the higher number is used as an upper bound for the estimate.

8.3.1 Potential Impacts

The estimated inventory of contaminants discharged to a waste site is considered as part of the initial evaluation of site conditions to confirm the presence or absence and relative degree of potential environmental contamination. In many instances, particularly when liquid discharges to soil are involved, the discharged inventory becomes distributed through the soil column. Because most risk assessment calculations are concentration-based, the two most relevant parameters are contaminant concentration in the affected media and the distribution of the contaminant through the media. The uncertainty in the total inventory of plutonium disposed at each individual waste site would not be expected to have a significant impact on the comparative analysis of alternatives. The concentration of the plutonium identified at each waste site and the lateral and vertical extent of the plutonium contamination is used to estimate the footprint for each of the barrier, RTD, and ISV options. Estimates of the total volume of excavated soil requiring disposal at the WIPP were made based on the observed concentrations from soil samples and spectral gamma logging. Assumptions regarding the lateral and vertical extent of the soil requiring excavation were also based on available sampling and logging results. The RTD alternatives evaluated were not proposed to recover the entire inventory of plutonium at each waste site; therefore, the total inventory uncertainty was considered consistently in the alternative evaluation. The uncertainty is not anticipated to have a significant impact on the comparative analysis.

8.4 Uncertainty with the Cost of Remedial Technologies

The purpose of a cost estimate is to provide adequate information so the remedial alternatives can be evaluated and compared on this criterion in the FS and the cost-effectiveness of the selected remedy(s) can be subsequently documented in the Proposed Plan and ROD. Uncertainties regarding both capital and annual costs are associated with the assumptions of the remedial alternatives and current economics. See Appendix D for the assumptions used and considered in the cost estimating.

The extent of contamination used in the analysis of remedial alternatives was based on the best data available at the time of analysis. Inherent uncertainty in the depth and lateral extent of contamination at each waste site is expected to impact the actual cost and duration of the selected remedy. Changes in the actual extent of contamination versus those used in the FS will not be known until pre-remedial design confirmatory investigations are conducted or remedial action is undertaken.

8.4.1 Potential Impacts

The potential impact from the uncertainty in the extent of contamination at each waste site is expected to have a similar impact on each of the remedial alternatives. This impact is expected to affect the estimated cost and duration of the remedial alternatives but not the order-of-magnitude cost differences between the alternatives.

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9 Summary and Path Forward

A summary of the FS evaluation process and the path forward for the 200-PW-1, 200-PW-3, and 200-PW-6 OUs is described in this chapter.

9.1 Feasibility Study Summary

The following key elements of the FS report are summarized in this section:

- The BRA and identification of final COPCs
- The RAOs
- The development and analysis of remedial alternatives

9.2 Baseline Risk Assessment and Contaminants of Concern

Several contaminant impact assessments typically included as part of the RI phase of the RI/FS—the BRA, the ecological risk assessment, and the fate and transport evaluation for groundwater protection—were completed during the FS phase and are therefore included as appendices to this FS report.

Two human health risk assessments were conducted: a BRA that evaluated a general U.S. population (Appendix A), and a separate assessment of Native American risks (Appendix G). The BRA evaluated exposure routes under an industrial land use scenario (to construction workers) and, for comparison, under an unrestricted land use scenario (to future well drillers and residential farmers). The results of the BRA indicate that, under an unrestricted land use scenario, there could be risk above the CERCLA-acceptable risk range at the waste sites evaluated, except at the 216-Z-8 French Drain and the 216-Z-10 Injection/Reverse Well. Because of the similarities between waste sites in each waste site group discussed in Section 2.6, the BRA results indicate that there is a need for remedial action at all of the waste sites (except at the 216-Z-8 French Drain and the 216-Z-10 Injection/Reverse Well) in order to protect HHE.

A SLERA was conducted for all 16 waste sites in these OUs (Appendix B), and a number of factors were found that eliminated these waste sites from further consideration of potential ecological risk.

The potential future impact to the groundwater from the migration of COPCs in the vadose zone was evaluated in fate and transport modeling (Appendix E). Carbon tetrachloride and methylene chloride were identified as having the potential to migrate to groundwater.

Table 9-1 summarizes the final COPCs for each waste site group and the risk receptor or exposure pathway based on the results of these risk assessment evaluations, the similarities of the waste sites in each waste site group, and the contaminant inventory for each waste site. The final COPCs identified in Table 9-1 that are considered to be principal threat contaminants found:

- Plutonium-239/240, americium-241, and cesium-137 (based on toxicity and baseline risk results).
- Carbon tetrachloride and methylene chloride (based on toxicity and mobility).
- The remaining final COPCs in Table 9-1 (neptunium-237, radium-226, cadmium, manganese, and thallium) are considered to be low-level threat contaminants.

Table 9-1. Summary of Contaminants of Concern for the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units

Waste Site Group (Waste Sites)	Risk Receptor/Exposure Pathway					
	Current/Future Worker	Future Well Driller	Future Subsistence Farmer	Future Native Americans	Ecological Receptors	Migration to Groundwater Pathway
High-Salt (216-Z-1A, 216-Z-9, 216-Z-18)	Plutonium-239/240, Americium-241[a]	--	Plutonium-239/240, Americium-241, Neptunium-237, Radium-226, Carbon Tetrachloride, Cadmium, Manganese	Plutonium-239/240, Americium-241, Neptunium-237[a]	--	Carbon Tetrachloride, Methylene Chloride, Technetium-99,[d] Nitrate[d]
Low-Salt (216-Z-1&2, 216-Z-3, 216-Z-5, 216-Z-12)	--	--	Plutonium-239/240, Americium-241	--	--	Technetium-99,[d] Nitrate[d]
Cesium-137 (216-A-7, 216-A-8, 216-A-24, 216-A-31, UPR-200-E-56)	Cesium-137[b]	--	Cesium-137, Thallium	Cesium-137, Thallium[b]	--	
Settling Tanks (241-Z-8, 241-Z-361)	Plutonium-239/240, Americium-241[c]	--	Plutonium-239/240, Americium-241[c]	Plutonium-239/240, Americium-241[c]	--	
216-Z-8	--	--	--	--	--	--
216-Z-10	--	--	--	--	--	--

a. Only at 216-Z-1A and 216-Z-9 where direct contact risks are possible.

b. Only at 216-A-7, 216-A-8, and UPR-200-E-56 where direct contact risks are possible.

c. Other potential final COPCs may include metals at 241-Z-361 based on the estimated tank inventory reported in Section 2.4.

d. As part of the preferred alternative, additional characterization data will be collected to reduce uncertainties associated with the future threat to groundwater.

