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Revision 0

Remedial Investigation/Feasibility Study for the 200-UP-1 Groundwater Operable Unit

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

U.S. DEPARTMENT OF ENERGY | Richland Operations Office
P.O. Box 550
Richland, Washington 99352

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Executive Summary

This document presents the results of a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*[1] (CERCLA) Remedial Investigation (RI) and Feasibility Study (FS) undertaken for the 200-UP-1 Groundwater Operable Unit (OU) located on the Hanford Site. Based on the results of the RI, a determination has been made that contaminants in the groundwater pose a threat to human health, and further evaluation of CERCLA remedial action alternatives is warranted.

This report documents the results of the RI and presents an FS of remedial alternatives. The RI defines the problem by describing the nature and extent of groundwater contamination and associated risks, which establishes the basis for possible remedial action. The FS evaluates what can be done about the problem by formulating remedial action objectives (RAOs), and developing and evaluating a range of viable remedial alternatives to achieve those objectives.

The 200-UP-1 OU consists of the groundwater beneath the southern portion of the 200 West Area of the Hanford Site. The groundwater contamination has resulted largely from operations and disposal of process liquid wastes associated with uranium and plutonium recovery processes. The primary waste sites that contributed to this contamination included ponds, cribs, and trenches that received liquid waste from S Plant and U Plant operations, and unplanned releases from Waste Management Area (WMA) S-SX. Bulk liquid waste discharges contributing the majority of contamination to the subsurface occurred from 1944 to the early 1990s. Currently, there are no liquid waste discharges to the ground above the OU (with the exception of septic drain fields). As effluents were discharged to these sites, more mobile contaminants migrated through the vadose zone to the groundwater. Less mobile contaminants and residual contamination remain in the vadose zone soil. The scope of this RI/FS addresses contaminants in groundwater. Waste sites and associated vadose contamination overlying the OU will be addressed under separate source OU RIs and FSs (such as 200-WA-1 and 200-DV-1 OUs).

[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.

Remedial Investigation

The RI includes activities and field investigations used to define the physical characteristics of the study area, determine the nature and extent of groundwater contamination, establish contaminants of potential concern (COPCs), and conduct a baseline risk assessment (BRA) to evaluate current and potential future risks to human health and the environment. The physical characteristics of the study area, and the nature and extent of groundwater contamination are established based on information gathered from multiple studies and investigations, including the more recent field investigations performed under the RI/FS work plan for the 200-UP-1 OU. The work plan included the installation of new groundwater monitoring wells, and groundwater sampling and analyses.

Located on the Central Plateau of the Site, the water table for the 200-UP-1 OU is relatively deep, averaging approximately 75 m (250 feet) below the ground surface. Groundwater contamination is largely contained within the uppermost unconfined aquifer, which ranges in thickness from approximately 10 m (33 feet) to 100 m (330 feet), and lies within the Ringold Formation unit E composed of silty sandy gravel. The unconfined aquifer controls the lateral movement of groundwater contaminants across the 200-UP-1 OU and is bounded below by the Ringold Formation lower mud unit, which forms a low permeability confining layer limiting the vertical movement of contaminated groundwater into the deeper confined aquifer.

The 200-UP-1 OU groundwater contamination plumes (Figure ES-1) include the following:

- Technetium-99 (Tc-99) plumes primarily associated with U Plant cribs and WMA S-SX
- A uranium plume originating from U Plant cribs
- A widespread iodine-129 (I-129) plume originating from U Plant and S Plant cribs

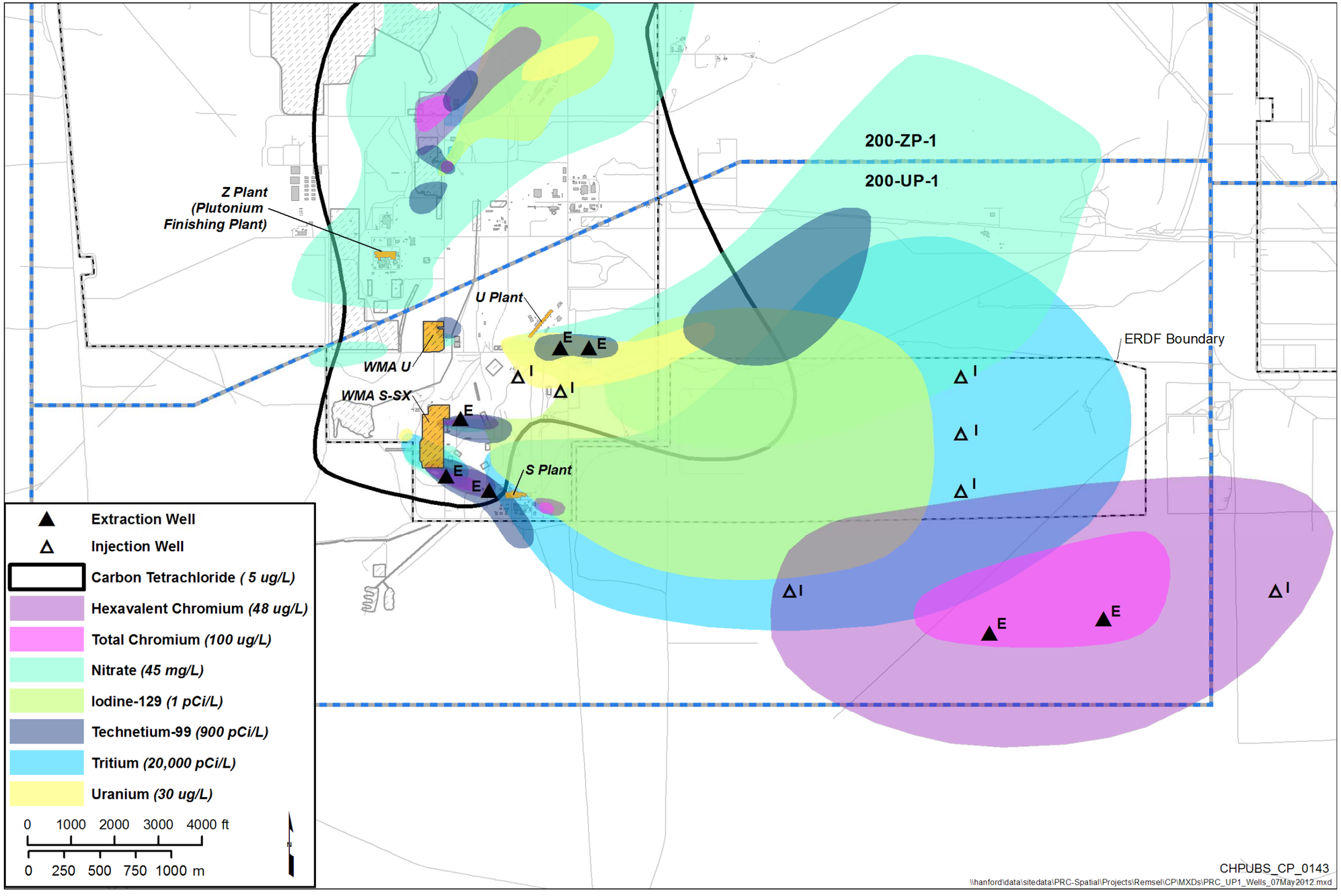

Figure ES-1. 200-UP-1 Operable Unit Groundwater Plume Map

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- A chromium plume associated with WMA S-SX and a disperse chromium plume in the southeastern corner of the OU that originated from an S Plant crib. The chromium plumes were differentiated to show the portion exceeding the federal drinking water standard (DWS) of 100 µg/L and the "Model Toxics Control Act—Cleanup,"[2] hereinafter referred to as MTCA, groundwater cleanup level of 48 µg/L.
- A widespread tritium plume originating from S Plant cribs.
- A widespread nitrate plume originating from U Plant and S Plant cribs, and WMA S-SX.
- A widespread carbon tetrachloride plume originating from Plutonium Finishing Plant (Z Plant) waste sites.

As part of the BRA, groundwater data collected during the RI (years 2004 to 2009) are evaluated to identify COPCs and assess current and future potential risks to human receptors associated with groundwater contamination within the 200-UP-1 OU. Exposure routes to human receptors evaluated include ingestion, dermal contact, and inhalation. The results of the risk evaluation indicate that there are no current risks to onsite industrial workers or offsite receptors from the contaminated groundwater because the existing Hanford Site access and institutional controls prevent groundwater use and exposure. However, there is a need to remediate groundwater within the OU because current groundwater concentrations pose an unacceptable level of risk. In addition, there could be potential future risks to human health that exceed the acceptable CERCLA excess lifetime cancer risk (ELCR) range or the hazard index (HI) threshold in the absence of controls preventing groundwater consumption. Nonradiological and radiological COPC's that are carried forward into the FS and their associated risks are summarized in Tables ES-1 and ES-2.

Ecological exposure to 200-UP-1 OU contaminants is not expected because ecological receptors will not be directly or indirectly exposed to 200-UP-1 OU groundwater now or in the future and any future remedial action that is necessary for human health risk mitigation and to restore the aquifer for beneficial use will also prevent contaminants from reaching the Columbia River.

[2] 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.

Table ES-1. 90th Percentile Current Groundwater Concentrations for Nonradiological COPCs, Associated Excess Lifetime Cancer Risk and Noncancer Hazard Quotients (HQ), and MTCA Cleanup Levels

Final COPC	Units	90th Percentile Concentration	Non Carcinogen Hazard			Cancer Risk		
			MTCA B Cleanup Level Noncarcinogens at HQ=1*	90th Percentile HQ	Percent Contribution to HI	MTCA B Cleanup Level Carcinogens at 10^{-6} Risk Level*	90th Percentile ELCR	Percent Contribution to ELCR
Carbon Tetrachloride	µg/L	189	5.6	34	83%	0.34	5.6×10^{-4}	95.6%
Chloroform	µg/L	7.2	80	0.09	0%	1.4	5.1×10^{-6}	0.9%
1,4-Dioxane	µg/L	6.0	800	<0.01	0%	4.0	1.5×10^{-6}	0.3%
Tetrachloroethene (PCE)	µg/L	1.0	80	0.01	0%	0.081	1.2×10^{-5}	2.1%
Trichloroethene (TCE)	µg/L	3.3	--	--		0.49	6.7×10^{-6}	1.2%
Total ELCR						**--**	**5.8×10^{-4}**	**100%**
Total Chromium	µg/L	99	24,000	<0.01	0%	--	--	
Hexavalent Chromium	µg/L	52	48	1.1	3%	--	--	
Nitrate as NO_3	mg/L	133	113.6	1.2	3%	--	--	
Nitrate as N	mg/L	30.1	25.6	1.2	3%			
Uranium (total)	µg/L	206	48	4.3	11%	--	- -	
Hazard Index				**41**	**100%**			

* Source: WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

Table ES-2. 90th Percentile Current Groundwater Concentrations for Radiological COPCs, Associated Excess Lifetime Cancer Risk (ELCR) and Federal Drinking Water Standards (DWS)

Final COPC	90th Percentile Concentration (pCi/L)	Federal DWS (pCi/L)	Federal DWS ELCR	Individual Risk Fraction of DWS	90th Percentile ELCR	% Contribution to ELCR
Iodine-129	3.5	1	2.8×10^{-6}	3.5	9.80×10^{-6}	4%
Strontium-90	0.66	8	8.5×10^{-6}	0.08	6.80×10^{-7}	0%
Technetium-99	4,150	900	4.7×10^{-5}	4.6	2.16×10^{-4}	78%
Tritium*	51,150	20,000	$1.9 \times 10^{-5*}$	2.6	4.94×10^{-5}	18%
Cumulative ELCR for Radiological COPCs				-	2.76×10^{-4}	100%

* An excess lifetime cancer risk for tritium, which includes the ingestion and inhalation exposure routes, would be 1.3×10^{-4}. The ELCR for tritium would be 1.9×10^{-5} for the ingestion exposure route only.

Fate and transport modeling was performed to determine the year in which the DWS would be reached if no remedial action was undertaken (that is, no further action scenario). The modeling results based on the 90th percentile concentration for primary groundwater plumes originating within the OU are as follows:

- The uranium plume, beginning with an initial concentration of 206 µg/L, decreases to less than the federal DWS of 30 µg/L in 600 years.
- The Tc-99 plumes decrease from an initial concentration of 4,150 pCi/L to less than the federal DWS of 900 pCi/L within 25 years.
- The tritium plume decreases from an initial concentration of 51,150 pCi/L to less than the federal DWS of 20,000 pCi/L within 50 years.
- The I-129 plume, beginning with an initial concentration of 3.5 pCi/L, decreases to less than the federal DWS of 1 pCi/L in 400 years.
- The nitrate plumes (NO_3) decrease from an initial concentration of 133 mg/L to less than the federal DWS of 45 mg/L within 75 years.
- The total chromium plumes begin with an initial concentration of 99 µg/L, which is below the federal DWS of 100 µg/L. These same plumes, reported as hexavalent

chromium, begin with an initial concentration of 52 µg/L and decrease to below the Washington State WAC 173-340-720[3] cleanup level of 48 µg/L in 25 years.

Feasibility Study

The primary objective of the FS is to ensure that an appropriate range of remedial alternatives are developed and evaluated. The FS consists of several steps:

- Establish RAOs and preliminary remediation goals (PRGs) that define what the remedial action needs to accomplish to protect human health and the environment.
- Identify and screen technologies that can achieve the RAOs and PRGs.
- Assemble remediation technologies into remedial alternatives.
- Perform a detailed and comparative analysis of viable remedial alternatives.

As part of RAO development, final COPCs defined in the risk assessment are further evaluated to develop a list of contaminants of concern (COCs) to guide the remedial technology screening and remedial alternatives development process. Based on the results of this evaluation, eight COCs were identified: carbon tetrachloride, uranium, chromium (total), hexavalent chromium, nitrate, Tc-99, I-129, and tritium. Str-90, 1,4-dioxane, tetrachloroethene, trichloroethene, and chloroform were not carried forward into the FS as COCs for the following reasons:

- They contribute to less than 5 percent of the overall cancer risk.
- They were infrequently detected in the groundwater monitoring network.
- They do not occur with persistence in a wide area above the DWS or MTCA groundwater cleanup levels.

The RAOs provide the basis for evaluating the ability of a technology or remedial alternative to achieve cleanup levels that are protective of human health and the environment. Under CERCLA and the "National Oil and Hazardous Substances Pollution Contingency Plan,"[4] hereinafter referred to as NCP, a groundwater remedy must be protective of human health and the environment and meet applicable or relevant and

[3] WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards," Washington Administrative Code, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-720.
[4] 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," *Code of Federal Regulations*. Available at: http://www.gpo.gov/fdsys/pkg/CFR-2010-title40-vol27/xml/CFR-2010-title40-vol27-part300.xml.

appropriate requirements (ARARs) (or satisfy criteria for an ARAR to be waived). Based on these requirements and NCP expectations for groundwater restoration, the proposed RAOs for 200-UP-1 OU include:

- RAO 1: Return the 200-UP-1 OU groundwater to beneficial use as a potential drinking water source.
- RAO 2: Apply ICs to prevent groundwater use until drinking water standards are achieved.

The PRGs, which are based on federal DWSs and WAC 173-340-720 cleanup levels, are presented in Table ES-3 for 200-UP-1 OU COCs. Remedial technologies expected to meet the RAOs were identified and evaluated based on effectiveness, implementability, and relative cost. The most viable technologies were retained and assembled into a range of remedial alternatives, from no action without institutional controls to various degrees of active restoration employing groundwater pump and treat (P&T) as the primary remedial technology.

The remedial alternatives assembled to achieve RAOs include the following:

- No Action
- Alternative 2 – 45 Years Active Remediation and Monitored Natural Attenuation (MNA)
- Alternative 3 – 35 Years Active Remediation and MNA
- Alternative 4 – 25 Years Active Remediation and MNA

The no action alternative serves as a baseline for evaluating other remedial action alternatives. No action means that no further remediation would be implemented to alter the existing groundwater conditions and includes the termination of existing institutional controls and interim remedial actions.

The active remediation alternatives rely on P&T and differ by years of active remediation and the rate of pumping. In addition to the P&T component, Alternatives 2 through 4 include the common elements of hydraulic containment for I-129, institutional controls, performance monitoring, and to varying degrees, MNA. The active remedial alternatives and associated component technologies and costs are summarized in Table ES-4.