-- No final COPCs were identified in the risk evaluation process.

Technetium-99 and nitrate were not screened out as potential threats to groundwater. Additional post-ROD sampling for mobile contaminants is warranted to improve the approximations of the distribution of these contaminants in the vadose zone and to improve estimates of the potential threat to groundwater.

9.3 Remedial Action Objectives

The RAOs are descriptions of what the remedial action is expected to accomplish (i.e., medium-specific or site-specific goals for protecting H). They provide a basis for evaluating the capability of a remedial alternative to achieve compliance with potential ARARs and/or an intended level of risk reduction in order to protect HHE. Specific RAOs for this FS were defined based on the RME assumptions used in the risk assessment, the risk assessment results, fate and transport modeling of contaminants, and the current and reasonably anticipated future industrial land use for the 200 Area. The RAOs for this FS are as follows:

- **RAO 1** – Prevent or mitigate unacceptable risk to human health and ecological receptors associated with radiological exposure to wastes or soil contaminated above risk-based criteria by removing the source or eliminating the pathway.
- **RAO 2** – Prevent or mitigate unacceptable risk to human and ecological receptors associated with nonradiological exposure to wastes or soil contaminated above risk-based criteria by removing the source or eliminating the pathway.
- **RAO 3** – Control the sources of potential groundwater contamination to support the Central Plateau groundwater goal of restoring and protecting the beneficial uses of groundwater, including protecting the Columbia River from adverse impacts.

9.4 Development and Analysis of Remedial Alternatives

Potential remedial technologies were identified based on their ability to mitigate the identified risks or achieve compliance with potential ARARs for a remedial action. Those selected for evaluation were screened with respect to their implementability, effectiveness, and relative cost in accordance with EPA guidance. Process options were combined into a range of remedial alternatives that were then evaluated with respect to the CERCLA criteria in a detailed and comparative analysis.

The development of remedial alternatives was guided by the expectations listed in the NCP (40 CFR 300.430[a][1][iii]), the feedback obtained from an early-involvement public workshop on the draft remedial alternatives for the 200-PW-1 OU waste sites held on April 15, 2008, and the resulting HAB Consensus Advice #207 (HAB 207) issued after that workshop.

The remedial alternatives evaluated in this FS include the following:

- **"No Action" Alternative.** The NCP requires consideration of a No Action Alternative. This alternative would leave a waste site "as-is" in its current state, with no additional remedial activities or access restrictions.
- **Alternative 1 – Barrier.** This alternative provides no treatment for radionuclides, but prevents and controls exposure to hazardous substances through engineering controls and institutional controls to protect HHE.

- **Alternative 2 – In Situ Vitrification.** This alternative utilizes ISV to reduce the mobility of hazardous substances as a principal element. It is primarily considered applicable for the 200-PW-1 OU waste sites that contain plutonium and americium. Institutional controls are also a component of this alternative at waste sites where the treatment process leaves residual contamination that will require long-term controls.

- **Alternative 3 – Removal, Treatment and Disposal.** This alternative removes waste site soil, sludge, and/or debris, treating it as necessary to meet ARARs, and then disposing of it onsite (ERDF) or offsite (WIPP) as appropriate. Five RTD options were developed to achieve different removal objectives, from partial removal of the highest contaminant concentrations to removal of concentrations posing greater than a 10^{-4} risk level. For the RTD options that leave residual contamination above risk levels, institutional controls and ET barriers are incorporated as components to protect HHE. The five RTD options evaluated included the following:

  - **Option 3A** – Remove the highest concentrations of contaminated soils to 0.6 m (2 ft) below the base of a waste site.

  - **Option 3B** – Remove contaminated soils that could be a direct contact risk to industrial workers and that are less than 4.6 m (15 ft) below the current ground surface.

  - **Option 3C** – Remove a significant portion of plutonium contamination based on an evaluation of soil contaminant concentration with depth. A significant portion of Cs-137 contamination would be removed at the Cs-137 waste sites based on a similar evaluation.

  - **Option 3D** – Remove contaminated soils containing greater than 100 nCi/g of transuranic radionuclides.

  - **Option 3E** – Remove contaminated soils with greater than a 10^{-4} risk level so that long-term institutional controls at a waste site are not necessary.

All of the remedial alternatives, except the No Action Alternative, include the following common components: institutional controls where residual contamination remains above acceptable risk levels, continued SVE system at the 216-Z-1A Tile Field, 216-Z-9 Trench, and 216-Z-18 Crib, removal of the abovegrade structures at the 216-Z-9 Trench that were constructed for the 1976 to 1977 soil mining operation, decommissioning of process waste pipelines into each waste site, decommissioning of vadose zone and groundwater wells impacted by the remedial alternative, environmental surveillance (including post-ROD sampling) and groundwater monitoring to ensure the remedy is protective of HHE.

The remedial alternatives were evaluated in a detailed analysis in Chapter 6 and a comparative analysis in Chapter 7 with respect to the following CERCLA threshold and balancing criteria:

- Overall protection of HHE
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost

The two modifying criteria, state acceptance and community acceptance, will be addressed in the ROD for these OUs.

The No Action Alternative meets the threshold criteria for the 216-Z-8 French Drain, and a limited remedial action is needed at the 216-Z-10 Injection/Reverse Well to decommission this well in accordance with ARARs. Otherwise, no remedial action is necessary at these two waste sites to protect HHE.

The only remedial alternative evaluated in the FS for the 241-Z-8 and 241-Z-361 Settling Tanks was the Preferred Alternative developed in an engineering evaluation of the 241-Z-361 Settling Tank (DOE/RL-2003-52). Alternative 3 would remove the sludge in these tanks, stabilize it to comply with ARARs, dispose of the stabilized sludge at WIPP, and backfill the empty tanks with CDF.

The key findings of the FS evaluations include the following:

- Alternatives 1, 2, and 3 are protective and would comply with potential ARARs.
- Alternatives 1, 2, and 3 require long-term institutional controls for residual contamination, except for Alternative 2 at the Low-Salt sites and the Alternative 3 RTD option where excavation from 6.7 to ≥27.4 m (22 to ≥90 ft) at some waste sites would be required before institutional controls are not necessary for long-term protection of HHE.

The remedial action footprint from waste site excavation, soil stockpile, and haul roads, contaminated soil handled and backfill volumes required, the short-term impacts to remedial action workers and the environment, implementability issues, and costs all increase with RTD depth in Alternative 3 without a proportionate increase in long-term effectiveness and permanence. It is noted that Option D is similar to Option E, which only applies to the High-Salt and Low-Salt sites. Because they are similar in the amount of excavation required and therefore also the cost estimates, only Option E was carried forward in the Proposed Plan for these four OUs.