Table ES-3. 200-UP-1 OU COCs and Associated Current Groundwater Concentrations and Proposed PRGs with Federal DWSs and MTCA Cleanup Levels

Contaminants of Concern (COCs)	Units	90th Percentile Groundwater Concentrations for COCs	Federal Drinking Water Standards[a] (DWS)	Model Toxics Control Act Method B Cleanup Levels		200-UP-1 OU PRGs[b]
				Non-Carcinogens at HQ = 1	Carcinogens at 1×10^{-5} Risk Level	
Iodine-129	pCi/L	3.5	1	--	--	1[e]
Technetium-99	pCi/L	4,150	900	--	--	900
Tritium	pCi/L	51,150	20,000	--	--	20,000
Uranium	µg/L	206	30	--	--	30
Nitrate[c] (as NO_3)	mg/L	133	45	113.6	--	45
Nitrate[c] (as N)	mg/L	30.1	10	25.6	--	10
Chromium (total)	µg/L	99	100	24,000	--	100
Hexavalent Chromium	µg/L	52	--[d]	48	--	48
Carbon Tetrachloride	µg/L	189	5	5.6	3.4	3.4[f]

Source: WAC 173-340, "Model Toxics Control Act—Cleanup."

a. Federal DWSs are from 40 CFR 141, "National Primary Drinking Water Regulations," with I-129 and Tc-99 values from EPA 816-F-00-002, *Implementation Guide for Radionuclides*.

b. The final cleanup levels achieved at the conclusion of the remedial action will correspond to an ELCR less than 1×10^{-6} and an HI of less than 1.

c. Nitrate may be expressed as nitrate (NO_3) or as nitrate-nitrogen (NO_3-N). The federal DWS for NO_3-N is 10,000 µg/L and 45,000 µg/L for NO_3. The state DWS is 10,000 µg/L as NO_3-N.

d. There is no federal or state DWS for hexavalent chromium.

e. Current technology may not enable this level of treatment to be achieved. Feasibility of treatment and levels that can be achieved will be determined though a technology evaluation.

f. This cleanup level is a risk-based calculation used for the carbon tetrachloride in the 200-ZP-1 OU, which is in the same aquifer as 200-UP-1 OU.

-- = not applicable

Table ES-4. 200-UP-1 OU Remedial Alternatives

Remedial Components	Alternative 2 – 45 Years Active Remediation and MNA	Alternative 3 – 35 Years Active Remediation and MNA	Alternative 4 – 25 Years Active Remediation and MNA
Pump-and-treat	P&T for Tc-99, uranium, carbon tetrachloride, chromium, and concentrated nitrate plume areas	Moderately aggressive P&T for Tc-99, uranium, carbon tetrachloride, chromium, and concentrated nitrate plume areas	Highly aggressive P&T for Tc-99, uranium, carbon tetrachloride, chromium, and all nitrate plume areas
Monitored Natural Attenuation	Tritium, diffuse parts of nitrate plume, remaining parts of carbon tetrachloride plume	Tritium, diffuse parts of nitrate plume, remaining parts of carbon tetrachloride plume	Tritium, remaining parts of carbon tetrachloride plume
Hydraulic Containment	I-129	I-129	I-129
Institutional Controls	All COCs	All COCs	All COCs
Time to Reach PRGs*	45 years	35 years	25 years
Cost (present value)	$304 Million	$319 Million	$342 Million

* The time required to reach PRGs for all COCs present within each remediation area except carbon tetrachloride.

The remedial alternatives were subjected to a detailed and comparative evaluation to identify the advantages and disadvantages of each alternative. The detailed evaluation was conducted using seven of the nine CERCLA criteria. Two criteria, overall protection of human health and the environment and compliance with ARARs, are threshold criteria. The next five criteria are balancing criteria and include long-term effectiveness; reduction of toxicity, mobility, and volume through treatment; short-term effectiveness; implementability; and cost. The two remaining criteria, state acceptance and community acceptance, are modifying criteria and will be addressed following the public comment period on the proposed plan.

The no action alternative was not evaluated because it does not meet threshold criteria for protection of human health and the environment; therefore, it cannot be selected.
The active remediation alternatives were similar and meet threshold criteria because they protect current and future human health by preventing exposure to contaminated groundwater through the use of institutional controls until RAOs are achieved. The active

remediation alternatives also have comparable ratings for long-term effectiveness, permanence, and short-term effectiveness.

Alternative 4 (25 years active remediation and MNA) ranks higher for reduction of toxicity, mobility, and volume through treatment. Alternative 3 ranks next highest for reduction of toxicity, mobility, and volume for all COCs except nitrate. Alternative 4 employs more aggressive pumping rates, but Alternative 4 presents challenges with implementation. Alternative 4 is expected to pose a greater implementation challenge than Alternative 3 would because of the increased operations and maintenance burden associated with operation of the biological treatment process required to treat the larger volumes of nitrate-contaminated groundwater. The estimated costs for each alternative are provided in Table ES-4, with Alternative 4 being the most costly and Alternative 2 the least costly.

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Terms

AAMS	aggregate area management study
AAMSR	aggregate area management study report
ALARA	as low as reasonably achievable
ARAR	applicable or relevant and appropriate requirement
BRA	baseline risk assessment
C-max	maximum concentration
CalEPA	California Environmental Protection Agency
CCU	Cold Creek unit
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	*Code of Federal Regulations*
CLARC	Cleanup Levels and Risk Calculations
COC	contaminant of concern
COPC	contaminant of potential concern
Cs-137	cesium-137
CSM	conceptual site model
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
DDD	dichlorodiphenyldichloroethane
DDT	dichlorodiphenytrichlorethane
DNAPL	dense nonaqueous phase liquid
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy, Richland Operations Office
DQA	data quality assessment
DQO	data quality objective
DST	double-shell tank
DWS	drinking water standard
Ecology	Washington State Department of Ecology
ELCR	excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency

EPC	exposure point concentration
ERDF	Environmental Restoration Disposal Facility
ESD	explanation of significant difference
ETF	Effluent Treatment Facility
FS	feasibility study
FY	fiscal year
GAC	granular activated carbon
GRA	general response action
HCP-EIS	Hanford Comprehensive Land Use Plan-Environmental Impact Statement
HEAST	Health Effects Assessment Summary Tables
HEIS	Hanford Environmental Information System
HI	hazard index
HQ	hazard quotient
HSU	hydrostratigraphic unit
HWMA	Washington State *Hazardous Waste Management Act of 1976*
I-129	iodine-129
ICP	inductively coupled plasma
IRA	interim response action
IRIS	Integrated Risk Information System
ISCO	in situ chemical oxidation
K_d	distribution coefficient
LFI	limited field investigation
MCL	maximum contaminant level
MIBK	methyl isobutyl ketone
MNA	monitored natural attenuation
MS	mass spectrometry
MTCA	*Model Toxics Control Act*
N/A	not applicable *or* not analyzed
NBS	National Bureau of Standards
NCP	National Oil and Hazardous Substances Pollution Contingency Plan

ND	not detected
NEPA	*National Environmental Policy Act of 1969*
NJDEP	New Jersey Department of Environmental Protection
NPL	National Priorities List
NPV	net present value
O&M	operations and maintenance
OEHHA	Office of Environmental Health Hazard Assessment
OES	optical emission spectrometry
OU	operable unit
P&T	pump-and-treat
PCE	tetrachloroethene
PFP	Plutonium Finishing Plant
PNNL	Pacific Northwest National Laboratory
PRB	permeable reactive barrier
PRG	preliminary remediation goal
PUREX	Plutonium-Uranium Extraction (Plant or process)
QC	quality control
Ra	radium
RAD	radionuclide
RAIS	Risk Assessment Information System
RAO	remedial action objective
RCRA	*Resource Conservation and Recovery Act of 1976*
RCW	*Revised Code of Washington*
REDOX	Reduction-oxidation (Plant or process)
RfD	reference dose
RI	remedial investigation
RL	DOE Richland Operations Office
ROD	record of decision
RPD	relative percent difference
SALDS	State-approved Land Disposal Site

SAP	sampling and analysis plan
Sr-90	strontium-90
SST	single-shell tank
SVE	soil vapor extraction
SVOC	semivolatile organic compound
TBC	to be considered
Tc-99	technetium-99
TCE	trichloroethene
TEDF	Treated Effluent Disposal Facility
TPA	Tri-Party Agreement (*Hanford Federal Facility Agreement and Consent Order)*
UCL	upper confidence limit
UIC	underground injection control
USACE	U.S. Army Corps of Engineers
USC	United States Code
VOC	volatile organic compound
WAC	*Washington Administrative Code*
WDFW	Washington Department of Fish and Wildlife
WMA	waste management area
WNHP	Washington National Heritage Program

1 Introduction

In 1989, the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology (Ecology) (known as the Tri-Parties) signed the *Hanford Federal Facility Agreement and Consent Order* (hereinafter called Tri-Party Agreement [TPA] [Ecology et al., 1989]) to provide a framework for the cleanup of the Hanford Site (Figure 1-1). The scope of the agreement addressed the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) remediation of hazardous waste sites, active waste management operations, *Resource Conservation and Recovery Act of 1976* (RCRA) corrective action for solid waste management units, and closure of RCRA treatment, storage, and disposal units across the Hanford Site.

For the purpose of CERCLA cleanup, four sections of the Hanford Site were placed on the 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," "Appendix B, "National Priorities List" (hereinafter called NPL), as separate areas: 100 Area, 200 Area, 300 Area, and 1100 Area.

The four areas of the Hanford Site are generally defined below:

- The 100 Area is the former nuclear reactor operations area along the southern bank of the Columbia River in the northern portion of the Site.
- The 200 Area is the former irradiated nuclear fuel processing area and central waste management area (WMA) in the central upland portion of the Site.
- The 300 Area is the former reactor nuclear fuel fabrication and research and development area near the southern Site boundary along the Columbia River.
- The 1100 Area is the site support services area formerly used for equipment storage and maintenance. The waste sites in this NPL (40 CFR 300, Appendix B) site were delisted from the NPL (40 CFR 300, Appendix B) in 1996.

Because of the large number of waste sites, unplanned releases, and extensive groundwater contamination, the 200 Area was further divided into source and groundwater operable units (OUs) for management of the investigation and remediation. The 200 Areas NPL (40 CFR 300, Appendix B) site is in a region referred to as the Central Plateau that includes the 200 West and 200 East Areas (Figures 1-1 and 1-2). The 200-UP-1 OU consists of groundwater under the southern portion of the 200 West Area that is bounded on the eastern side by the 200-PO-1 Groundwater OU and to the north by the 200-ZP-1 Groundwater OU. The 200-UP-1 OU is about 8 km (5 mi) from the Columbia River and 11.3 km (7 mi) from the nearest Site boundary.

The primary waste site types that contributed to groundwater contamination in the OU included ponds, cribs, and trenches that received liquid waste in the past from S Plant and U Plant operations, and unplanned releases from WMA S-SX. This document presents the results of a CERCLA Remedial Investigation (RI)/Feasibility Study (FS) undertaken for the 200 UP-1 OU (Figure 1-1).

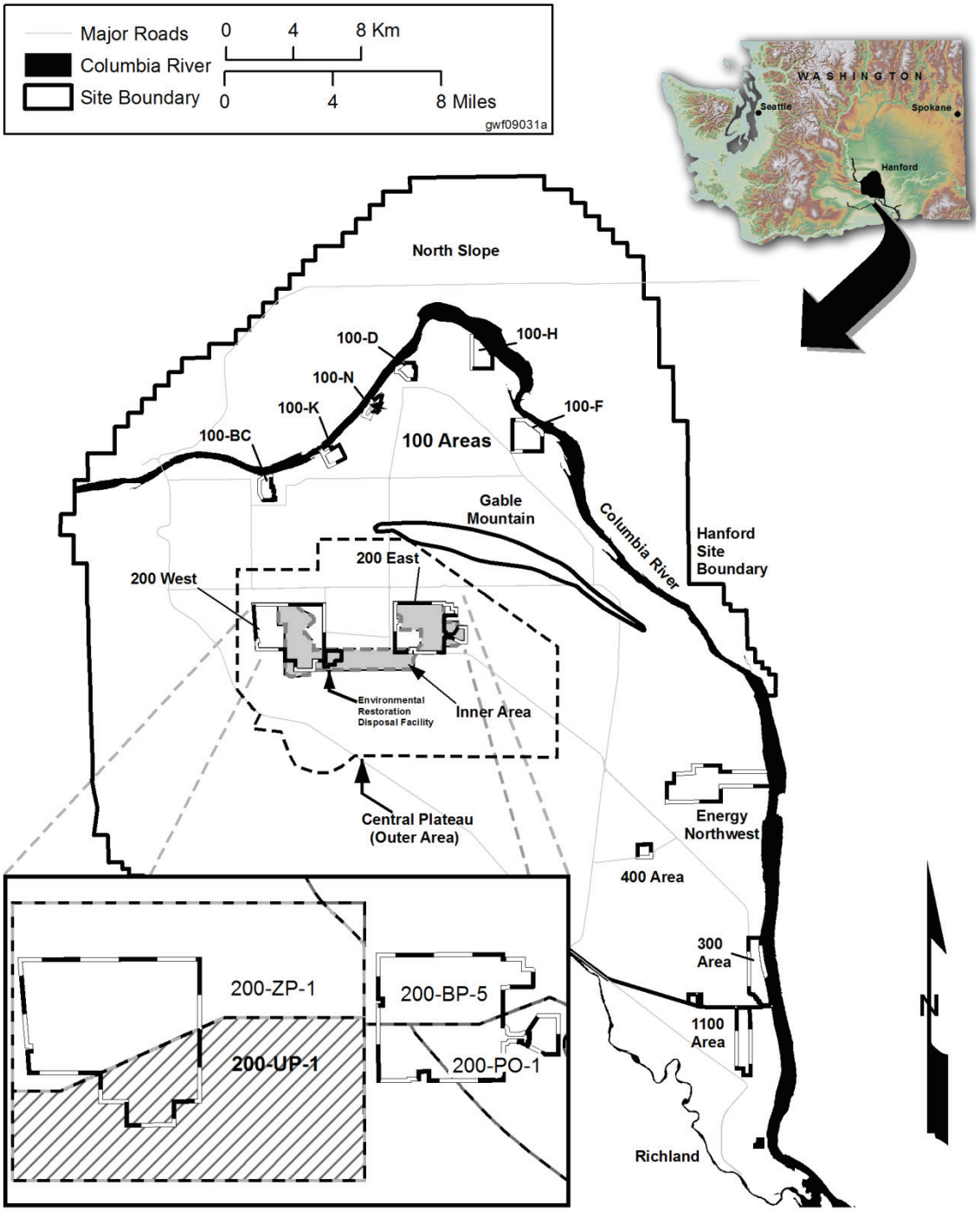


Figure 1-1. Hanford Site Map Illustrating the Location of the 200 West Area and 200-UP-1 OU

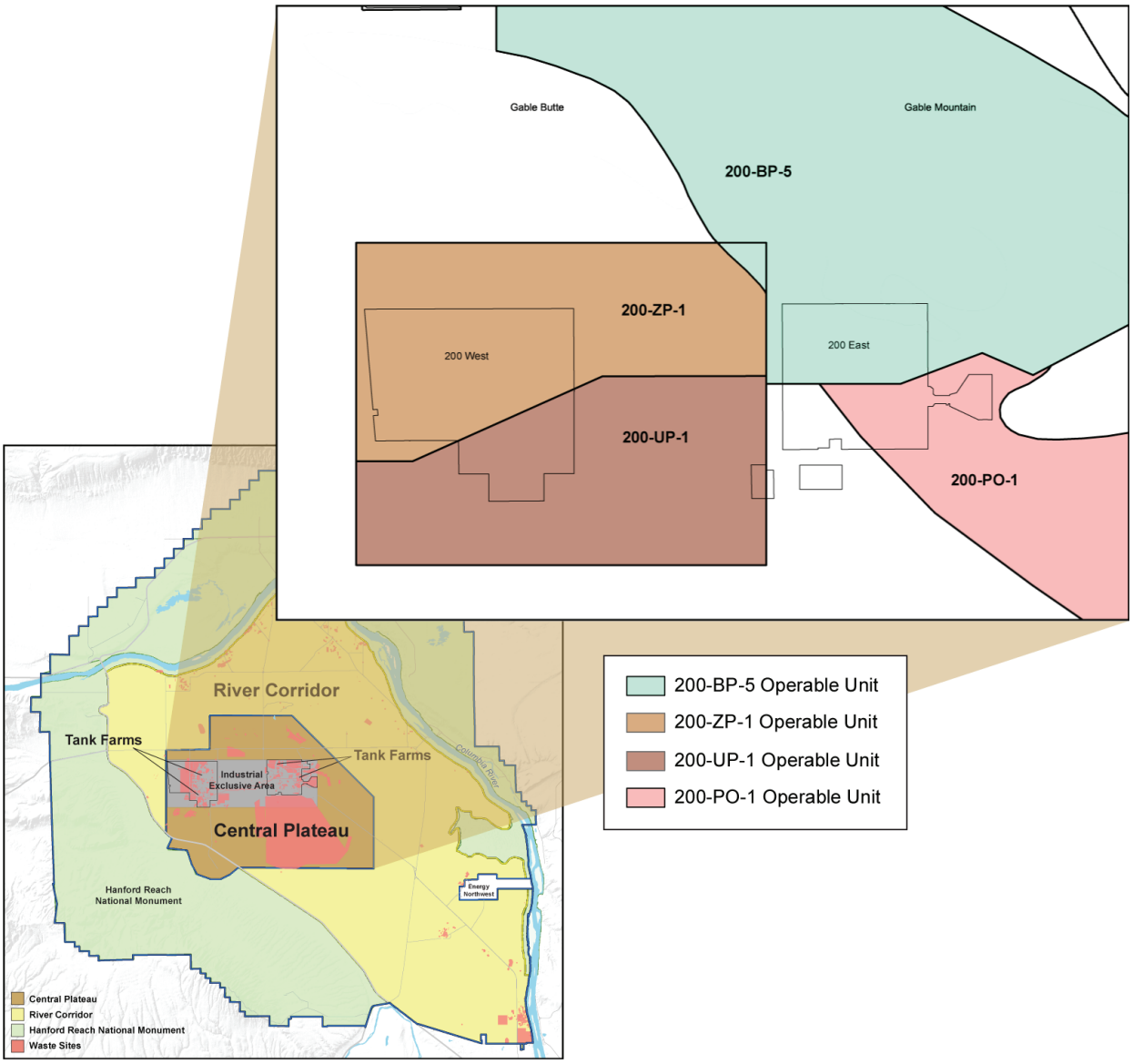


Figure 1-2. Central Plateau Groundwater OUs

1.1 Purpose and Scope of Report

The overall purpose of the RI/FS process is to characterize the nature and extent of groundwater contamination in the OU to assess risks and to evaluate potential remedial alternatives. The RI included activities and field investigations to characterize site conditions, determine the nature and extent of groundwater contamination, and conduct a baseline risk assessment (BRA) to evaluate current and potential risks to human health and the environment in the absence of any remedial action. Field investigation needs required to support the RI were defined in the revised 200-UP-1 RI/FS Work Plan (DOE/RL-92-76, Rev. 1, *Remedial Investigation/Feasibility Study Work Plan for the 200-UP-1 Groundwater Operable Unit*) and associated sampling and analysis plan (SAP), and included the installation of new groundwater wells, groundwater sampling and analyses, and aquifer testing. The results of this RI and associated BRA are described in this report.

The purpose of this FS is to develop and evaluate alternatives for remediation of the 200-UP-1 OU using the results of the RI. The FS is executed in several steps, including developing and screening remedial technologies, assembling appropriate technologies into remedial alternatives, and performing a detailed evaluation and comparison of the alternatives. The alternatives considered provide a range of potential response actions (i.e., no action, institutional controls, natural attenuation, containment and active remediation [pump-and-treat or P&T]) that are appropriate to address 200-UP-1 OU's specific conditions. The alternatives are evaluated against CERCLA evaluation criteria defined in EPA/540/G-89/004 *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final*.

The scope of the RI/FS for the 200-UP-1 OU addresses contaminants in the groundwater. The RI/FS process for the waste sites overlying the OU, including the vadose zone, will be executed under separate remedial actions. A description of other OUs located on Hanford's Central Plateau are outlined in Table 1-1. As acknowledged in DOE documents, *Hanford Site Groundwater Strategy: Protection, Monitoring, and Remediation* (DOE/RL-2002-59), and *Hanford Integrated Groundwater and Vadose Zone Management Plan* (DOE/RL-2007-20), and then reaffirmed in the 200-ZP-1 final ROD (EPA et al., 2008, *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton County, Washington*), the overall goal is to restore groundwater to its beneficial use, unless restoration is determined to be technically impracticable.

1.2 Document Organization

Chapter 1 presents the purpose and scope of the RI/FS, a description of the site background including facilities and waste sites associated with the 200-UP-1 OU, and a summary of interim actions performed in the 200 West Area. The RI is summarized in Chapters 2 through 6 with a description of OU investigations in Chapter 2, and a summary of physical characteristics of the study area in Chapter 3. The nature and extent of groundwater contamination is described in Chapter 4 followed by a discussion of the approach to groundwater fate and transport modeling and the conceptual exposure model in Chapter 5. The BRA is presented in Chapter 6.

The FS is summarized in Chapters 7 through 9. Remedial action objectives (RAOs), general response actions (GRAs) for achieving the RAOs, and applicable or relevant and appropriate requirements (ARARs) are discussed in Chapter 7. Potential remediation technologies and process options associated with each GRA are identified and screened in Chapter 7 to identify viable technologies for the 200-UP-1 OU. In Chapter 8, the viable technologies are assembled into remedial alternatives, which are then screened based on effectiveness, implementability, and cost. As the final step, a detailed and comparative analysis of the remedial alternatives is presented in Chapter 9. References are in Chapter 10.

Table 1-1. OU Designations within the 200 NPL Site (Central Plateau)

OU	Scope/Focus
Groundwater	
200-ZP-1	Contaminated groundwater associated with T Plant and Z Plant wastes and T, TX, and TY WMAs in the 200 West Area.
200-UP-1	Contaminated groundwater associated with S Plant, U Plant, S-SX, SY, and U WMAs.
200-BP-5	Contaminated groundwater associated with B Plant and C Plant and B, BX, BY, and C WMAs.
200-PO-1	Contaminated groundwater associated with PUREX Plant and A, AN, and AX WMAs.
Waste Site	
200-PW-1/3/6 and 200-CW-5	Key plutonium-bearing waste sites in the Inner Area.
200 West Inner Area/200-WA-1	Majority of the waste sites in the 200 West Area.
200 East Inner Area/200-EA-1 and Pipelines/200-IS-1	Majority of the waste sites in the 200 East Area. Includes the majority of pipelines across the Inner Area (200 East and West Areas).
Deep Vadose Zone/200-DV-1	Key waste sites in the Inner Area representing significant deep vadose zone contamination. Many sites are associated with the Central Plateau's tank farms.
Burial Grounds/200-SW-2	The 200 Area Radioactive and Hazardous Waste landfills.
B Plant Canyon and Associated Waste Sites/200-CB-1	One of the four remaining canyon decisions.
PUREX Canyon and Associated Waste Sites/200-CP-1	One of the four remaining canyon decisions.
REDOX Canyon and Associated Waste Sites/200-CR-1	One of the four remaining canyon decisions.
U Canyon/200-CU-1	U Canyon final decision documented in 2005.
Outer Area/200-OA-1, 200-CW-1 and 200-CW-3	All areas of the Central Plateau beyond the Inner Area.

Source: NPL (40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," Appendix B, "National Priorities List").

1.3 Site Background

The following subsections present a discussion of the site background and a description of the facilities and waste sites above the 200-UP-1 OU.

1.3.1 Site Description/Operations

The 200 Area encompasses the 200 West and 200 East Areas, which contain inactive reactor fuel processing and waste management facilities. The 200 West OUs are grouped into four process areas: U Plant, Z Plant, S Plant (Reduction-Oxidation [REDOX] Plant), and T Plant. The 200 West Area encompasses groundwater affected by waste disposal operations at each of the four areas. With the

exception of ERDF most of these facilities and waste sites located above the 200-UP-1 Groundwater OU were associated with operation of U Plant and S Plant(Figure 1-3).

Groundwater in the uppermost-unconfined aquifer of the 200-UP-1 OU flows east toward the western boundary of the 200-PO-1 OU. In the northern portion of the 200 West Area, the unconfined aquifer flows east-northeast toward Gable Mountain and east to the 200-BP-5 OU boundary. Figure 1-4 presents the inferred regional groundwater elevation contours beneath the Hanford Site (PNNL-18427, *Hanford Site Environmental Report for Calendar Year 2008*).

Groundwater contamination in 200-UP-1 occurs predominantly in the upper part of the unconfined aquifer (Ringold unit E), which consists of gravels with intercalated sands and silts. Carbon tetrachloride contamination, generated from operations of the Plutonium Finishing Plant (PFP) and the T Plant to the north in 200-ZP-1, is an exception, with concentrations generally increasing with depth in the eastern part of the 200 West aquifer.

1.4 Waste Sites and Disposal History

The following section presents a discussion of the U Plant and S Plant facilities, the operating history and the related waste disposal practices that have impacted groundwater. Figure 1-5 presents the primary facilities, building and waste sites that overlie the 200-UP-1 OU.

Operations associated with the 200-UP-1 OU involved separation of special nuclear materials from spent nuclear fuel and storage of process liquids and wastes in tanks (WMAs). Spent nuclear fuel is fuel that has been withdrawn from a nuclear reactor following irradiation. The 200-UP-1 OU is also associated with nonradioactive support facilities, including transportation maintenance buildings, service stations, coal-fired powerhouses, steam transmission lines, raw water treatment plants, electrical maintenance facilities, and subsurface sewage disposal systems.

1.4.1 U Plant Source Area

The primary waste generating processes in the area of U plant were associated with the operation of the 221-U Building and its ancillary support facilities. Operations in the 221-U Building complex included uranium reclamation, uranyl nitrate calcination, and decontamination and reclamation of process equipment. Table 1-2 provides a list of radionuclides, organic chemicals, and inorganic chemicals disposed to ground in the U Plant area (DOE/RL-91-52, *U Plant Source Aggregate Area Management Study Report*).

The primary waste-generating facilities and associated processes include the following:

- 221-U Building (U Canyon) (Uranium Recovery Process)
- 224-U Building (UO_3 Conversion Process)
- 276-U Solvent Facility (Solvent Treatment)
- 222-U Laboratory (Analytical Laboratory Programs)

The **221-U Building**, also known as the 221-U Canyon Building or U Plant, was the primary location of the uranium recovery program. The 221-U Building was originally designed as a bismuth phosphate separations facility but was not operated for that purpose because B Plant and T Plant had enough capacity to meet the plutonium production requirements. In 1952, this complex was converted to support the uranium recovery process. The process was designed to use tributyl phosphate, an organic solvent, to extract uranium from waste generated by the bismuth phosphate process.

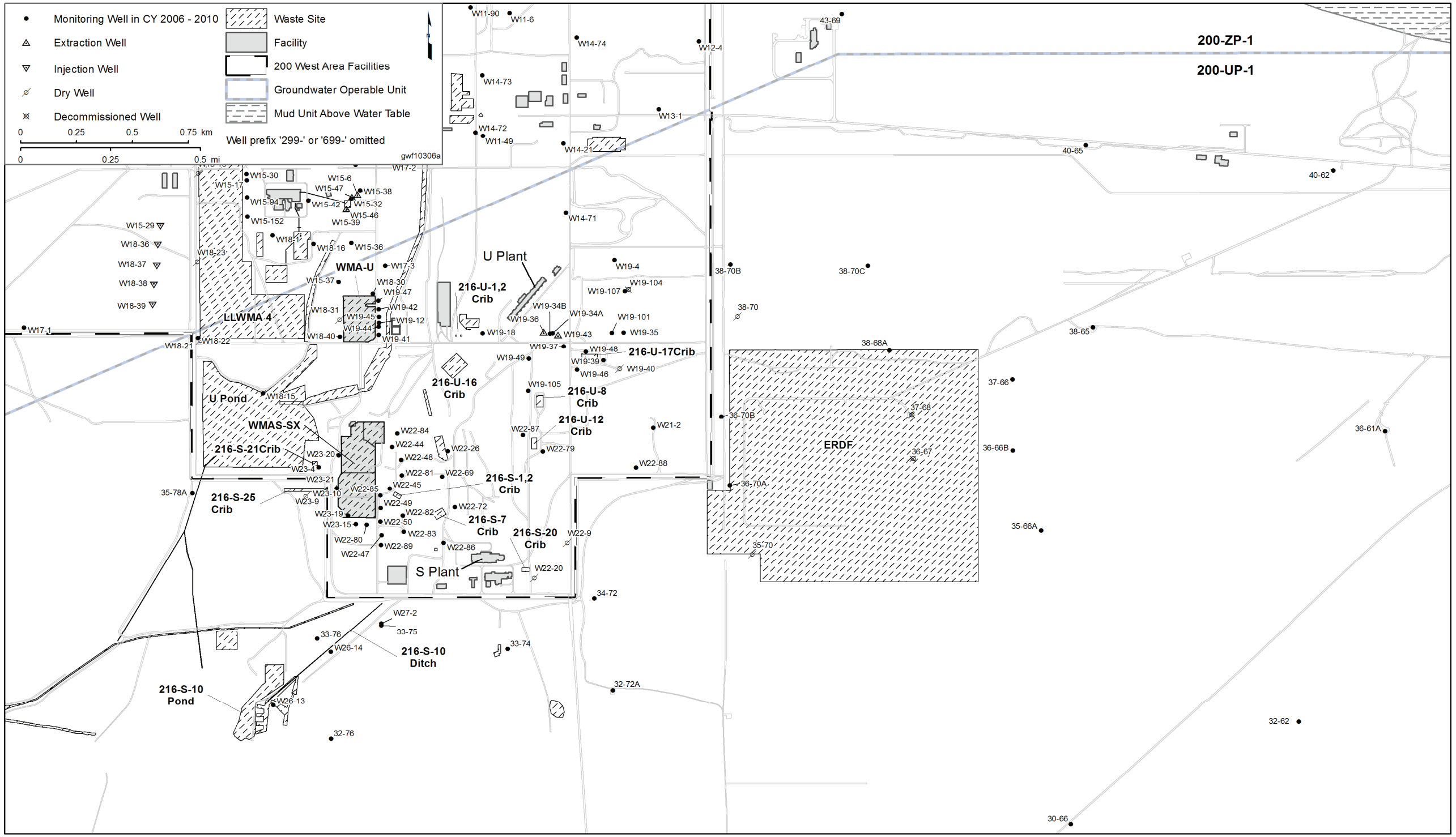
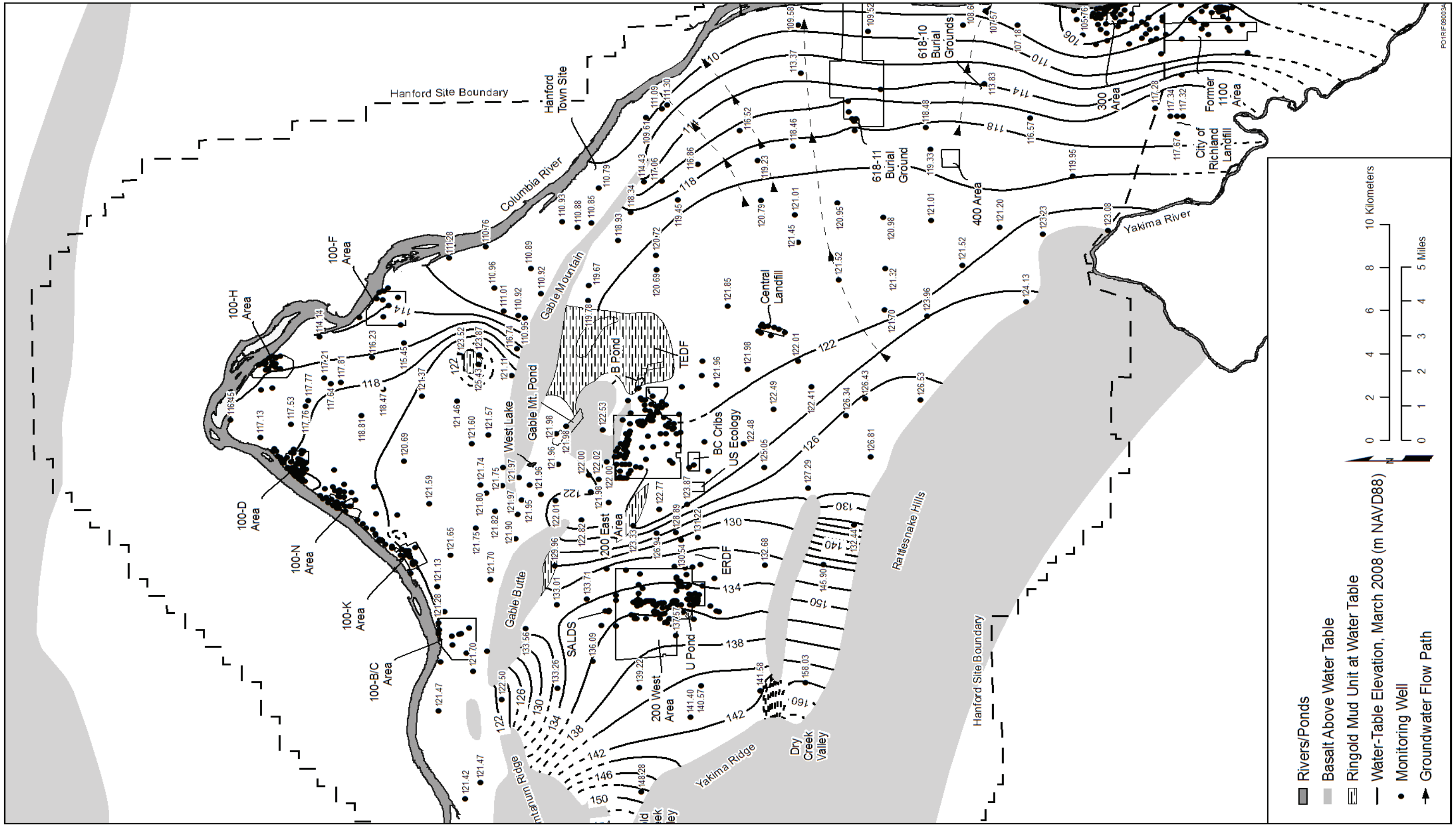


Figure 1-3. Location of RI/FS Monitoring Wells, Overlying Facilities, and Waste Sites Aassociated with the 200-UP-1 OU



Source: PNNL-18427, *Hanford Site Environmental Report for Calendar Year 2008*.