9.5 Path Forward

Remedy selection for the 200-PW-1, 200-PW-3, and 200-PW-6 OU waste sites will be based on information contained in the RI and in this FS, as well as input by risk managers, the public and Tribal Nations, and other interested parties. The path forward for completion of remedy selection for these OUs is described in the following subsections.

9.5.1 Proposed Plan

The Proposed Plan is the document issued to the public that identifies the Preferred Alternative(s) for these OU waste sites. The document outlines pertinent information from the RI and FS and provides a summary of the remedial alternatives that were evaluated. When the Proposed Plan for the 200-PW-1, 200-PW-3, and 200-PW-6 OUs (which also includes 200-CW-5) is issued, written comments from the public and Tribal Nations on the Proposed Plan will be considered. After the public comments have been reviewed, the Tri-Parties will sign a ROD that documents the final decision for the assessment. Along with the ROD, the Tri-Parties will issue a responsiveness summary that provides responses to all significant comments submitted during the public comment period.

9.5.2 Record of Decision

After the public comment period on the FS report and the Proposed Plan has closed, the ROD process will begin. The ROD will describe the decision-making process for remedy selection and summarize the alternatives developed, screened, and evaluated in accordance with CERCLA and the NCP. The comments received on the FS report and the Proposed Plan will be reviewed and a responsiveness summary will be prepared that will accompany the ROD. The ROD will be signed by the Tri-Parties and will become part of the administrative record for each OU. The lead regulatory agency will continue its role after issuance of the ROD, including oversight of the remedial design and remedial action phases.

9.5.3 Post-Record of Decision

After the ROD is signed, new information may be received or generated that could affect the implementation of the remedy selected in the ROD or that could prompt the reassessment of that remedy. The information could be identified at any time during, immediately before, or after the implementation of the remedy. Where information is submitted by a potentially responsible party, the public, and Tribal Nations, or the supporting agency after a ROD is signed, the lead agency must consider and respond to this information and place such comments and responses in the Administrative Record file when all of the following NCP criteria are met (40 CFR 300.825[c], "Record Requirements after the Decision Document is Signed").

- The comments contain significant information.
- The new information is not contained elsewhere in the Administrative Record file.
- The new information could not have been submitted during the public comment period.
- The new information substantially supports the need to alter the remedial action significantly.
- The lead agency also may evaluate whether a remedy change is warranted on its own merits, even where the requirements of the NCP (40 CFR 300.825[c]) are not triggered.

9.5.4 Remedial Design

The technical specifications for cleanup remedies and technologies are detailed in the remedial design after development of the RD/RA work plan. The EPA oversees development of the design and specifications for the selected remedy based on the specifications described in the ROD.

9.5.5 Remedial Action

Remedial action follows the remedial design phase and involves the actual construction or implementation phase of site cleanup. EPA oversees construction and operation of the remedy based on the specifications described in the ROD and the remedial design.

9.5.6 Five-Year Review

If a remedial action is selected that results in hazardous substances remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such action no less often than every 5 years after initiation of the selected remedial action (40 CFR 300.430(f)(4)(ii)). The 5-year review provides EPA an opportunity to evaluate the implementation and performance of a remedy to determine whether it remains protective of HHE.

9.5.7 Deletion from the National Priorities List

Since 1986, EPA has followed the procedures listed for deleting a site from the NPL:

- The Regional Administrator approves a "close-out report" that establishes that all appropriate response actions have been taken or that no action is required.
- The Regional Office obtains State concurrence.
- EPA publishes a notice of intent to delete in the *Federal Register* and in a major newspaper near the community involved. A public comment period is provided.

EPA responds to the comments and, if the site continues to warrant deletion, publishes a deletion notice in the *Federal Register*.

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10 References

0000X-DC-W0001, 1997, *Supplemental Waste Acceptance Criteria for Bulk Shipments to the Environmental Restoration Disposal Facility*, Rev. 1, Bechtel Hanford, Inc., Richland, Washington.

02-HAB-0006, 2002, "Consensus Advice #132: Exposure Scenarios Task Force on the 200 Area" (letter to Todd Martin, Hanford Advisory Board, from Keith A. Klein, U.S. Department of Energy, Richland Operations Office; David R. Einan, U.S. Environmental Protection Agency; and Michael A. Wilson, State of Washington Department of Ecology), Richland, Washington, July 11. Available at: http://www.hanford.gov/hanford/files/HAB_resp-132.pdf.

10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste," *Code of Federal Regulations*. Available at: http://www.access.gpo.gov/nara/cfr/waisidx_09/10cfr20_09.html.

10 CFR 835, "Occupational Radiation Protection," *Code of Federal Regulations*. Available at: http://www.access.gpo.gov/nara/cfr/waisidx_09/10cfr835_09.html.

40 CFR 61, "National Emission Standards for Hazardous Air Pollutants," Subpart H, "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities," *Code of Federal Regulations*. Available at: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=b82e7384296a8862ac89f0477bac61d4&rgn=div6&view=text&node=40:8.0.1.1.1.8&idno=40.

40 CFR 61, "National Emission Standards for Hazardous Air Pollutants," Subpart M, "National Emission Standard for Asbestos," *Code of Federal Regulations*. Available at: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=b82e7384296a8862ac89f0477bac61d4&rgn=div6&view=text&node=40:8.0.1.1.1.13&idno=40.

40 CFR 61.52, "National Emission Standards for Hazardous Air Pollutants," "Emission Standard," *Code of Federal Regulations*. Available at: http://edocket.access.gpo.gov/cfr_2009/julqtr/40cfr61.52.htm.

40 CFR 141, "National Primary Drinking Water Regulations," *Code of Federal Regulations*. Available at: http://www.access.gpo.gov/nara/cfr/waisidx_09/40cfr141_09.html.

40 CFR 268, "Land Disposal Restrictions," *Code of Federal Regulations*. Available at: http://www.access.gpo.gov/nara/cfr/waisidx_09/40cfr268_09.html.

40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," *Code of Federal Regulations*. Available at: http://www.access.gpo.gov/nara/cfr/waisidx_09/40cfr300_09.html.

300.400, "General."

300.430, "Investigation/Feasibility Study and Selection of Remedy."

300.440, "Procedures for Planning and Implementing Off-Site Response Actions."

300.825, "Record Requirements after the Decision Document is Signed."

300, Appendix B, "National Priorities List."

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_09/40cfr761_09.html.

40 CFR 1502.16, "Environmental Impact Statement," "Environmental Consequences," *Code of Federal Regulations*. Available at: http://edocket.access.gpo.gov/cfr_2009/julqtr/40cfr1502.16.htm.