Figure 1-4. Regional Groundwater Elevation Contours beneath the Hanford Site (PNNL-18427)

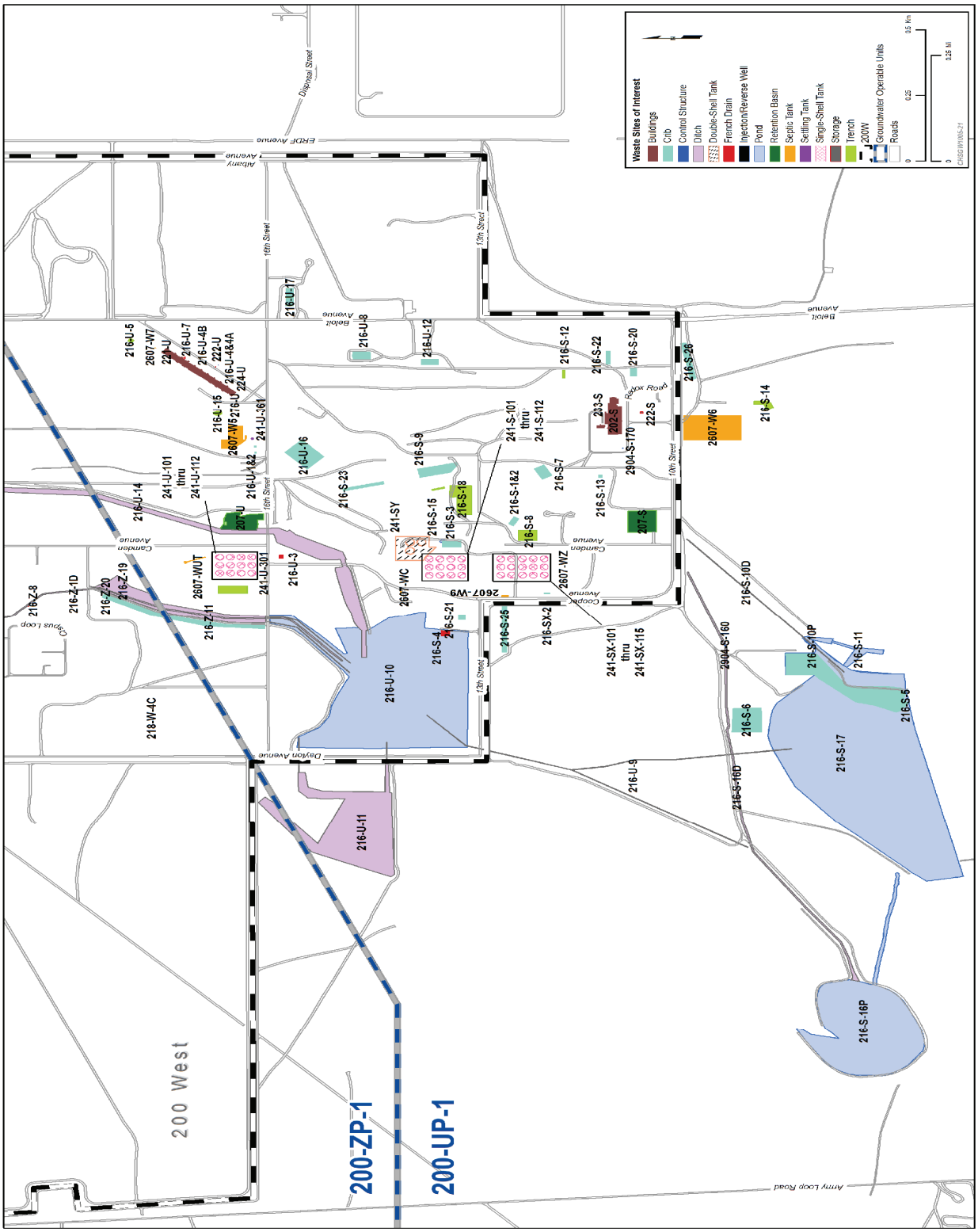


Figure 1-5. Primary 200 West Area Facilities, Building, and Waste Sites Overlying 200-UP-1 OU

Table 1-2. Radionuclides and Chemicals Disposed of into U Plant Aggregate Area Waste Management Units

Radionuclides		
Actinium-225	Actinium-227	Americium-241
Americium-242	Americium-242	Americium-243
Antimony-126	Antimony-126	Astitine-217
Barium-135	Barium-137	Bismuth-210
Bismuth-211	Bismuth-213	Bismuth-214
Carbon-14	Cerium-141	Cerium-144
Cesium-134	Cesium-135	Cesium-137
Cobalt-57	Cobalt-58	Cobalt-60
Curium-242	Curium-244	Curium-245
Europium-152	Europium-154	Europium-155
Francium-221	Francium-223	Iodine-129
Iron-59	Lead-209	Lead-210
Lead-211	Lead-212	Lead-214
Manganese-54	Neptunium-237	Neptunium-239
Nickel-63	Nickel-59	Niobium-93
Niobium-95	Palladium-107	Plutonium-238
Plutonium-239/240	Plutonium-241	Polonium-210
Polonium-213	Polonium-214	Polonium-215
Polonium-218	Potassium-40	Protactinium-231
Protactinium-233	Protactinium-234	Radium
Radium-223	Radium-225	Radium-226
Ruthenium-103	Ruthenium-106	Samarium-151
Selenium-79	Silver-110	Sodium-22
Strontium-85	Strontium-90	Technetium-99
Thallium-207	Thorium-227	Thorium-229
Thorium-230	Thorium-231	Thorium-233
Thorium-234	Tin-126	Tritium
Uranium-233	Uranium-234	Uranium-235
Uranium-238	Yttrium-90	Zinc-65
Zirconium-93	Zirconium-95	

Table 1-2. Radionuclides and Chemicals Disposed of into U Plant Aggregate Area Waste Management Units

Inorganic Chemicals		
Aluminum	Ammonium ion	Ammonium nitrate
Arsenic	Barium	Bismuth
Bismuth phosphate	Boron	Cadmium
Calcium	Carbonate	Cerium
Chloride	Chromium (total and hexavalent)	Copper
Cyanide	Ferric cyanide	Fluoride
Hydroxide	Iron	Lanthanum
Lead	Lithium	Magnesium
Manganese	Mercury	Nickel
Nitrate	Nitric acid	Nitrite
Phosphate	Phosphoric acid	Potassium
Selenium	Silica	Silicon
Silver	Sodium	Sodium hydroxide
Strontium	Sulfamic acid	Sulfate
Sulfuric acid	Thorium	Uranium
Tin	Titanium	Uranium oxide
Uranyl nitrate hexahydrate	Vanadium	Zinc
Zirconium oxide		
Organic Chemicals		
Acetone	Ammonium	Butyl alcohol
Carbon tetrachloride	Chloroform	Citrate
Ethylene diamine tetraacetate	Gylcolate	Kerosene
Methylene chloride	MIBK (Hexone)	N-(2-hydroxyethyl) ethylenediaminetriacetate
Paraffin hydrocarbons	Other degradation products	Oxalate
Toluene	Trichloroethane	Tributyl phosphate

Source: DOE/RL-91-52, *U Plant Source Aggregate Area Management Study Report*.

Bismuth phosphate waste sludge was stored in underground single-shell tanks (SSTs) in the 200 West and 200 East Areas. The sludge was sluiced from the SSTs and transferred to U Plant, where it was dissolved with nitric acid. The uranium in the acidified feed was separated from the bulk of the fission products and small amounts of plutonium in the solvent extraction process. The tributyl phosphate was dissolved in a kerosene diluent, to extract the uranium from the aqueous phase in extraction columns. The aqueous phase waste stream from the solvent extraction process was neutralized with sodium hydroxide and transferred to cribs in the B Plant complex in the 200 East Area. The uranium from the organic phase was

stripped using nitric acid and then concentrated to a uranyl nitrate hexahydrate feed to the 224-U Building.

Within the extraction process, an evaporator condensate stream containing radioactive and chemical contaminants was generated in the evaporators that concentrated process liquids. A gas stream containing radioactive and chemical contaminants was also generated in the evaporation process and the vessel vent system. The steam condensate and cooling produced from heating and cooling process equipment and tanks were generally uncontaminated.

Spills of process liquids within the building created additional wastes. Sumps collected spilled liquids and discharged the materials to cribs. Process wastes were discharged to the 216-U-1 Crib, 216-U-2 Crib, 216-U-7 French Drain, 216-U-8 Crib, 216-U-10 Pond, 216-U-14 Ditch, and the 216-U-16 Crib.

The **224-U Building** (UO_3 Plant) is immediately southeast of the 221-U Building and consists of several buildings, tank farms, storage areas, and loading facilities. The building was constructed in 1944 to concentrate plutonium-bearing product solutions for plutonium processing but was not used for that purpose. It was operated as a training facility from 1944 to 1950 and was converted in 1952 to a uranium reduction facility. It was converted again in 1955 in support of the Plutonium-Uranium Extraction (PUREX) Plant.

The PUREX waste (uranyl nitrate hexahydrate) was transferred to 224-U Building by tanker truck, where it was converted to powdered UO_3. The building produced process condensate waste from the concentration and calcination of uranyl nitrate hexahydrate. The UO_3 Plant process condensate was a highly acidic waste containing high concentrations of uranium, nitrate, and Technetium-99 (Tc-99).The process condensate stream was mixed with other liquids from sumps and rainwater collected in radiation areas. After 1980, DOE required neutralization of the UO_3 Plant process condensate before disposal. Phosphoric acid and potassium hydroxide were used as buffering and neutralizing agents.

After 1955, the UO_3 Plant wastewater was discharged to the 216-U-10 Pond through the 216-U-14 Ditch and 216-U-1, 216-U-2, 216-U-8, 216-U-12, 216-U-16, and 216-U-17 Cribs. Noncorrosive steam condensate from the building heating systems, process equipment, condensers (cooling water), and rain water from the nonradiation areas was sent through the 207-U Retention Basin to the 216-U-14 Ditch.

The **276-U Solvent Facility** treated used organic solvent from the uranium extraction processes at the 221-U Building. The solvent (particularly tributyl phosphate) was treated and cleaned by a carbonate scrub process and returned to the 221-U Building. A carbonate scrub solution waste was generated that contained sludge materials cleaned from the solvents and discharged to cribs. Other spent solvents were also a part of this waste stream and were disposed of in the 216-U-15 trench.

The **222-U Laboratory**, directly southeast of the 221-U Building, was used from about 1947 to 1970 for laboratory analysis in support of the uranium recovery process and the UO_3 process. This facility disposed of various laboratory liquid wastes into the 216-U-4 Reverse Well, 216-U-4A French Drain, and 216-U-4B French Drain.

1.4.1.1 Tanks

Sixteen SSTs were used in the U Plant Area, all of which were contained in the 241-U Tank Farm WMA. Of these tanks, 12 had a 2,014,700 L (533,000 gal) capacity, and 4 had a 208,000 L (55,000 gal) capacity. Several of these tanks have leaked and are a source of groundwater contamination.

Settling Tank 241-U-361 settled liquid wastes en route to the 216-U-1 and 216-U-2 Cribs (1951 through 1967). The wastes included cell drainage from the 221-U Building, waste from the UO_3 Plant,

contaminated solvent from the 276-U Settling Tank, and decontamination and reclamation wastes from the 221-U Building. Approximately 4,000 kg (8,900 lb) of uranium was discharged to this tank.

1.4.1.2 Cribs, French Drains, and Reverse Wells

Cribs, French drains, and reverse wells were designed to dispose of wastewater into the ground without exposure to the open air. More information about how cribs, French drains, and reverse wells functioned at the Site follows:

- Cribs are shallow excavations that are backfilled with permeable material or held open by wood structures. Both types of cribs were covered at ground level with an impermeable material. Water flowed directly into the backfilled material or open space and percolated into the vadose zone soils.
- French drains were generally constructed of steel or concrete pipe and were open or filled with gravel.
- Reverse wells were vertically drilled columns designed to inject water into the ground at depth.

Full descriptions of the various crib, drain, and reverse well construction details can be found in DOE/RL-91-52 and DOE/RL-91-60, *S Plant Aggregate Area Management Study Report*. The cribs, drains, and reverse wells received radioactive liquids until the specific retention or radionuclide capacity of the unit was met. The following subsections describe the major waste units associated with U Plant operations.

1.4.1.3 Cribs

The **216-U-1** and **216-U-2 Cribs** are north of 16th Street and east of the 207-U Retention Basin. Wastes flowed to these cribs from the 241-U-361 Settling Tank. The cribs operated from 1951 until 1967, and 4,040 kg (8,890 lb) of uranium was reportedly discharged there between 1957 and 1967. The uranium reacted with the sediments to form carbonate-phosphate compounds. After 1967, other cribs (notably 216-U-12) were used to dispose of this wastewater. In 1984, a newer crib (216-U-16*)* was installed south of the 216-U-1/U-2 Cribs. By 1985, liquid discharges to the 216-U-16 Crib formed a perched groundwater zone above a caliche layer. The perched groundwater moved north under the 216-U-1 and 216-U-2 Cribs. Acid wastes discharged to the cribs reacted with the uranium complexes to form compounds that are soluble and relatively nonsorbing on sediments. The uranium was transported through the caliche layer to the aquifer.

The **216-U-8 Crib** is west of Beloit Avenue and south of 16th Street. The crib operated from 1952 until 1960, receiving approximately 378,000,000 L (100,000,000 gal) of acidic process condensate from the 221-U and 224-U Buildings and the 291-U Stack Drainage System. In 1960, the surface above the 216-U-8 Crib began to subside. In response to this, the incoming line was blanked off and waste was diverted to the 216-U-12 Crib. The 216-U-8 Crib reportedly holds the largest inventory of waste uranium of any 200 West Area crib.

The **216-U-12 Crib** is southwest of the intersection of Beloit Avenue and 16th Street. It operated from 1960 to 1988, and was taken out of service once the crib began to subside. The 216-U-12 Crib reportedly received 150,000,000 L (40,000,000 gal) of liquid waste. Drainage was received from the 291-U Stack Drainage System, from the acidic (pH 1) UO_3 Process Condensate System, from the C-5 and C-7 tanks, and storm drain wastes from the 224-U Building. The crib was removed from service as the 216-U-17 Crib was placed into service.

The **216-U-16 Crib** is south of 16th Street and midway between Beloit Avenue and Cooper Avenue. The 216-U-16 Crib is a large, gravel filled, drain field crib that operated from 1984 until 1987, receiving

a combined 409,000,000 L (108,201,000 gal) of UO_3 laboratory, process condensate, 271-U Compressor cooling water, 221-U Building chemical sewer waste, 224-U Building process condensate, and chemical sewer waste. By 1985, enough liquid waste had been discharged to the crib to create a perched groundwater zone that moved north below the 216-U-1 and 216-U-2 Cribs and mobilized uranium to the groundwater. The 216-U-15 Trench received miscellaneous liquid waste and waste from the treatment of spent solvents from the 276-U Solvent Facility. The re-conditioned solvent was then returned to U Plant for reuse.

The **216-U-17 Crib** was constructed in 1988 to replace the 216-U-12 Crib, which had received its maximum-allowed inventory of radioactive wastes. A total of 2,110,000 L (558,200 gal) of 224-U Building process condensate was discharged to this crib. A neutralization system maintained the pH within a range of 2.0 to 12.5. In 1995, disposal to the crib ceased.

1.4.1.4 French Drains

The **216-U-3 French Drain** is south of the 241-U Tank Farm, and operated from 1954 until 1955, receiving approximately 791,000 L (209,000 gal) of low-salt, neutral basic condensate from the 241-U Tank Farm.

The **216-U-4A French Drain** received 222-U Laboratory hood sink wastes after the 216-U-4 Reverse Well began to plug in 1955. From 1955 to 1970, the drain received 545,000 L (144,000 gal) of acidic plutonium and fission product decontamination waste.

The **216-U-4B French Drain** is south of the 222-U Laboratory and received hot cell and hood liquid waste from the 222-U Laboratory. It operated from 1960 to 1968, receiving approximately 33,000 L (8,700 gal) of low-salt, neutral basic lab waste.

The **216-U-7 French Drain** was connected to the U Plant counting box and is south of the 221-U Building. From 1952 to 1957, the drain received liquid wastes from a counting box floor drain during the metal recovery program at the 221-U Building, with about 140 kg (300 lb) of uranium introduced in the form of uranyl nitrate hexahydrate. The uranyl nitrate hexahydrate introduced to the drain was identified as an unplanned release.

1.4.1.5 Reverse Wells

The **216-U-4 Reverse Well** was the only reverse well in the U Plant Area and is northwest of the western corner of the 222-U Laboratory Building. It was a State of Washington registered underground injection well that operated from 1947 to 1955, receiving 302,400 L (80,000 gal) of decontamination waste from laboratory hood sinks (acidic plutonium and fission product waste). In 1955, the well was deactivated.

1.4.1.6 Ponds, Ditches, Trenches and Basins

The ponds, ditches, trenches and basins were designed to percolate large volumes of wastewater into the ground. Until its closure in 1985, the 216-U-10 Pond was at the center of this disposal system and was fed by ditches that originated at the various waste-generation facilities.

1.4.1.7 Ponds

The **216-U-10 Pond System** was constructed in 1944 to receive radioactive liquid effluent from PFP. The pond system was active until 1985 and received 1.62×10^{11} L (4.3×10^{10} gal) of contaminated liquid. The system received powerhouse cooling water, steam condensate wastewater laundry wastes, chemical sewer wastes, laboratory wastes, tank condenser water, and Pacific Northwest National Laboratory (PNNL) operations waste (231-Z Laboratory and 242-S Evaporator steam condensate). The large volumes of radioactive wastewater resulted in the accumulation of transuranic waste, fission products, and

activation product inventories, estimated to include 8.2 kg (18 lb) of plutonium, 1,500 kg (3,300 lb) of uranium, 15.3 Ci of cesium-137 (Cs-137), and 22.6 Ci of strontium-90 (Sr-90).

1.4.1.8 Ditches

The **216-U-14 Ditch** began operation in 1944 and was an open ditch running from northeast to southwest across about 1.6 km (1 mi) of the 200 West Area. It originated north of U Plant and terminated at the 216-U-10 Pond. The ditch was originally known as the laundry ditch because it received wastewaters from the 2724-W Laundry Building. It also received other waste types that included: cooling water, wastewater, chemical sewer liquids, and evaporator condensate. Reportedly, 567,000 L (150,000 gal) of wastewater per day was discharged to this ditch. In 1986, approximately 3,000 L (800 gal) of 50 percent reprocessed nitric acid was released to the ditch. The total release to the ditch was about 102,058 kg (225,000 lb) of corrosive solution (pH less than 2.0) and 45.36 kg (100 lb) of uranium. In 1992, a portion of the ditch was stabilized in response to TPA Milestone 17-17B (Ecology et al., 1989).

1.4.1.9 Trenches

The **216-U-11 Trench** was west of the 216-U-10 Pond. It was active from 1944 to 1957 and received overflow from the pond. The site contains less than 0.1 Ci beta activity. The site has been covered with soil and seeded. Aliases for this site are U Swamp Extension Ditch, U-12, U-11 Ditch, U-11 Old Ditch, and U-11 New Ditch.

The **216-U-15 Trench** was first used in May 1957 and backfilled almost immediately after receiving wastes. This trench is north of 16th Street and west of the 271-U Building. The trench was opened to receive about 26,500 L (7,000 gal) of interface waste, activated charcoal, and diatomaceous earth containing about 1 Ci of fission products from 338-U Tank in the 276-U Solvent Storage Area. While the information for this trench varies, it is reported that 40,000 kg (88,000 lb) of hexone, 13,000 kg (29,000 lb) of tributyl phosphate, and possibly paraffin hydrocarbons were disposed of.

1.4.1.10 Retention Basin

The **207-U Retention Basin** is the only basin within the U Plant Area. This retention basin consisted of two concrete-lined, open settling ponds where wastewater was held before overflowing into a ditch. The basin was placed in service in 1952, receiving steam condensate and cooling water from the UO_3 Plant and chemical sewer waste from the 221-U Building. After 1972, the basin received only cooling water from the 224-U Building.

1.4.2 S Plant Source Area

The primary waste-generating processes in the S Plant Area were associated with the operation of the S Plant (202-S REDOX Plant). The S Plant was built around 1950 and was shut down in 1967. The first process to recover plutonium and uranium from fission products occurred at the S Plant. It was built to improve the plutonium and uranium recovery process from the initial bismuth phosphate plutonium separations process. The new process used a continuously operating solvent extraction process (hexone) to extract plutonium and uranium from acidic, fission-product-rich solutions in which the fuel rods had been dissolved. The volumes of concentrated fission-product-rich solutions were much smaller than the solutions produced by the bismuth phosphate process, thereby reducing the volume sent to SSTs. Radioactive decay occurring in these wastes caused self-heating and caused some of these wastes to boil. The high-heat sludges created wastes known as self-boiling wastes.

The 202-S Building and the 222-S Laboratory generated significant wastes and, depending on the type of wastes, the liquids were discharged to 1 of 26 ponds, cribs, ditches, French drains, or trenches. Open-air ponds and ditches received the highest volumes of generally nonradioactive contact cooling water and

steam condensates from the major 202-S process vessels used to heat and cool chemical solutions. More radioactive (and chemical-rich), but less voluminous quantities of condensed process vapors and cell drainage were sent to cribs. The nonradioactive, low-volume chemical sewer wastes were generally sent to ponds and ditches. Very low-volume radioactive waste streams were sent to the French drains. Building septic systems used tile drain fields to dispose of nonradioactive wastes.

Table 1-3 provides a list of radionuclides, organic chemicals, and inorganic chemicals disposed of in the S Plant Source area (DOE/RL-91-60). The following subsections discuss the details of the chemicals and materials used and the related major waste disposal locations for the S Plant.

1.4.2.1 Tanks

Several types of tanks were used including 4 catch tanks, 27 SSTs, 3 double shell tanks (DSTs), and 1 receiver tank. Catch tanks were associated with diversion boxes and other transfer units, and were designed to accept overflows and spills. The receiver tank (frequently called a double-contained receiver tank or vault) received waste from SSTs; SSTs were used to collect and store large quantities of mixed wastes. DSTs also were used to store large quantities of mixed wastes.

Of the 27 SSTs, 12 are contained within the 241-S Tank Farm and 15 are contained within the 241-SX Tank Farm. The three DSTs are in the 241-SY Tank Farm. The 241-S Tank Farm is northeast of the Cooper Avenue and 13th Street intersection. The 241-S and 241-SX Tank Farms were constructed from 1950 to 1951 and 1953 to 1954, respectively. The tank designs were very similar in both tank farms with the tanks being vertical cylinders with domed tops, and constructed of reinforced concrete with a carbon steel liner on the base and sides. The tanks are all underground. The 12 tanks in the 241-S Tank Farm are numbered 241-S-101 through 241-S-112, and the 15 tanks in the 241-SX Tank Farm are numbered 241-SX-101 through 241-SX-115. The 241-S Tanks and 241-SX Tanks have a capacity of 3,785,412 L (1,000,000 gal) each.

SSTs in the S and SX Tank Farm WMAs are known contributors to groundwater contamination. The high-heat sludges from the REDOX process created self-boiling conditions in a number of S and SX Tank Farm SSTs. These high temperatures caused the tanks to become susceptible to stress corrosion cracking that attacked the welds in the tanks' walls and bottoms.

The DSTs in the 241-SY Tank Farm were constructed from 1974 to 1976. The tanks were designed as vertical cylinders with an inner primary tank, an outer secondary tank surrounded by a steel-reinforced concrete shell, and a steel-reinforced domed top. The three tanks in the 241-SY Tank Farm are numbered 241-SY-101 through 241-SY-103, with a capacity of 3,785,412 L (1,000,000 gal) each. These tanks have not leaked.

1.4.2.2 Cribs and French Drains

The following subsection presents information on the cribs and French drains in the area that are thought to be the major contributors to groundwater contamination in the southern portion of the OU. Similar to the cribs described previously for U Plant, the S Plant cribs are shallow excavations that are backfilled with permeable material or held open by wooden structures. Both types of cribs are covered with an impermeable layer at the surface. Wastewater flowed directly into the crib and percolated into the vadose zone soils. French drains were generally constructed of steel or concrete pipe and were open or filled with gravel. The S Plant Area contained 12 cribs and 2 French drains. The cribs and drain received radioactive waste and were designed to receive liquid until the unit's specific retention or radionuclide capacity was met.

Table 1-3. Radionuclides and Chemicals Disposed of in the S Plant Aggregate Area Waste Management Units

Radionuclides		
Aluminum-28	Americium-241	Antimony-122
Antimony-124	Antimony-125	Antimony-126
Barium-133	Barium-137	Beryllium-7
Beryllium-10	Cadmium-109	Calcium-45
Carbon-14	Cerium-141	Cesium-134
Cesium-137	Chlorine-36	Chromium-51
Cobalt-57	Cobalt-58	Cobalt-60
Curium-243	Einsteinium-254	Europium-152
Europium-154	Europium-155	Gadolinium-153
Germanium-68	Iodine-123	Iodine-125
Iodine-129	Iron-55	Iron-59
Krypton-85	Lead-214	Manganese-54
Lead-212	Niobium-93m	Niobium-94
Molybdenum-93	Nickel-59	Nickel-63
Niobium-95	Phosphorus-32	Plutonium-238
Plutonium-239	Plutonium-241	Potassium-40
Plutonium-240	Polonium-210	Proactinium-231
Promethium-147	Radium-228	Rhenium-187
Rhodium-106	Rubidium-86	Ruthenium-103
Ruthenium-103	Scandium-46	Selenium-75
Silver-108	Silver-110	Sodium-22
Strontium-82	Strontium-90	Sulfur-35
Tantalum-182	Technetium-99	Tellurium-121
Tellurium-125m	Tellurium-127	Tellurium-129
Thallium-204	Thullium-170	Tin-121
Tin-123m	Tritium	Uranium-234
Uranium-235	Uranium-236	Uranium-238
Vanadium-49	Yttrium-87	Yttrium-88
Zinc	Zinc-65	Zirconium-95

Table 1-3. Radionuclides and Chemicals Disposed of in the S Plant Aggregate Area Waste Management Units

Inorganic Chemicals		
Aluminum	Aluminum nitrate	Aluminum oxide
Ammonia	Ammonium fluoride	Ammonium hydroxide
Ammonium nitrate	Ammonium oxalate	Boric acid
Boron	Cadmium	Ceric ammonium nitrate
Ceric sulfate	Chromic nitrate	Copper
Ferrous ammonium sulfate	Ferrous sulfamate	Ferrous sulfate
Hydrazine	Hydrochloride	Hydrochloric acid
Hydrofluoric acid	Hydrogen	Hydroxylamine
Iron	Lead nitrate	Manganese dioxide
Magnesium	Mercuric nitrate	Mercuric thiocyanate
Mercury	Nitric acid	Nitric oxide
Nitrogen dioxide	Oxalic acid	Periodic acid
Potassium dichromate	Potassium fluoride	Potassium oxalate
Potassium permanganate	Silicon	Silicon dioxide
Silver nitrate	Sodium aluminate	Sodium bismuthate
Sodium carbonate	Sodium dichromate	Sodium fluoride
Sodium hydroxide	Sodium metasilicate	Sodium nitrate
Sodium nitrite	Sulfamic acid	Tetrabromoethane
Tin	Titanium chloride	Xenon
Zinc		
Organic Chemicals		
Acetone	Bromonapthalene	Di-2-ethyl hexyl phosphoric acid
Hydroxyquinoline	Methyl isobutyl carbinal	Methyl isopropyl di-ketone
Mineral oil	Normal paraffin hydrocarbon	O-phenanthroline
Propane	S-diphenyl carbazide	Tetraphenyl boron
Thenoyltrifluoroacetone	Tributyl phosphate	Tri-iso-octylamine
Tri-n-octylamine	Xylene	

Source: DOE/RL-91-60, *S Plant Aggregate Area Management Study Report*.

1.4.2.3 Cribs

The **216-S-1** and **216-S-2 Cribs** are located west of WMA S-SX and northwest of the 202-S Building. These cribs were in service from 1952 to 1956 and received approximately 1.6×10^8 L (4.2×10^7 gal) of cell drainage waste from the D-1 Receiver Tank and redistilled condensate from the D-2 Receiver Tank in the 202-S Building. These radioactive process condensate wastes were acidic and contained high concentrations of volatile radionuclides including tritium and iodine-129 (I-129).

The **216-S-5 Crib** is southwest of the 207-S Retention Basin and west of the 216-S-10D Ditch. The crib operated from 1954 to 1957 and was built as a replacement for the contaminated 216-S-17 Pond. The crib received 4.1×10^9 L (1.1×10^9 gal) of acidic process vessel cooling water and steam condensate from the 202-S Building. The unit was deactivated because of insufficient capacity and a series of vessel coil failures, which resulted in operational problems and surface contamination.

The **216-S-6 Crib** is southwest of the 202-S Building and southwest of the 200 West Area perimeter fence. The crib started receiving waste in 1954 and stopped in 1972. The crib received 4.47×10^9 L (1.18×10^9 gal) of low-salt, neutral basic liquid waste. Until 1967, the crib received process vessel cooling water and steam condensate from the 202-S Building. After 1967, it received steam condensate from the D-12 and D-14 waste concentrators in the 202-S Building.

The **216-S-7 Crib** is northwest of S Plant. The crib began operating in 1956 as the replacement for the 216-S-1 and 216-S-2 Cribs and was retired in 1965. Until 1959, the crib received cell drainage from the D-1 Receiver Tank, process condensate from the D-2 Receiver Tank, and condensate from the H-6 Condenser. The crib received 3.9×10^8 L (1.0×10^8 gal) of waste. The crib was retired in July 1965.

The **216-S-9 Crib** is east of the 241-S and 241-SY Tank Farms. The crib operated from 1965 to 1969, as the replacement for the 216-S-7 Crib, receiving 5.03×10^7 L (1.33×10^7 gal) of process condensate from the D-2 Receiver Tank. The waste was primarily composed of nitric acid and contained high levels of tritium and I-129.

The **216-S-13 Crib** is west of the 202-S Building and north of 10th Street. The crib was built in 1952 and stopped receiving waste in 1972. Until 1967, it received liquid waste from the 203-S Decontaminated Metal Storage Facility, the 204-S Uranyl Nitrate Hexahydrate Facility, and the 276-S Organic Solvent Make-up Facility. After 1967, the crib received occasional sump waste from the 204-S Uranyl Nitrate Hexahydrate Facility. The unit received 5.0×10^6 L (1.3×10^6 gal) of low- salt, neutral basic waste, mainly composed of nitrate, sodium, and sodium dichromate.

The **216-S-20 Crib** is southeast of the 202-S Building and north of 10th Street. The crib operated from 1952 until 1973, receiving 1.35×10^8 L (3.57×10^7 gal) of waste. Until 1953, the crib received miscellaneous waste from laboratory hoods and decontamination sinks in S Plant via the 219-S Waste Handling Facility. From 1963 to 1969, the crib received miscellaneous waste from laboratory hoods and decontamination sinks in the 222-S Laboratory via the 219-S Waste Handling Facility. After 1969, 300 Area laboratory wastes were rerouted to the 216-T-28 Crib.

The **216-S-21 Crib** is southeast of the 216-U-10 Pond, north of 13th Street, and west of the 241-S Tank Farm. From 1954 to 1969, the crib received 241-SX Tank Farm condensate generated from self-boiling waste and from waste collected in the condensers in the 401-SX Condenser Facility. The unit was retired in 1969, after receiving 8.7×10^7 L (2.3×10^7 gal) of low-salt, neutral basic liquid waste. The chemicals disposed of were sodium and ammonium nitrate.

The **216-S-25 Crib** is northwest of the 202-S Building outside the 200 West Area perimeter fence, south and east of the 216-U-10 Pond. The unit began operation in 1973 and received 242-S Evaporator process

steam condensate through 1980. From 1980 until 1984, the crib received 3.0×10^8 L (8.0×10^7 gal) of cooling water from the 241-SX Tank Farm. In 1985, the crib was reactivated to receive treated groundwater from the 1985 216-U-1 and 216-U-2 groundwater remediation system.

The **216-S-26 Crib** is southeast of the 222-S Laboratory outside the 200 West Area perimeter fence. It operated from 1984 to 1988 and received 1.64×10^8 L (4.02×10^7 gal) of steam condensate, equipment cooling water, and sink wastes. The wastes contained a variety of chemicals including acetone, nitrate, nitric acid, and lesser amounts of sulfuric and hydrofluoric acids. The crib also received three or more 4,200 L (1,100 gal) tanker discharges of PFP caustic flush water with a pH of 12.5, which retarded percolation of the fluids into the ground and prevented the crib from ever recovering to normal flows.

1.4.2.4 French Drains

The **216-S-3 French Drain** is along the eastern border of the 241-S Tank Farm, east of the 241-S-104 SST. This drain operated from 1953 to 1956 and received 4.2×10^6 L (1.06×10^6 gal) of condensate from the 241-S-101 and 241-S-104 Storage Tanks in the 241-S Tank Farm. The waste solution was low-salt, neutral basic liquids.