50 CFR 10.13, "General Provisions," "List of Migratory Birds," *Code of Federal Regulations*. Available at: http://edocket.access.gpo.gov/cfr_2008/octqtr/50cfr10.13.htm.

50 CFR 17.12, "Endangered and Threatened Wildlife and Plants," "Endangered and Threatened Plants," *Code of Federal Regulations*. Available at: http://edocket.access.gpo.gov/cfr_2008/octqtr/50cfr17.12.htm.

64 FR 61615, "Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS)," *Federal Register*, Vol. 64, No. 218, pp. 61615-61625, November 12, 1999. Available at: http://gc.energy.gov/NEPA/nepa_documents/rods/1999/61615.pdf.

ANL, 2005, RESRAD, Version 6.3, Environmental Assessment Division, Argonne National Laboratory, Argonne, Illinois.

Archeological and Historic Preservation Act of 1974, 16 USC 469a-1 – 469a-2(d). Available at: http://www.nps.gov/history/local-law/FHPL_ArchHistPres.pdf.

ARH-231, 1967, *Hanford Low Level Waste Management Reevaluation Study*, Atlantic Richfield Hanford Company, Richland, Washington.

ARH-1278, 1969, *Plutonium-Americium Soil Penetration at 234-5 Building Crib Sites*, Atlantic Richfield Hanford Company, Richland, Washington.

ARH-1562, 1970, *200 East and North Areas Radioactive Liquid Waste Disposal Sites*, Atlantic Richfield Hanford Company, Richland, Washington.

ARH-2155, 1971, *Radioactive Liquid Waste Disposal Facilities 200 West Area*, Atlantic Richfield Hanford Company, Richland, Washington.

ARH-2915, 1973, *Nuclear Reactivity Evaluations of 216-Z-9 Enclosed Trench*, Atlantic Richfield Hanford Company, Richland, Washington.

ARH-CD-745, 1976, *Input and Decayed Values of Radioactive Liquid Wastes Discharged to the Ground in the 200 Areas Through 1975*, Atlantic Richfield Hanford Company, Richland, Washington.

ARH-ST-156, 1977, *Evaluation of Scintillation Probe Profiles from 200 Area Crib Monitoring Wells*, Atlantic Richfield Hanford Company, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D195064660.

Atomic Energy Act of 1954, 42 USC 2011, et seq. Available at: http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0980/ml022200075-vol1.pdf.

Bald and Golden Eagle Protection Act of 1940, 16 USC 668-668d, et seq. Available at: http://www.fws.gov/migratorybirds/mbpermits/regulations/BGEPA.PDF.

BHI-00184, 1995, *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington*, Rev. 00, Bechtel Hanford, Inc., Richland, Washington.

BHI-00431, 1995, *DNAPL Investigation Report*, Rev. 0, Bechtel Hanford, Inc., Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D196004443.

BHI-01105, 1997, *Rebound Study Report for the Carbon Tetrachloride Soil Vapor Extraction Site, Fiscal Year 1997*, Rev. 0, Bechtel Hanford, Inc., Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D198067101.

BNWL-CC-649, 1966, *Disposal Characteristics of Plutonium and Americium in a High Salt Aqueous Waste*, Battelle Pacific Northwest Laboratories, Richland, Washington.

Cantrell, K.J. and R.G. Riley, 2008a, *A Review of Subsurface Behavior of Plutonium and Americium at the 200-PW-1/3/6 Operable Units*, letter report from Pacific Northwest National Laboratory to Fluor Hanford, Inc., and the U.S. Department of Energy, Richland, Washington, January.

Cantrell, K.J. and R.G. Riley, 2008b, *Subsurface Behavior of Plutonium and Americium at Non-Hanford Sites and Relevance to Hanford*, letter report from Pacific Northwest National Laboratory to Fluor Hanford, Inc., and the U.S. Department of Energy, Richland, Washington, February.

Clean Air Act of 1990, 42 USC 7401, et seq., Pub. L. 101-549. Available at: http://www.epa.gov/air/caa/.

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

Cook, Beverly, 2002, "DOE Policies on Application of NEPA to CERCLA and RCRA Cleanup Actions" (memorandum to Secretarial Officers and Heads of Field Organizations), Environment, Safety and Health, U.S. Department of Energy, Washington, D.C., July 11. Available at: http://www.gc.energy.gov/NEPA/documents/CERCLA-RCRA-NEPAguidance.pdf.

DOE/EA-1403, 2001, *Environmental Assessment: Use of Existing Borrow Areas, Hanford Site, Richland, Washington*, U.S. Department of Energy, Richland, Operations Office, Richland, Washington.

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

DOE-EM/GJ918-2005, 2005, *Log Data Report for 299-W15-59 (A7360)*, Stoller Hanford Office, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-EM/GJ919-2005, 2005, *Log Data Report for 299-W15-60 (A7361)*, Stoller Hanford Office, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-EM/GJ920-2005, 2005, *Log Data Report for 299-W15-61 (A7362)*, Stoller Hanford Office, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-EM/GJ1273-2006, 2006, *299-W18-09 (A7526) Log Data Report*, Stoller Hanford Office, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE G 430.1-4, 1999, *Decommissioning Implementation Guide*, U.S. Department of Energy, Washington, D.C. Available at: http://www.directives.doe.gov/pdfs/doe/doetext/neword/430/g4301-4.pdf.

DOE G 441.1-1C, 2008, *Radiation Protection Programs Guide for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection*, U.S. Department of Energy, Washington, D.C. Available at: https://www.directives.doe.gov/directives/current-directives/441.1-EGuide-1c/view.

DOE O 451.1B Chg 1, 2001, *National Environmental Policy Act Compliance Program*, U.S. Department of Energy, Washington, D.C. Available at: https://www.directives.doe.gov/directives/current-directives/451.1-BOrder-bc1/view.

DOE O 470.4A, 2007, *Safeguards and Security Program*, U.S. Department of Energy, Washington, D.C. Available at: https://www.directives.doe.gov/directives/current-directives/470.4-BOrder-a/view.

DOE/RL-89-12, 1995, *Hanford Site Ground Water Protection Management Plan*, Rev. 2, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D196018651.

DOE/RL-91-32, 1991, *Expedited Response Action Proposal (EE/CA & EA) for 200 West Area Carbon Tetrachloride Plume*, Draft B, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D196078303.

DOE/RL-91-50, 2008, *Environmental Monitoring Plan United States Department of Energy Richland Operations Office*, Rev. 4, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www.pnl.gov/ecomon/docs/DOE-RL-91-50_Rev4.pdf.