The **216-S-4 French Drain** was active from 1953 to 1956 and received 1,000,000 L (264,000 gal) of waste from the condensers on the 241-S-101 and 241-S-104 Tanks. This drain is north of 13th Street, between the 241-S Tank Farm and the 216-U-10 Pond.

1.4.2.5 Ponds, Ditches, Trenches, and Basins

Generally, low level radioactive waste was disposed of into the ponds. Ponds typically have natural or diked surface depressions used for disposal of high volume, low-concentration liquid effluent and designed to promote percolation of the liquid effluent. As the liquid infiltrated into the ground, the radionuclides were absorbed and concentrated by the upper soil layer. The major sites are presented in the following subsections.

1.4.2.6 Ponds

The **216-S-10P Pond** is southwest of the 202-S Building and covers approximately 20,300 m^2 (218,000 ft^2). The pond was designed to percolate approximately 567,000 L/day (150,000 gal/day) of liquid waste. The pond operated from 1954 to 1984 and received approximately 4.12×10^9 L (1.07×10^9 gal) of discharge. Until 1965, the pond received the chemical sewer waste from the S Plant Complex and overflow from the high water tower. The pond was stabilized in 1984.

The **216-S-11 Pond** is southwest of the 202-S Building and covers approximately 6,070 m^2 (65,300 ft^2). The pond began operation in 1954 and closed in 1965. The pond received waste from air conditioning drains and chemical sewers from the 202-S Building. In 1965, the 216-S-10D Ditch was dammed, diverting all building effluent to the 216-S-10P Pond. A total of 2.23×10^9 L (5.89×10^8 gal) of liquid waste was discharged to this unit. The pond was covered in 1975.

The **216-S-15 Pond** is directly east of the 241-S Tank Farm. The pond was built in 1951 and retired in 1952. The pond received 10,000 L (2,600 gal) of condenser spray cooling water from the 241-S-110 SST. The waste was low-salt, neutral basic and was mainly composed of nitrate and methyl isobutyl ketone.

The **216-S-16P Pond** is southwest of the 202-S Building. The total unit area is approximately 125,400 m^2 (1,350,000 ft^2) and operated from 1957 to 1975, receiving approximately 4.07×10^{10} L (1.08×10^{10} gal) of liquid waste. Until 1967, the pond received process cooling water and steam condensate from the S Plant Complex. After 1967, the pond received condenser and vessel cooling water from the concentrator boil-down operations in the 202-S Building.

The **216-S-17 Pond** is southwest of the 202-S Building. The pond has a total area of approximately 85,000 m^2 (920,000 ft^2). The pond operated from 1951 to 1954, receiving approximately 6.44×10^9 L (1.7×10^9 gal) of liquid waste. Until 1953, it received process cooling water and steam condensate from the S Plant Complex. After 1953, it received 202-S Building effluent and the overflow from 216-U-10 Pond. A series of process vessel coil failures beginning in 1952 resulted in the release of high levels of radioactivity to the 207-S Retention Basin and subsequently to the 216-S-17 Pond. This pond has been stabilized.

1.4.2.7 Ditches

Ditches were long, open, unlined excavations used to transfer low concentrations of radioactive liquid wastes from process facilities to ponds. Two ditches in the S Plant Area are discussed as follows:

The **216-S-10D Ditch** is southwest of the 202-S Building. The ditch operated from 1951 to 1991 and received and transferred 4.3×10^8 L (1.16×10^8 gal) of liquid waste. Discharges were received from the 202-S Building, 241-S Tank Farm, 211-S Valve House, 276-S Solvent Handling Facility, and 2901-S-901 Water Tower.

The **216-S-16D Ditch** is southwest of the 202-S Building. The ditch operated from 1957 to 1975. A total of 4.07×10^8 L (1.1×10^8 gal) of liquid waste was discharged to this unit, including process cooling water and steam condensate from S Plant.

1.4.2.8 Trenches

Trenches are unlined excavations used for disposing of process waste into the subsurface by infiltration. Quantities disposed of into trenches were limited compared to quantities disposed of into cribs or ponds. All of the trenches have now been backfilled.

1.4.2.9 Retention Basins

Retention basins were used for intermittent storage of liquid waste before it was transferred to ponds, ditches, or cribs.

The **207-S Retention Basin**, also referred to as the 202-S Building Retention Basin, is a concrete structure with a volume of 3,220,000 L (850,000 gal). The basin received low level radioactive liquid wastes, such as process cooling water and steam condensate from the 202-S Building, from 1951 through 1954.

1.5 Previous Investigations and Actions

In 1995, the Tri-Parties agreed to examine the need for interim response actions (IRAs) across the Site to prevent further degradation of groundwater and protect at-risk resources. In order to evaluate and screen potential candidate groundwater plumes for IRAs, the Tri-Parties agreed that if a contaminant concentration in a plume exceeded the appropriate standard by greater than a factor of 10, that contaminated plume was highly likely to further degrade the groundwater downgradient. The second step in the screening process was to determine whether treatment processes were readily available and capable of bringing contaminant concentrations down to acceptable levels. For the 200 West Area, it was determined that IRAs were necessary and appropriate for uranium, Tc-99, and carbon tetrachloride.

The following subsections present summaries of the IRAs near 200-UP-1 starting in 1985 and progressing to the current period.

1.5.1 216-U-1 and 216-U-2 Groundwater

An IRA was designed to treat groundwater below these cribs. About 7.9×10^6 L (2.09×10^6 gal) of groundwater was recovered and treated between June and August of 1985, removing 700 kg (1,510 lb) of uranium via an ion exchange column and resulting in a decrease of uranium activity in the groundwater to a concentration of 17,000 pCi/L.

1.5.2 200-PW-1 OU Action Memorandum

In October 1991, the Tri-Parties agreed to initiate expedited response actions at three specific locations across the Site. In the 200 West Area, the parties agreed that the mass of carbon tetrachloride in the soil column beneath 216-Z-1A, 216-Z-9, and 216-Z-18 constituted a substantial continuing source of future groundwater contamination. Concurrently, EPA issued guidance for the implementation of presumptive remedies (EPA 540/R-96/023, *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance*). Soil vapor extraction (SVE) was among those presumptive remedies. The conditions suitable for employing SVE as a presumptive remedy were as follows: concentrations in coarse sand or silts with relatively low-moisture contents, and a deep, unsaturated thickness above the water table from which to extract soil vapors. Based on the guidance, 200-PW-1, formerly 200-ZP-2, was an ideal location for the implementation of SVE. Under the "Action Memorandum: Expedited Response Action Proposal for 200 West Area Carbon Tetrachloride Plume" (Smith and Stanley, 1992), implemented in 1992, SVE has been in operation continually or seasonally and has recovered in excess of 5.67×10^5 L (1.5×10^5 gal) of carbon tetrachloride from the soil column beneath the 200 West Area.

1.5.3 U Plant Pilot Treatability Testing

A pilot-scale treatability test was constructed and operated between March 1994 and September 1995 as a recommendation from the 1994 *200 West Groundwater Aggregate Area Management Study Report* (DOE/RL-92-16) which concluded that uranium, Tc-99, and nitrate plumes should be remediated under an IRA. The agreement specified a P&T system using ion exchange as a pilot-scale treatability test and identified uranium and Tc-99 as the primary contaminants of concern (COCs). The 200-UP-1 RI/FS Work Plan (DOE/RL-92-76) and *Pilot-Scale Treatability Test Plan for the 200-UP-1 Groundwater Operable Unit* (DOE/RL-93-105) were prepared. Carbon tetrachloride was added as a secondary contaminant. The pilot-scale treatability test was constructed and operated between March 1994 and September 1995 (DOE/RL-95-02, *Treatability Test Report for the 200-UP-1 Operable Unit – Hanford Site*). The test consisted of an onsite P&T system constructed adjacent to the 216-U-17 Crib, plus single extraction and injection wells. Groundwater was extracted at a rate of 57 L/min (15 gallons per minute [gal/min]). Ion exchange was used as the treatment media.

1.5.4 200-ZP-1 OU Interim Response Action

In 1996, a P&T system was implemented as an interim action for groundwater. The goals for this IRA were to reduce the mass of carbon tetrachloride in the groundwater and to contain the plume where concentrations exceeded 2 ppm. The system treated extracted groundwater using air stripping to remove carbon tetrachloride (and other organic constituents) and then injected the treated water into the aquifer upgradient from the extraction area. The contaminated air from the stripping tower was treated with vapor phase activated carbon prior to discharge. The IRA was shut down in 2012 and portions of the system have been integrated into the final remedy.

1.5.5 U Plant Groundwater Interim Response Action

An IRA was undertaken to address the high-concentration of uranium and Tc-99 in groundwater in the vicinity of U Plant. The IRA created a work plan, SAP, and data quality objectives (DQOs) document that were created after the initial 200-UP-1 RI/FS Work Plan (DOE/RL-92-76, Rev. 0, *Remedial Investigation/Feasibility Study Work Plan for the 200-UP-1 Groundwater Operable Unit*, *Hanford Site, Richland, Washington*). Information collected as a part of the IRA was used to support this RI/FS report.

The ROD for the IRA (EPA/ROD/R10-97/048, *Interim Remedial Action Record of Decision for the 200-UP-1 Operable Unit, Hanford Site, Benton County, Washington*) was issued on February 25, 1997. Remedial action objectives (RAOs) were established for uranium and Tc-99 at concentrations equal to 10 times the maximum contaminant level (MCL) or Washington State risk-based concentrations. The selected remedy consisted of pumping from the highest-concentration zone of the uranium and Tc-99 groundwater plumes and routing the groundwater to the Effluent Treatment Facility (ETF) in the 200 East Area for treatment. Effluent from the ETF was discharged to the State-approved Land Disposal Site (SALDS). In 2004, monitoring of the IRA indicated that the RAOs specified in the interim ROD were met. The system was turned off on January 26, 2005, to perform a rebound study to evaluate the stability of the observed conditions. Following the rebound study, the P&T system was restarted and an explanation of significant difference (ESD) was undertaken to define and implement changes in operating conditions and performance requirements. The ESD specified several changes, including the following:

- The interim RAO for uranium in groundwater was changed to 300 µg/L to reflect the establishment of a new MCL for uranium in drinking water at 30 µg/L. The RAO was established at 10 times the MCL.
- The required pumping rate for extraction wells was reduced from 50 gal/min to a sustainable rate to be determined by site aquifer conditions.

The IRA system was found to meet the interim RAOs and was shut down in 2011.

1.5.6 S-SX Tank Farms Interim Response Action

The implementation of a groundwater P&T system for Tc-99 at the S-SX Tank Farms is underway as required by the revised 200-UP-1 RI/FS Work Plan (DOE/RL-97-36, Rev. 3, *200-UP-1 Groundwater Remedial Design/Remedial Action Work Plan*). The design consists of a three-well extraction system, aboveground pipelines, and a transfer building to pump extracted groundwater to the 200 West Area treatment facility for treatment and reinjection. An average pumping rate is designed at 300 L/min (80 gal/min).

In addition to the three extraction wells, one monitoring well was drilled north of the S Plant. Installation of a second monitoring well is planned within the S Tank Farm plume. Also, automated water level monitoring systems were installed in eight existing wells in 2011. The new wells and the water level monitoring wells will be used to evaluate plume capture by the P&T system. The system has been constructed and is awaiting acceptance testing. The system is scheduled to become operational in 2012.

1.5.7 200-ZP-1 OU Final Remedial Action

Based on groundwater characterization activities and interim P&T operations, the final remedy was developed and formalized in *Record of Decision Hanford 200-ZP-1 Superfund Site Benton County*, *Washington* (EPA et al., 2008). The selected remedy identified the source of the highest concentration area for carbon tetrachloride as being in the vicinity of the 216-Z Cribs and Trenches. The list of COCs was expanded to include the major contaminant plumes that exceed the federal and state DWSs. The COCs include carbon tetrachloride, trichloroethene (TCE),

I-129, Tc-99, nitrate, hexavalent chromium, total chromium, and tritium. Protection of the Columbia River from impacts caused by 200-ZP-1 OU contaminants must last until the cleanup levels are achieved, which is estimated to be within 150 years.

The RAOs will be achieved through four remedy components: (1) groundwater P&T, (2) monitored natural attenuation (MNA), (3) flow-path controls, and (4) institutional controls of the contamination. The ROD recognizes that carbon tetrachloride is distributed throughout the 200 West Area unconfined aquifer and (including the 200-UP-1 OU) and incorporates extraction wells that are screened through the entire high-concentration regions of the plume within the greater than 100 µg/L surface contour of the current carbon tetrachloride plume. Effluent from the extraction wells will be treated at a dedicated treatment plant and returned to the aquifer using injection wells (at the perimeter of the plume) to establish hydraulic containment. The groundwater P&T system has been constructed and will be operational in 2012.

2 Study Area Investigations

The Study Area Investigation included the contaminated groundwater as guided by the revised 200-UP-1 RI/FS Work Plan (DOE/RL-92-76, Rev. 1), which was based on review and evaluation of relevant documented information and data for the 200-UP-1 OU and identified the additional information needed to support remedial alternatives development, evaluation, and remedy decision making.

The following sections of this chapter describe the RI/FS field activities, as well as other investigations and ongoing activities that contributed to this RI/FS. These sections summarize the scope of work and document any deviations from the work plan. Some field deviations were made to the well locations, sample frequencies from those locations, and frequencies specified in the SAP (DOE/RL-2002-10, *Sampling and Analysis Plan for the 200-UP-1 Groundwater Monitoring Well Network*) because some wells were found to be dry, and modifications were requested by Ecology.

During the drilling of the new groundwater monitoring wells, depth-discrete groundwater samples were collected to assist in defining the three-dimensional distribution of contaminants of potential concern (COPCs) within the aquifer (WMP-29656, *Six Monitoring Wells Drilled in 200-UP-1 OU Fiscal Year 2006: Summary of Drilling Activities*; SGW-38141, *Borehole Summary Report for the Installation of Six Monitoring Wells at 200-UP-1 Operable Unit, FY 2008*). Details of depth-discrete groundwater sampling results and findings from other groundwater monitoring activities for the 200-UP-1 OU are included in PNNL-15070, *Hanford Site Groundwater Monitoring for Fiscal Year 2004*; PNNL-15670, *Hanford Site Groundwater Monitoring for Fiscal Year 2005*; PNNL-16346, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*; DOE/RL-2008-01, *Hanford Site Groundwater Monitoring for Fiscal Year 2007*; and DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*.

In addition to the RI findings, the documents reviewed to support this RI/FS report are listed in the annotated bibliography in Appendix B and are summarized below. Figure 2-1 illustrates the chronology of 200-UP-1 OU investigation activities through 2010. Table 2-1 presents a summary of the RI activities and remedial actions.

The findings from these efforts and the data collected from groundwater sampling between 2004 and 2009 were used to support the risk evaluation process and generation of the remedial action alternatives presented in this report.

2.1 Aggregate Area Management Study Reports

In 1991, the Aggregate Area Management Study (AAMS) approach was incorporated into the TPA (Ecology et al., 1989a), and the 200 West and 200 East Areas groundwater aggregate areas were defined. Summaries of historical operations, disposal practices, geology, and hydrogeology were presented in Aggregate Area Management Study Reports (AAMSRs). In 1993, the AAMSRs provided significant characterization information to support the field investigations that followed. The 200 West Groundwater AAMSR (DOE/RL-92-16) discussed groundwater impacts resulting from liquid waste disposal operations from four source aggregate areas: U Plant, S Plant, T Plant, and Z Plant. The U Plant and S Plant source aggregate areas associated with the 200-UP-1 OU are presented in the following subsections.