DOE/RL-91-58, 1992, *Z Plant Source Aggregate Area Management Study Report*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D196124396.

DOE/RL-92-04, 1993, *PUREX Source Aggregate Area Management Study Report*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D196124097. http://www5.hanford.gov/arpir/?content=findpage&AKey=D196124099.

DOE/RL-96-32, 2001, *Hanford Site Biological Resources Management Plan*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www.pnl.gov/ecomon/docs/brmap/BRMaP.pdf.

DOE/RL-96-81, 1997, *Waste Site Grouping for 200 Areas Soil Investigations*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D197197143.

DOE/RL-97-56, 1998, *Hanford Site Manhattan Project and Cold War Era Historic District Treatment Plan*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

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.

DOE/RL-2001-01, 2004, *Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit RI/FS Work Plan: Includes the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*, Rev. 0, Re-issue, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at:
http://www2.hanford.gov/arpir/?content=findpage&AKey=D4573392.
http://www5.hanford.gov/arpir/?content=findpage&AKey=D4361348.
http://www5.hanford.gov/arpir/?content=findpage&AKey=D4361603.

DOE/RL-2001-41, 2009, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions*, Rev. 4, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=0095932.

DOE/RL-2002-39, 2002, *Standardized Stratigraphic Nomenclature for Post-Ringold-Formation Sediments Within the Central Pasco Basin*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2002-68, 2002, *Hanford's Groundwater Management Plan: Accelerated Cleanup and Protection*, Draft, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2003-52, 2003, *Tank 241-Z-361 Engineering Evaluation/Cost Analysis*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2004-05, 2004, *Engineering Evaluation/Cost Analysis for the Plutonium Finishing Plant Above-Grade Structures*, Rev. 1, Re-issue, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at:
http://www5.hanford.gov/arpir/?content=findpage&AKey=D6309710.

DOE/RL-2006-24, 2006, *Remedial Investigation Report for the 200-ZP-1 Groundwater Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2006-51, 2007, *Remedial Investigation Report for the Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit: Includes the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at:
http://www2.hanford.gov/arpir/?content=findpage&AKey=DA05807591.
http://www2.hanford.gov/arpir/?content=findpage&AKey=DA05807868.
http://www2.hanford.gov/arpir/?content=findpage&AKey=0805130070.
http://www2.hanford.gov/arpir/?content=findpage&AKey=0805130071.

DOE/RL-2007-28, 2008, *Feasibility Study Report for the 200-ZP-1 Groundwater Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at:
http://www5.hanford.gov/arpir/?content=findpage&AKey=0808050315.
http://www5.hanford.gov/arpir/?content=findpage&AKey=00098828.

DOE/RL-2007-34, 2008, *Regulatory Criteria for the Selection of Vadose Zone Modeling in Support of the 200-UW-1 Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2009-81, 2009, *Central Plateau Cleanup Completion Strategy*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www2.hanford.gov/arpir/?content=findpage&AKey=1002180676.

DOE/RL-2009-10, 2010, *Hanford Site Cleanup Completion Framework*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=1008190506.

DOE/RL-2009-81, 2009, *Central Plateau Cleanup Completion Strategy*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www2.hanford.gov/arpir/?content=findpage&AKey=1002180676.

DOE/RL-2009-117, 2010, *Proposed Plan for 200-CW-5, 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*, Draft C, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/WIPP-02-3122, 2009, *Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant*, Rev. 6.3, U.S. Department of Energy, Carlsbad Field Office, Carlsbad, New Mexico. Available at: http://www.wipp.energy.gov/library/wac/wac.pdf.

Drummond, Marshall E., 1992, *The Future for Hanford: Uses and Cleanup: The Final Report of the Hanford Future Site Uses Working Group*, prepared by the Hanford Future Site Uses Working Group for the U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D196123428.

ECF-200CW5-10-0075, 2010 *Calculation of Preliminary Remediation Goals in Soil for an Industrial Worker Exposure Scenario*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, 2 vols., as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington. Available at: http://www.hanford.gov/?page=81.

ECR#2004-200-048, 2004, *Biological Review of the Borehole and Geoprobe Casings Installation at 216-A-8 Project, 200W Area*, Pacific Northwest National Laboratory, Richland, Washington.

ECR#2005-200-045, 2005, *Biological Review of the Cone Penetrometer Probes South of 234-5Z Project, 200 W Area*, Pacific Northwest National Laboratory, Richland, Washington.

ECR#2006-200-031, 2006, *Biological Review of the Stage 5 VET Probes Project, 200W Area*, Pacific Northwest National Laboratory, Richland, Washington.

EDF-RWMC-523, 1992, *Evaluation of Engineered Barriers for Closure Cover of the RWMC SDA*, Idaho National Engineering Laboratory, Idaho Falls, Idaho.

EGG-WM-10974, 1993, *A Simulation Study of Moisture Movement in Proposed Barriers for the Subsurface Disposal Area*, Idaho National Engineering Laboratory, Idaho Falls, Idaho.

EM 1110-1-4001, 2002, *Engineering and Design: Soil Vapor Extraction and Bioventing*, U.S. Army Corps of Engineers, Washington, D.C. Available at: http://140.194.76.129/publications/eng-manuals/em1110-1-4001/entire.pdf.

Endangered Species Act of 1973, 16 USC 1531, et seq. Available at: http://www.fws.gov/endangered/pdfs/ESAall.pdf.

EPA, 2006, *EPA Region 6 Human Health Medium-Specific Screening Levels 2007 and Supplemental Information*, December 14, U.S. Environmental Protection Agency, Region 6, Dallas, Texas.

EPA-520/1-88-020, 1988, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*, Federal Guidance Report No. 11, Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://www.epa.gov/rpdweb00/docs/federal/520-1-88-020.pdf.

EPA 540-F-93-048, 1993, *Presumptive Remedies: Site Characterization and Technology Selection for CERCLA Sites with Volatile Organic Compounds in Soils*, OSWER Directive 9355.0-48FS, U.S. Environmental Protection Agency, Washington, D.C.

EPA/540/G-89/004, 1988, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, Interim Final, OSWER Directive 9355.3-01, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://epa.gov/superfund/policy/remedy/pdfs/540g-89004-s.pdf.

EPA/540/G-89/006, 1988, *CERCLA Compliance with Other Laws Manual: Interim Final*, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C. Available at: http://www.epa.gov/superfund/resources/remedy/pdf/540g-89006-s.pdf.

EPA 540-R-00-002, 2000, *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*, OSWER 9355.0-75, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://epa.gov/superfund/policy/remedy/sfremedy/rifs/costest.htm.

EPA/540-R-00-006, 2000, *Soil Screening Guidance for Radionuclides: Technical Background Document*, OSWER 9355.4-16, Office of Radiation and Indoor Air, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C. Available at: http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/sstbd.pdf.

EPA 540-R-97-006, 1997, *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments: Interim Final*, OSWER 9285.7-25, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://www.epa.gov/swerrims/riskassessment/ecorisk/ecorisk.htm.

EPA 540-R-97-013, 1997, *Rules of Thumb for Superfund Remedy Selection*, OSWER 9355.0-69, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://www.epa.gov/superfund/policy/remedy/rules/rulesthm.pdf.

EPA/540/R-99/009, 1999, *Use of Monitored Natural Attenuation at Superfund RCRA Corrective Action and Underground Storage Tank Sites*, OSWER 9200.4-17P, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C.

EPA 542-F-03-015, 2003, *Evapotranspiration Landfill Cover Systems Fact Sheet*, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://www.epa.gov/tio/download/remed/epa542f03015.pdf.

EPA/600/R-01/070, 2001, *Development of Recommendations and Methods to Support Assessment of Soil Venting Performance and Closure*, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://www.epa.gov/ada/download/reports/epa_600_r01_070.pdf.

EPA 910/R-98-001, 1998, *EPA Region 10 Interim Final Guidance: Developing Risk-Based Cleanup Levels at Resource Conservation and Recovery Act Sites in Region 10*, U.S. Environmental Protection Agency, Washington, D.C.

EPA, Ecology, and DOE, 2008, *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton County, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. Available at: http://www.epa.gov/superfund/sites/rods/fulltext/r2008100003103.pdf.

Executive Order 12898, 1994, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, William J. Clinton, February 11. Available at: http://www.epa.gov/fedrgstr/eo/eo12898.htm.

FH-0002791, 2000, "Submittal of Documentation in Fulfillment of Hanford Federal Facility Agreement and Consent Order Milestone M-15-37B" (letter to P.M. Knollmeyer, U.S. Department of Energy, Richland Operations Office, from G.W. Jackson), Fluor Hanford, Inc., Richland, Washington, May 23.

H-2-12292, 1973, *216-Z-3 Crib Waste Effluent Disposal Facilities Plot Plan & Crib Details*, Rev. 13, General Electric Company, Richland, Washington.

HAB 132, 2002, "Exposure Scenarios Task Force on the 200 Area" (letter to K. Klein, H. Boston, J. Iani, and T. Fitzsimmons from T. Martin), Hanford Advisory Board Consensus Advice #132, Richland, Washington, June 7.

HAB 207, 2008, "Criteria for Development of the Proposed Plan for 200-PW-1, 3, and 6" (letter to D. Brockman, S. Olinger, J. Hedges, and N. Ceto from S. Leckband), Hanford Advisory Board Consensus Advice #207, Richland, Washington, June 6.

HGLP-LDR-024, 2006, *299-E25-54 (A6043) Log Data Report*, Stoller Hanford Office, Richland, Washington.

HGLP-LDR-048, 2006, *299-W18-67 (A7550) Log Data Report*, Stoller Hanford Office, Richland, Washington.

HGLP-LDR-051, 2006, *299-W18-68 (A7551) Log Data Report*, Stoller Hanford Office, Richland, Washington.

HNF-1989, 1997, *Tank 241-Z-361 Process and Characterization History*, Rev. 0, prepared by B&W Hanford Company for Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-2867, 1999, *Tank 241-Z-361 Vapor Sampling and Analysis Plan*, Rev. 0-A, Lockheed Martin Hanford Corporation, Richland, Washington.

HNF-4371, 1999, *241-Z-361 Sludge Characterization Sampling and Analysis Plan*, Rev. 1, prepared by Lockheed Martin Hanford Corporation for Babcock and Wilcox Hanford Company, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D199150972.

HNF-8735, 2002, *241-Z-361 Tank Characterization Report*, Rev. 0A, Fluor Hanford, Inc., Richland, Washington.

HNF-31792, 2007, *Characterization Information for the 216-Z-9 Crib at the Plutonium Finishing Plant*, Rev. 0, Fluor Hanford, Inc., Richland, Washington.

HNF-SD-WM-TI-707, 2004, *Exposure Scenarios and Unit Dose Factors for the Hanford Tank Waste Performance Assessment*, Rev. 4, prepared by Fluor Federal Services for CH2M HILL Hanford Group, Inc., Richland, Washington.

Hunter, J.R., 1987, "NEPA Information for the In Situ Vitrification (ISV) Large Scale Radioactive Test (LSRT)" (letter to R.E. Gerton), U.S. Department of Energy, Richland, Washington, June 1.

HW-9671, 1948, *Underground Waste Disposal at Hanford Works: An Interim Report Covering the 200 West Area*, Health Instrument Department, Hanford Works, Richland, Washington. Available at: http://www2.hanford.gov/ddrs/common/findpage.cfm?AKey=D197251749.

HW-12468, 1949, *Audit of Radioactive Waste to Ground Through the 231 Dry Well and Cribs, February 1945 Through December 1948*, General Electric Company, Richland, Washington.

HW-17088, 1950, *The Underground Disposal of Liquid Wastes at the Hanford Works, Washington*, General Electric Company, Richland, Washington.

HW-23769, 1952, *Calculation Constants Used by Regional Survey: Part II Alpha Sample Counting Rate Conversion Factors*, General Electric Company, Richland, Washington.

HW-55196, 1958, *Replacement Disposal Facilities for 241-Z Tank Wastes Process Technology – Preliminary Design*, General Electric Company, Richland, Washington.

HW-55497, 1958, *Project Proposal Crib and Test Wells for 234-5 Building Wastes*, General Electric Company, Richland, Washington.

HW-61137, 1959, *Waste Disposal Monitoring Activities Summary, July, 1959*, General Electric Company, Richland, Washington.

HW-78967, 1963, *Process Waste Disposal Facility – Plutonium Reclamation Operations – Z Plant*, General Electric Company, Richland, Washington.

HW-79068, 1963, *Design Scope Process Waste Disposal Facility Plutonium Reclamation Operation – Z Plant*, General Electric Company, Richland, Washington.

ISO-698, 1967, *Radioactive Contamination in Liquid Wastes Discharged to Ground at the Separations Facility Through December, 1966*, ISOCHEM, Inc., Richland, Washington.

ITRC, 2003, *Technology Overview Using Case Studies of Alternative Landfill Technologies and Associated Regulatory Topics*, ALT-1, Interstate Technology and Regulatory Council, Washington, D.C. Available at: http://www.itrcweb.org/Documents/ALT-1.pdf.