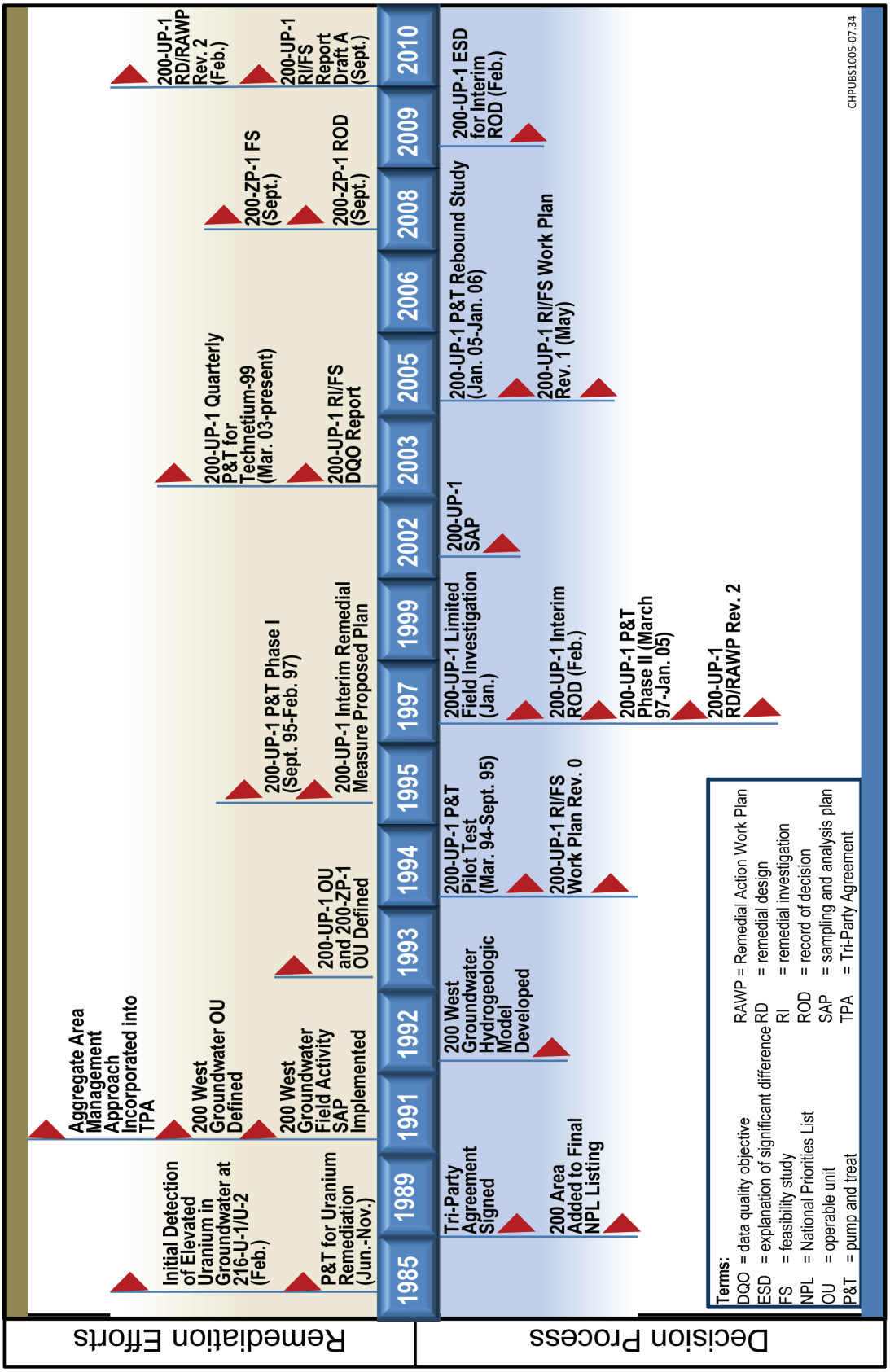


Figure 2-1. Timeline of Major Activities for the 200-UP-1 OU

Table 2-1. Summary of 200-UP-1 OU RI Activities

Activity		Description of Work Task
Routine Monitoring Activities	Analysis of routine COPCs listed in Table A1-1 of the Work Plan/SAP* for existing wells according to Section A1.3.2 and frequencies shown in Table A3-1 of the Work Plan/SAP. If any of the additional COPCs are detected above the detection limits, these COPCs will be added to the routine sampling program according to Section A1.3.3 of the Work Plan/SAP.	Comparison of additional COPC concentrations with the associated detection limits was conducted on a continuous basis as new data became available. Three of the additional COPCs (carbon-14, 1,4-dioxane, and selenium-79) were persistently detected and were thus added to the routine sampling for selected wells.
Supplemental Data Collection	Collect supplemental information according to Section A1.3.7 of the Work Plan/SAP.	DNAPL investigations and quality assurance activities (co-sampling); supplemental information identified in Section A1.3.7 of the Work Plan/SAP was collected.
Microscopic Contaminant Characterization	Incorporate microscopic contaminant characterization data from the RI scoping studies identified in Section A1.3.8 of the Work Plan/SAP during the selection of remedial alternatives.	RI scoping studies were conducted and results were included in PNNL-15502, *Characterization of 200-UP-1 Aquifer Sediments and Results of Sorption-Desorption Tests Using Spiked Uncontaminated Groundwater*.
Enhanced Monitoring Well Network	Install 12 new groundwater monitoring wells (UP-1 to UP-12) according to Section A1.3.1 of the Work Plan/SAP.	In total, 12 new groundwater monitoring wells, UP-1 to UP-12 (299-W19-107, 299-W19-105, 299-W22-69, 299-W22-72, 299-W22-86, 699-34-72, 699-33-74, 699-33-75, 699-32-76, 699-33-76, 299-W22-87, and 299-W22-88) were installed between 2006 and 2009. Well 299-W19-107 was developed as a replacement well for 299-W19-104 (UP-1/C4967), which was damaged and decommissioned.
Depth-discrete Groundwater Sampling to Assist in Defining the Three-dimensional Distribution of COPCs	Collection of five depth-discrete groundwater samples from selected new wells included in Section A1.3.5 of the Work Plan/SAP and onsite analysis for Tc-99 and volatile organics.	Depth-discrete groundwater samples were collected according to Section A1.3.5 of the Work Plan/SAP and results are summarized in the corresponding Hanford Site Groundwater Monitoring Report.
Modeling Input Parameter Collection	Collection of additional modeling input data (well development and aquifer testing) following well installation for selected wells (299-W19-48, 699-30-66, and 699-36-70B) according to Section A1.3.4 of the Work Plan/SAP. Conduct one to three hydrologic tests (slug tests, slug interference tests, constant rate discharge tests, and tracer tests) according to Section A1.3.6 at multiple depth intervals at approximately three well locations. Select depth intervals and hydrologic parameters, and develop a final detailed hydrologic test plan according to Section A1.3.6 of the Work Plan/SAP.	Slug tests were conducted at multiple depth intervals for all three wells according to Section A1.3.4 of the Work Plan/SAP and results are summarized in PNNL-19482, *Slug Test Characterization Results for Multi-Test/Depth Intervals Conducted During the Drilling of CERCLA Operable Unit OU UP-1 Wells 299-W19-48, 699-30-66, and 699-36-70B*.

Table 2-1. Summary of 200-UP-1 OU RI Activities

Activity			Description of Work Task
New Well Monitoring for Routine COPCs	Analysis of routine COPCs listed in Table A1-1 of the Work Plan/SAP for all new wells and frequencies shown in Table A3-1 of the Work Plan/SAP.		Samples were collected and analyzed according to Table A3-1 of the Work Plan/SAP.
New Well Monitoring for Additional COPCs	Analysis of additional COPCs listed in Tables A2-1 and A2-2 of the Work Plan/SAP for selected new wells and frequencies listed in Table A3-2 of the Work Plan/SAP.		Samples were collected at frequencies listed in and analyzed for additional COPCs identified in Table A3-2 of the Work Plan/SAP, and according to methods included in Table A2-1 of the Work Plan/SAP. Comparison of additional COPC concentrations with detection limits specified in Table A2-1 of the Work Plan/SAP were conducted on a continuous basis as new data became available.
New Well Initial Sampling	Drilled to the top of the Ringold lower mud unit.	299-W19-107 (UP-1/C5193) 699-34-72 (UP-5/C4972) 299-W22-88 (UP-12/C4978)	Depth-discrete groundwater samples were collected during well drilling, and each discrete sample was analyzed for the parameters specified in Section A1.3.5 of the Work Plan/SAP. Appropriate screen interval was selected according to instructions included in Section A1.3.1 of the Work Plan/SAP. Discrete sample results are summarized in PNNL-16346, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*.
	Drilled 36.6 m (120 ft) below the water table.	299-W19-105 (UP-2/C4968) 299-W22-69 (UP-3/C4969) 299-W22-72 (UP-4/C4970) 299-W22-86 (UP-5/C4971) 699-33-74 (UP-7/C4973) 699-33-75 (UP-8/C4974) 699-32-76 (UP-9/C4975) 699-33-76 (UP-10/C4976) 299-W22-87 (UP-11/C4977)	Depth-discrete groundwater samples were collected during well drilling, and each discrete sample was analyzed for the parameters specified in Section A1.3.5 of the Work Plan/SAP. Appropriate screen interval was selected according to instructions included in Section A1.3.1 of the Work Plan/SAP. Discrete sample results are summarized in DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*.

* The reference for every mention of the Work Plan/SAP in this table is DOE/RL-92-76, Rev. 1, *Remedial Investigation/Feasibility Study Work Plan for the 200-UP-1 Groundwater Operable Unit* (Appendix A).

2.1.1 200 West Groundwater Aggregate Area Management Study Report

The 200 West Groundwater AAMSR (DOE/RL-92-16) summarized information about groundwater contaminants beneath the 200 West Area and provided recommendations for prioritizing, investigating, and remediating various contaminants and plumes. The document also provided a detailed description of contaminant plumes that contained uranium, Tc-99, and nitrate in the 200-UP-1 OU. The 200 West Area Groundwater AAMSR (DOE/RL-92-16) recommended that the three plumes containing the highest concentrations of uranium, Tc-99, and nitrate be addressed under an IRA to reduce the potential risk of contaminants in the groundwater. Tritium was recommended for a direct risk assessment path because a proven technology at the scale needed to implement an IRA was not available.

2.1.2 U Plant Aggregate Area Management Study Report

The U Plant AAMSR (DOE/RL-91-52) detailed the operations and processes designed to recover uranium from the bismuth-phosphate process wastes stored in SST farms. The process used a continuous tributylphosphate-based solvent extraction chemistry to separate uranium from solutions with large quantities of fission products. The U Plant AAMSR (DOE/RL-91-52) provides background, environmental setting, and known contamination data to support development of a preliminary conceptual model and assess human health and environmental concerns.

2.1.3 S Plant Aggregate Area Management Study Report

The S Plant AAMSR (DOE/RL-91-60) detailed the operations and processes conducted at the REDOX Plant in the S Area (S Plant) that show a significant improvement in the recovery of plutonium and uranium over the bismuth-phosphate plutonium separations process. Hexone was used as a diluent to extract plutonium and uranium from acidic, fission-product-rich solutions in which the fuel rods had been dissolved. The S Plant AAMSR (DOE/RL-91-60) provides background, environmental setting, and known contamination data to support development of a preliminary conceptual model and assess human health and environmental concerns.

2.2 Remedial Investigation Documents

The following subsections describe the investigation documents used in this RI/FS.

The 200-UP-1 OU RI was completed in accordance with the 200-UP-1 RI/FS Work Plan (DOE/RL-92-76, Rev. 1). The type, quantity, and quality of data needed to characterize groundwater to support the RI/FS process were identified in Appendix A of the 200-UP-1 RI/FS Work Plan (DOE/RL-92-76, Rev. 1), which is the associated 200-UP-1 RI/FS SAP.

The initial 200-UP-1 RI/FS Work Plan (DOE/RL-92-76, Rev. 0) was released in 1994 to support a limited field investigation (LFI) (DOE/RL-96-33, *Limited Field Investigation for the 200-UP-1 Operable Unit*). The LFI was conducted to refine the conceptual site model (CSM) for risk assessment to support construction of the U Plant interim remedial action that was built in 1997 (EPA/ROD/R10-97/048).

The findings from this work, including the data collected from groundwater sampling between 2004 and 2009, were used to support the risk evaluation process and generation of the remedial action alternatives presented in this RI/FS report.

2.2.1 RI/FS Work Plan (DOE/RL-92-76, Rev. 0)

The initial 200-UP-1 RI/FS Work Plan (DOE/RL-92-76, Rev. 0) was issued in January 1994 to provide a plan for implementing interim remedial measures and investigating groundwater contaminants designated for an LFI in the 200 West AAMSR (DOE/RL-92-16).

The work plan (DOE/RL-92-76, Rev. 0) identified 26 high priority groundwater contaminants for LFI based on a review of groundwater data from 1988 through 1990, as follows:

- Fifteen organic compounds, which are; 1,2-dichloroethane, 1,1-dichlorethene, carbon tetrachloride, chloroform, TCE, bis(2-ethylhexyl)phthalate, n-nitrosodimethylamine, and the pesticides aldrin, dichlorodiphenyldichloroethane (DDD), dichlorodiphenytrichlorethane (DDT), dieldrin, endrin, endrin aldehyde, gamma-BHC (Lindane), and heptachlor.
- Six radionuclides, which are; potassium-40 (K-40), Sr-90, I-129, plutonium-238 (Pu-238), gross alpha, and gross beta.
- Five inorganic constituents, which are; arsenic, cadmium, chromium, fluoride, and selenium.

The work plan also identified three groundwater contaminants designated for IRA, including Tc-99, uranium, and nitrate.

2.2.2 Limited Field Investigation (DOE/RL-96-33)

The LFI (DOE/RL-96-33) was based on the initial 200-UP-1 RI/FS Work Plan (DOE/RL-92-76, Rev. 0). These two historical documents provided valuable information in the understanding of the 200-UP-1 OU. The LFI (DOE/RL-96-33) focused on evaluation of the contaminated aquifer soils and groundwater within the 200-UP-1 OU. The primary objective of the LFI (DOE/RL-96-33) was to refine the CSM and provide data for the performance of a risk assessment. To assess the nature and extent of contamination, data for groundwater contaminants from 105 wells from 1990 through 1996 were evaluated.

Ten organic compounds (bis[2-ethylhexyl]phthalate, n-nitrosodimethylamine, and the pesticides: aldrin, DDD, DDT, dieldrin, endrin, endrin aldehyde, gamma-BHC [Lindane], and heptachlor) were eliminated as high priority groundwater contaminants based on one-time detection criteria. The following two criteria were used to evaluate the remaining 16 high priority groundwater contaminants:

- The constituent must be in at least three adjacent wells to constitute a plume; detection in a single well does not constitute a plume.
- The constituent must be present in concentrations that exceed background or a DWS.

K-40, Pu-238, and selenium were detected multiple times above background, but the minimums, maximums, and averages were below the MCL.

Of the 26 LFI (DOE/RL-96-33) groundwater contaminants, 13 were detected above the groundwater standards of the *Safe Drinking Water Act of 1974*; the *Uranium Mill Tailings Radiation Control Act of 1978*; or WAC 173-340, "Model Toxics Control Act—Cleanup" or MTCA. The contaminants exceeding the standards include 1,1-dichlororethene, 1,2-dichloroethane, arsenic, cadmium, carbon tetrachloride, chloroform, chromium, fluoride, I-129, Sr-90, Tc-99, TCE, and uranium. The distributions occurred as plumes and sporadic occurrences. As discussed in the LFI (DOE/RL-96-33), the future risk scenario assumed a residential scenario. The risk analysis attributed most of the current and future risk to carbon tetrachloride. Carbon tetrachloride was recommended for inclusion in the 200-ZP-1 IRA. Other 200-UP-1 OU groundwater contaminants were not recommended for IRA because fate and transport analysis suggested that concentrations present little risk.

2.2.3 Revised RI/FS Work Plan (DOE/RL-92-76, Rev. 1)

Issued in May 2005, 200-UP-1 RI/FS Work Plan (DOE/RL-92-76, Rev. 1) described actions to be completed for the 200-UP-1 OU RI/FS following two responses and plume extent and concentration changes over time. The first response was an IRA started in 1994 for groundwater contamination

P&T operations with uranium and Tc-99. The second response was for tank farm and vadose zone remediation to eliminate or mitigate all releases, or treat releases to the groundwater. The purpose of this work plan (DOE/RL-92-76, Rev. 1) was to describe the approach for completing the RI/FS to support selection of a remedy for the 200-UP-1 OU. The project scope included the collection of additional characterization data to better define the groundwater contamination and the collection of missing data needed to support risk modeling and screening of remedial alternatives. In addition to the evaluation of documented historical information, more recent monitoring data contained in the Hanford Environmental Information System (HEIS) were evaluated to supplement the determination of COPCs to support the RI/FS. The results of the data evaluation provided in Appendix C of this RI/FS were used to prepare the SAP (DOE/RL-92-76, Rev. 1, Appendix A) for use during the RI. Chapter 5 described the plan for an enhanced monitoring network and presented depth-discrete groundwater sample analysis results collected during installation of new monitoring wells. In total, 22 monitoring wells were identified for installation to complete the 200-UP-1 OU monitoring network and to obtain data for the CERCLA RI/FS process.

2.2.4 200-UP-1 OU Monitoring Well SAP (DOE/RL-2002-10)

The SAP (DOE/RL-2002-10) was prepared in response to the CERCLA five-year review of groundwater remedial actions at the Hanford Site. As a result of P&T operations, natural groundwater flow, source term variability, and a decrease in the discharge of other waste streams such as cooling water, the shape and concentration of the contaminant plumes have changed over time. Therefore, the network of wells used to monitor the OU, the sampling frequency, and the analytical methods needed to ensure that the monitoring meets the requirements for remediation performance and sitewide surveillance. In addition to presenting the revised monitoring approach, recommendations for the addition of new monitoring wells are included.

The SAP (DOE/RL-2002-10) presented a list of wells similar to that in Appendix A of the initial 200-UP-1 RI/FS Work Plan (DOE/RL-92-76, Rev. 0). The COPCs listed in the SAP (DOE/RL-2002-10) included carbon tetrachloride, chloroform, TCE, total chromium, arsenic, cadmium, Sr-90, I-129, Tc-99, uranium, tritium, and nitrate. The SAP (DOE/RL-2002-10) was used for monitoring until a new SAP was provided in Appendix A of the 200-UP-1 RI/FS Work Plan (DOE/RL-92-76, Rev. 1) in 2005. The results from the sampling programs have been presented annually in interim action monitoring reports.