LA-UR-03-6494, 2003, *IM Completion Report for the NTISV Hot Demonstration at SWMU 21-018(a)-99 (MDA V)*, Los Alamos National Laboratory, Los Alamos, New Mexico.

Linderoth, C.E., 1958, "Plutonium Contamination in Shallow Wells Adjacent to 234-5 Building Waste Cribs" (letter to W.N. Mobley), General Electric Company, Richland, Washington, February 19.

Liu, Chongxuan, John M. Zachara, Odeta Qafoku, James P. McKinley, Steve M. Heald, and Zheming Wang, 2004, "Dissolution of Uranyl Microprecipitates in Subsurface Sediments at Hanford Site, USA," *Geochimica et Cosmochimica Acta* 68(22):4519-4537.

Liu, Chongxuan, John M. Zachara, Wassana Yantasee, Paul D. Majors, and James P. McKinley, 2006, "Microscopic Reactive Diffusion of Uranium in the Contaminated Sediments at Hanford, United States," *Water Resources Research* 42(W12420).

Luftig, Stephen D. and Stephen D. Page, 1999, "Distribution of OSWER Radiation Risk Assessment Q&A's Final Guidance" (memorandum to Addressees), Office of Emergency and Remedial Response and Office of Radiation and Indoor Air, U.S. Environmental Protection Agency, Washington, D.C., December 17. Available at: http://epa.gov/superfund/health/contaminants/radiation/pdfs/riskqa.pdf.

Luftig, Stephen D. and Larry Weinstock, 1997, "Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination" (memorandum to Addressees), OSWER No. 9200.4-18, Office of Emergency and Remedial Response and Office of Radiation and Indoor Air, U.S. Environmental Protection Agency, Washington, D.C., August 22. Available at: http://www.epa.gov/oerrpage/superfund/health/contaminants/radiation/pdfs/radguide.pdf.

Magnusen-Stevens Fishery Conservation and Management Act of 1996, 16 USC 1801, et seq. Available at: http://uscode.house.gov/download/pls/16C38.txt.

McFarland, D., 2005, *Cultural Resource Review Notices to Proceed*, HCRC#2005-200-045, Pacific Northwest National Laboratory, Richland, Washington.

Migratory Bird Treaty Act of 1918, 16 USC 703, et seq. Available at: http://www.fws.gov/laws/lawsdigest/migtrea.html.

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

National Historic Preservation Act of 1966, 16 USC 470, et seq. Available at: http://www.achp.gov/NHPA.pdf.

Native American Graves Protection and Repatriation Act of 1990, 25 USC 3001, et seq. Available at: http://www.nps.gov/history/local-law/FHPL_NAGPRA.pdf.

Oostrom, Mart, Michael J. Truex, Guzel D. Tartakovsky, and Tom W. Wietsma, 2010, "Three-Dimensional Simulation of Volatile Organic Compound Mass Flux from the Vadose Zone to Groundwater," *Ground Water Monitoring and Remediation*, In Press.

OSWER 9355.4-24, 2002, *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://www.epa.gov/superfund/health/conmedia/soil/index.htm.

OSWER Directive No. 9355.0-63FS, 1996, *User's Guide to the VOCs in Soils Presumptive Remedy*, EPA 540/F-96/008, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://www.epa.gov/superfund/policy/remedy/presump/finalpdf/vc.pdf.

OSWER Directive 9355.3-01FS3, 1989, *The Feasibility Study: Development and Screening of Remedial Action Alternatives*, Fact Sheet, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://www.epa.gov/superfund/policy/remedy/pdfs/93-55301fs3-s.pdf.

PNL-8971, 1993, *Three-Dimensional Conceptual Model for the Hanford Site Unconfined Aquifer System, FY 1993 Status Report*, Pacific Northwest Laboratory, Richland, Washington. Available at: http://www.osti.gov/energycitations/servlets/purl/10116050-9Pd7wr/native/10116050.pdf.

PNNL-6415, 2005, *Hanford Site National Environmental Policy Act (NEPA) Characterization*, Rev. 17, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-6415rev17.pdf.

PNNL-11216, 1997, *STOMP: Subsurface Transport Over Multiple Phases Application Guide*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-11346, 1996, *Plutonium Dioxide Dissolution in Glass*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.osti.gov/energycitations/servlets/purl/416955-wggQnx/webviewable/416955.pdf.

PNNL-11978, 1998, *Results of 1998 Spectral Gamma-Ray Monitoring of Boreholes at the 216-Z-1A Tile Field, 216-Z-9 Trench, and 216-Z-12 Crib*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D199159400.

PNNL-11989, 2000, *Integrated Monitoring Plan for the Hanford Groundwater Monitoring Project*, Rev. 2, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D2760242.

PNNL-12261, 2000, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-13858, 2002, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-13858.pdf.

PNNL-14702, 2006, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf.

PNNL-15670, 2006, *Hanford Site Groundwater Monitoring for Fiscal Year 2005*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-15670.pdf.

PNNL-16103, 2006, *Borehole Geologic Data for the 216-Z Crib Facilities: A Status of Data Assembled through the Hanford Borehole Geologic Information System (HBGIS)*, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-16103.pdf.

PNNL-16346, 2007, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-16346.pdf.

PNNL-17031, 2007, *A Site Wide Perspective on Uranium Geochemistry at the Hanford Site*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www2.hanford.gov/arpir/?content=findpage&AKey=0911240713.

PNNL-17674, 2008, *Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17674.pdf.

PNNL-17839, 2008, *Plutonium Mobility Studies: 216-Z-9 Trench Sample Analysis Results*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17839.pdf.

PNNL-SA-32196, 2000, *Apex-3D: Activity Prediction Expert System with 3D QSAR*, Pacific Northwest National Laboratory, Richland, Washington.

Qafoku, Nikolla P., John M. Zachara, Chongxuan Liu, Paul L. Gassman, Odeta S. Qafoku, and Steven C. Smith, 2005, "Kinetic Desorption and Sorption of U(VI) During Reactive Transport in a Contaminated Hanford Sediment," *Environ. Sci. Technol.* 39(9):3157-3165.

RCW 70.94, "Public Health and Safety," "Washington Clean Air Act," *Revised Code of Washington*, Washington State, Olympia, Washington. Available at: http://apps.leg.wa.gov/RCW/default.aspx?cite=70.94.

Resource Conservation and Recovery Act of 1976, 42 USC 6901, et seq. Available at: http://www.epa.gov/epawaste/inforesources/online/index.htm.

RHO-CD-673, 1979, *Handbook 200 Areas Waste Sites*, 3 vols. Rockwell Hanford Operations, Richland, Washington. Available at:
http://www5.hanford.gov/arpir/?content=findpage&AKey=D196039027.
http://www5.hanford.gov/arpir/?content=findpage&AKey=D196039028.
http://www5.hanford.gov/arpir/?content=findpage&AKey=D196039028.

RHO-HS-EV-18, 1983, *Serviceability of Cribs Affected by PUREX Startup*, Rockwell Hanford Operations, Richland, Washington.

RHO-LD-80-75, 1980, *Effluent Controls Group Annual Report – CY1979*, Rockwell Hanford Operations, Rockwell Hanford Operations, Richland, Washington.

RHO-LD-114, 1981, *Existing Data on the 216-Z Liquid Waste Sites*, Rockwell Hanford Operations, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D196055124.

RHO-RE-EV-46P, 1984, *216-Z-8 French Drain Characterization Study*, Rockwell Hanford Operations, Richland, Washington.

RHO-ST-17, 1979, *Distribution of Plutonium and Americium Beneath the 216-Z-1A Crib: A Status Report*, Rockwell Hanford Operations, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D196055120.

RHO-ST-21, 1978, *Report on Plutonium Mining Activities at 216-Z-9 Enclosed Trench*, Rockwell Hanford Operations, Richland, Washington.

RHO-ST-44, 1982, *216-Z-12 Transuranic Crib Characterization: Operational History and Distribution of Plutonium and Americium*, Rockwell Hanford Operations, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D196055131.

Rockwell, 1986, "Alpha Contamination in the Z-1/Z-1A Crib Complex" (internal letter), Rockwell International, Richland, Washington, September 23.

Rodriguez, A., 2006, *Cultural Resource Review Notices to Proceed*, NPCE#2006-200-031, Cultural and Historic Resource Program, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

RPP-26744, 2005, *Hanford Soil Inventory Model, Rev. 1*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

SGW-33746, 2007, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Fiscal Year 2006*, Rev. 0, Fluor Hanford, Inc., Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=DA06100675.

SGW-33829, 2008, *200-PW-1 Operable Unit Report on Step II Sampling and Analysis of the Dispersed Carbon Tetrachloride Vadose-Zone Plume*, Rev. 0, Fluor Hanford, Inc., Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=0806240070.

SGW-35060, 2007, *Inventory Estimates for Liquid Discharges from the 231-Z Facility*, Rev. 0, Fluor Hanford, Inc., Richland, Washington, September.

SGW-37111, 2008, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Fiscal Year 2007*, Rev. 0, Fluor Hanford Inc., Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=0809171000.

SGW-35955, 2008, *Inventory Estimates for Sludge Currently in Tank 241-Z-361*, Rev. 0, Fluor Hanford, Inc., Richland, Washington, January.

SGW-39385, 2009, *Z Plant Complex Waste Streams Discharged to the Soil Column (1949 to 1973)*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-40456, 2009, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Fiscal Year 2008*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-44694, 2010, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Fiscal Year 2009*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

Toxic Substances Control Act of 1976, 15 USC 2601, et seq. Available at: http://frwebgate.access.gpo.gov/cgi-bin/usc.cgi?ACTION=BROWSE&TITLE=15USCC53.

Truex, M.J., M. Oostrom, and M.L. Brusseau, 2009, "Estimating Persistent Mass Flux of Volatile Contaminants from the Vadose Zone to Ground Water," *Ground Water Monitoring and Remediation* 29(2):63-72. Available at: http://www3.interscience.wiley.com/cgi-bin/fulltext/122389134/HTMLSTART.

WAC 173-160-381, "Minimum Standards for Construction and Maintenance of Wells," "What are the Standards for Decommissioning a Well?" *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-160-381.

WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-303.

303-140, "Land Disposal Restrictions."

303-665, "Landfills."

WAC 173-304, "Minimum Functional Standards for Solid Waste Handling," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-304.

WAC 173-340, "Model Toxics Control Act—Cleanup," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340.

340-720, "Ground Water Cleanup Standards."

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

340-7490, "Terrestrial Ecological Evaluation Procedures."

WAC 173-350, "Solid Waste Handling Standards," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-350.

WAC 173-400, "General Regulations for Air Pollution Sources," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-400.

400-040, "General Standards for Maximum Emissions."

400-113, "Requirements for New Sources in Attainment or Unclassifiable Areas."

WAC 173-460, "Controls for New Sources of Toxic Air Pollutants," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-460.

460-060, "Control Technology Requirements."

WAC 173-480, "Ambient Air Quality Standards and Emission Limits for Radionuclides," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-480.

WAC 246-247, "Radiation Protection—Air Emissions," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=246-247.

247-030, "Definitions."

247-040, "General Standards."

Waste Information Data System, Hanford Site database, Richland, Washington.

WCH-191, 2009, *Environmental Restoration Disposal Facility Waste Acceptance Criteria*, Rev. 1, Washington Closure Hanford, LLC, Richland, Washington.

WDFW, 2009, "Species of Concern in Washington State," Current Through June 1, 2009, Washington Department of Fish and Wildlife website. Available at: http://www.wdfw.wa.gov/wlm/diversty/soc/soc.htm.

Wellman, D.M., J.M. Zachara, C. Liu, N. Qafoku, S.C. Smith, and S.W. Forrester, 2008, "Advective Desorption of Uranium (VI) from Contaminated Hanford Vadose Zone Sediments under Saturated and Unsaturated Conditions," *Vadose Zone J.* 7(4):1144-1159. Available at: http://vzj.scijournals.org/cgi/reprint/7/4/1144.

WHC-MR-0391, 1992, *Field Trip Guide to the Hanford Site*, Westinghouse Hanford Company, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D196136627.

WHC-SD-DD-TI-057, 1991, *Summary of Radioactive Underground Tanks Managed by Hanford Restoration Operations*, Rev. 0, Westinghouse Hanford Company, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D196078266.

WHC-SD-EN-TI-248, 1994, *1994 Conceptual Model of the Carbon Tetrachloride Contamination in the 200 West Area at the Hanford Site*, Rev. 0, Westinghouse Hanford Company, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=D196075664.

WNHIS, 2009, "List of Known Occurrences of Rare Plants and Animals in Washington," Washington Natural Heritage Information System, Washington State Department of Natural Resources, Olympia, Washington.

WNHP, 2009, "List of Plants Tracked by the Washington Natural Heritage Program," Washington Natural Heritage Program, Washington State Department of Natural Resources, Olympia, Washington. Available at: http://www1.dnr.wa.gov/nhp/refdesk/lists/plantrnk.html.

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