2.2.5 Geologic Investigations

Data for the risk assessment were taken from all 23 wells installed from 2006 to 2008. Geological descriptions were collected during installation of new wells, and the descriptions were evaluated for consistency with the current conceptual model. WMP-29656 and SGW-38141 provide detailed geologic information for the new wells. A summary of the drilling activities, including information such as screen interval, borehole logs, and other well development data, is included in WMP-29656 and SGW-38141.

2.2.6 Groundwater Investigations

Groundwater sampling conducted specifically to support the 200-UP-1 RI/FS Work Plan (DOE/RL-92-76, Rev. 1) began in 2003 and ended in March 2009. Table 2-1 provides a summary of the groundwater sampling activities and the associated status. Groundwater samples were collected from 93 wells. Monitoring requirements for field parameters, such as conductivity, REDOX potential, pH, temperature, dissolved oxygen, and turbidity, were not specified in the SAP (Appendix A of DOE/RL-92-76, Rev. 1). Field parameters are generally measured during each monitoring event, and a summary of the field data quality assessment (DQA) is discussed in SGW-43140, *Data Quality Assessment of 200-UP-1 Operable Unit Groundwater Data – October 2003 Through March 2009*.

The wells selected for sampling included those from the monitoring well network of the 200-UP-1 OU, as established in SAP (DOE/RL-2002-10), and the monitoring wells from the U, S-SX, and 216-S-10 WMAs (see SGW-43140, Appendix A). The SAP (DOE/RL-2002-10) includes COPCs identified through DQO processes conducted in 1992 and again in 2003. These DQO processes resulted in a comprehensive list of COPCs that was revised to a final list of 56 COPCs. In addition to target analyses for RI/FS characterization or remedial design /remedial action work plan process monitoring, additional contaminants have been reported through method-based analysis. The dataset used for the DQA includes 259 individual analytical parameters. The analytical data for all groundwater monitoring samples and their associated field quality control (QC) samples are maintained in the HEIS; the data are summarized in annual groundwater monitoring reports.

Active evaluations of the source term, vadose zone, and groundwater subsequent to 1993 led to the groundwater interim ROD, *200-UP-1 Groundwater Remedial Design/Remedial Action Work Plan* (DOE/RL-97-36, Rev. 2), and preparation of the 200-UP-1 RI/FS Work Plan (DOE/RL-92-76, Rev. 1) in 2005.

2.3 RI Data Quality Review

The RI established a program to guide data collection and to review the quality of the information generated from the field and laboratory. The SAP can be found in Appendix A of the 200-UP-1 RI/FS Work Plan (DOE/RL-92-76, Rev. 1). It identifies the type, quantity, and quality of data needed to characterize groundwater in support of the risk evaluation and FS process. The SAP (Appendix A of DOE/RL-92-76, Rev. 1) includes sampling of monitoring wells as defined in CP-15315. The DQA report (SGW-43140) presents the results of each QC sample collected and the following is a brief summary.

2.3.5 Field Quality Control

In total, 24,290 field QC results were generated, approximately 35 percent of the total groundwater samples collected. These consisted of 3,911 field duplicate results; 957 field split results; and 19,422 blanks results, consisting of a combination of field transfer blanks, equipment rinsate blanks, full trip blanks, and trip blanks. (A “full trip blank” is a trip blank to be analyzed for all constituents rather than just the volatiles.)

2.3.6 Field Duplicate Samples

The analytical precision requirement is less than or equal to 25 percent for all COPCs. In total, 61 (1.6 percent) of the duplicate samples had relative percent differences (RPDs) that exceeded the required criteria of 25 percent. Lead exhibited a high percentage of unacceptable performance (71 percent).

2.3.7 Split Samples

The purpose of split samples is to monitor the comparability of the data generated by different laboratories. The acceptance criterion is an RPD of the two laboratories’ results of 20 percent or less. A total of 23 samples (2.4 percent) exceeded 25 percent RPD. Gross beta (100 percent) and fluoride (43 percent) did not meet the criteria.

2.3.8 Field Blank Samples

Three types of field blank samples were collected: equipment rinsate, field transfer, and trip. A total of 672 samples exceeded the QC threshold of twice the method detection limit. Constituents with high percentages of positive blanks included oil and grease (100 percent), calcium (31 percent), and methylene chloride (28 percent).

2.3.9 Laboratory QC

Laboratory contamination, accuracy, completeness, and comparability were evaluated. The dataset consists of 178,019 laboratory QC results, which includes 51,737 blanks, 17,820 duplicates, 43,137 laboratory control standards, 44,771 matrix spikes, and 20,554 surrogate recovery results. Of these, 21,622 (12 percent) could not be evaluated because the dataset did not include a reference to the associated method detection limit.

2.3.9.1 Data Usability

No major deficiencies were identified in the validated semivolatiles, pesticides, or inorganics data. In total, 31 samples (volatiles, nitrate, nitrite, phosphate, and biological oxygen demand) were rejected because of missing holding times. Two radiochemistry samples were rejected because of lack of traceability of the standards used to quantitate the result. Minor deficiencies resulted in the application of J or UJ flags. Overall completeness is estimated at 98 percent. All flags identified have been applied.

2.3.9.2 Data Comparison

In a comparison to the annual Hanford Site groundwater monitoring reports, and in terms of accuracy, precision, and blank contamination, the 200-UP-1 OU data are as good as the overall site groundwater dataset. Field and laboratory performance parameters are equal to or better than those for the Site groundwater data as a whole.

2.3.9.3 Detection Limits

The dataset contains non-detect data for many constituents that do not meet the criterion. More than 25 percent of the nondetects exceeded the identified risk-based, potentially applicable, action limits.

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3 Physical Characteristics of the Study Area

The areal extent of the 200-UP-1 OU is defined by a geographic polygon (Figures 1-1 and 1-2) that includes the southern portion of the 200 West Area. This OU boundary splits the 200 West Area groundwater contaminant plumes between the 200-ZP-1 and 200-UP-1 OUs. The 200-ZP-1 OU covers the northern half of the 200 West Area (coincident with the bulk of the carbon tetrachloride contaminant plume), and the 200-UP-1 OU covers the southern portion. During the operational period of the Hanford Site, the 200-UP-1 OU was dominated by a persistent, artificially elevated groundwater mound that developed under the 216-U-10 Pond (U Pond), on the western side of the 200 West Area. A 1955 map showing the historical groundwater mound is presented on Figure 3-1. Discharges of liquid effluent to the ground within the OU were discontinued by the early 1990s, and the groundwater mound began to slowly dissipate. The groundwater elevations within the OU remain elevated above background conditions (before man-made mounding) and are declining at a rate of about 1 m (3.3 ft) per year. The primary aquifer system of interest for the 200-UP-1 OU is the uppermost unconfined aquifer that is encountered mainly within the Ringold unit E, a thick sequence of semi-consolidated silty, sandy gravel.

Information describing the physical characteristics of the 200-UP-1 OU has been derived from measurements and observations collected during the OU RI, as well as information collected from previously published investigations. The *National Environmental Policy Act of 1969* (NEPA) characterization report (PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization*) describes the major features of the Site. Much of the following description of the setting and climate is taken from PNNL-6415.

3.1 Surface Features

The Site is in the Columbia Basin of the Pacific Northwest. The Columbia Basin is an intermontane basin between the Cascade Range and the Rocky Mountains and forms the northern part of the Columbia Plateau physiographic province and the Columbia River flood basalt province. Most of the geologic activity producing features visible in the Basin occurred during the last 18 million years of the Cenozoic Era, but events as far back as the late Precambrian (2.3 billion years ago) had significant influence on the Cenozoic history of the area.

The Site lies within the geographically smaller Pasco Basin (Figure 3-2), located in the Yakima Fold Belt along the western margin of the Palouse Slope. The Saddle Mountains form the northern boundary of the Pasco Basin, while Rattlesnake Mountain forms part of the southern boundary. The Central Plateau lie in the Cold Creek syncline between the Yakima Ridge and Umtanum Ridge in the central portion of the Pasco Basin (Figure 3-3). The physiographic setting of the Site is relatively low-relief, resulting from river and stream sedimentation filling the synclinal valleys and basins between the anticlinal ridges.

Site topography has been modified within the past several million years by Pleistocene cataclysmic flooding, Holocene eolian activity, and landsliding. Pleistocene floods eroded sediments and scoured into basalt bedrock, forming “scabland” topography visible north of the Pasco Basin, and left large-scale erosional channels and flood bars visible within the Central Plateau at the Site (Figure 3-3).

The topography above the 200-UP-1 OU is relatively flat to gently rolling, with a surface elevation ranging from about 183 to more than 213 m (600 and 700 ft) above mean sea level. The topography across the 200-UP-1 OU reflects the remnant terrain associated with the Cold Creek Bar, a large-scale paleo-flood feature that dominates the area (Figure 3-3). Groundwater beneath the OU is much deeper in this portion of the Site because of the increased vadose zone thickness associated with the paleo-bar deposits.

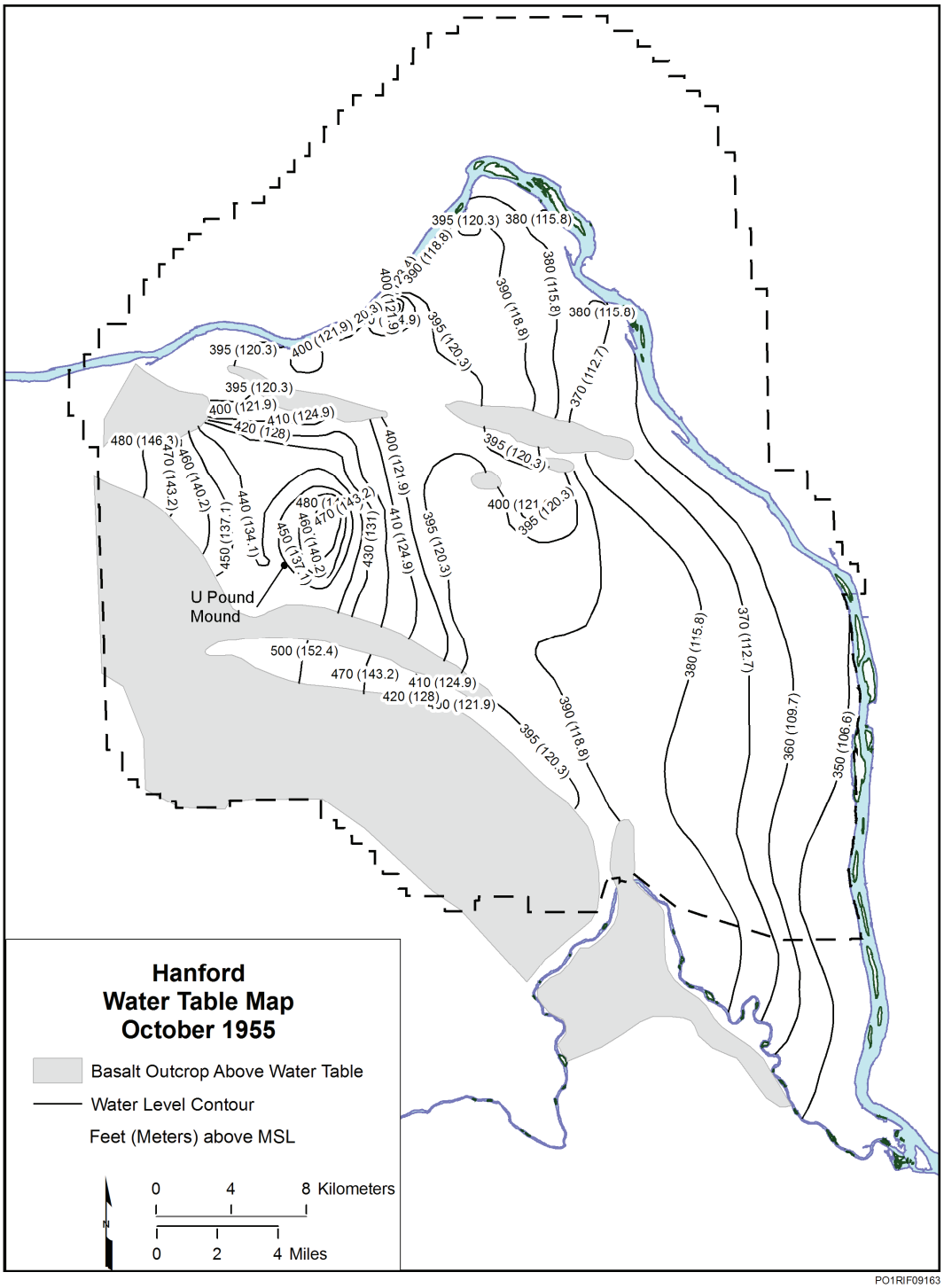
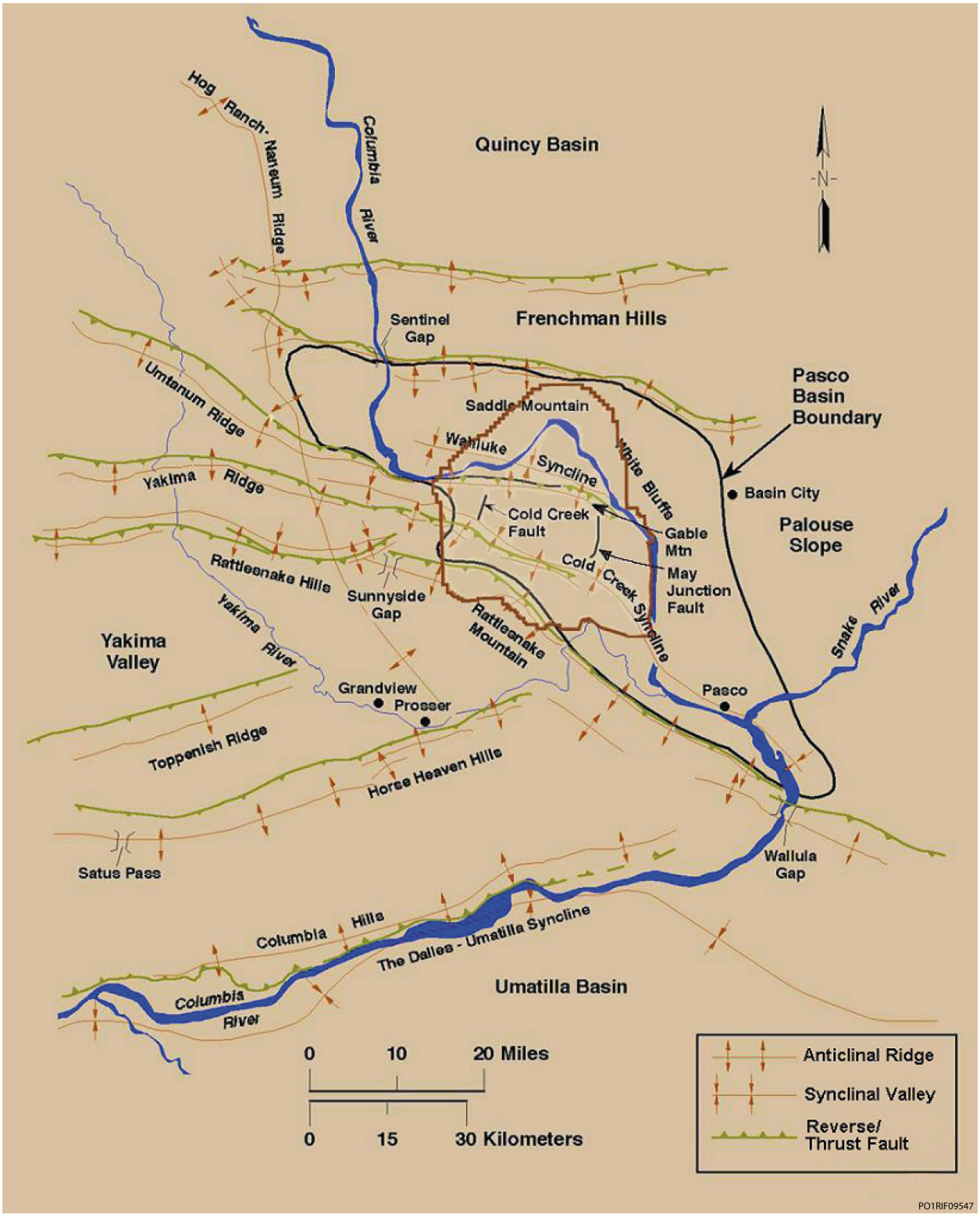


Figure 3-1. Hanford Site Water Table Map from 1955 Illustrating Historical Groundwater Mound beneath U Pond, 200-UP-1 OU



Note: Figure has been modified from PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization*.

Figure 3-2. Generalized Structure Map of the Pasco Basin

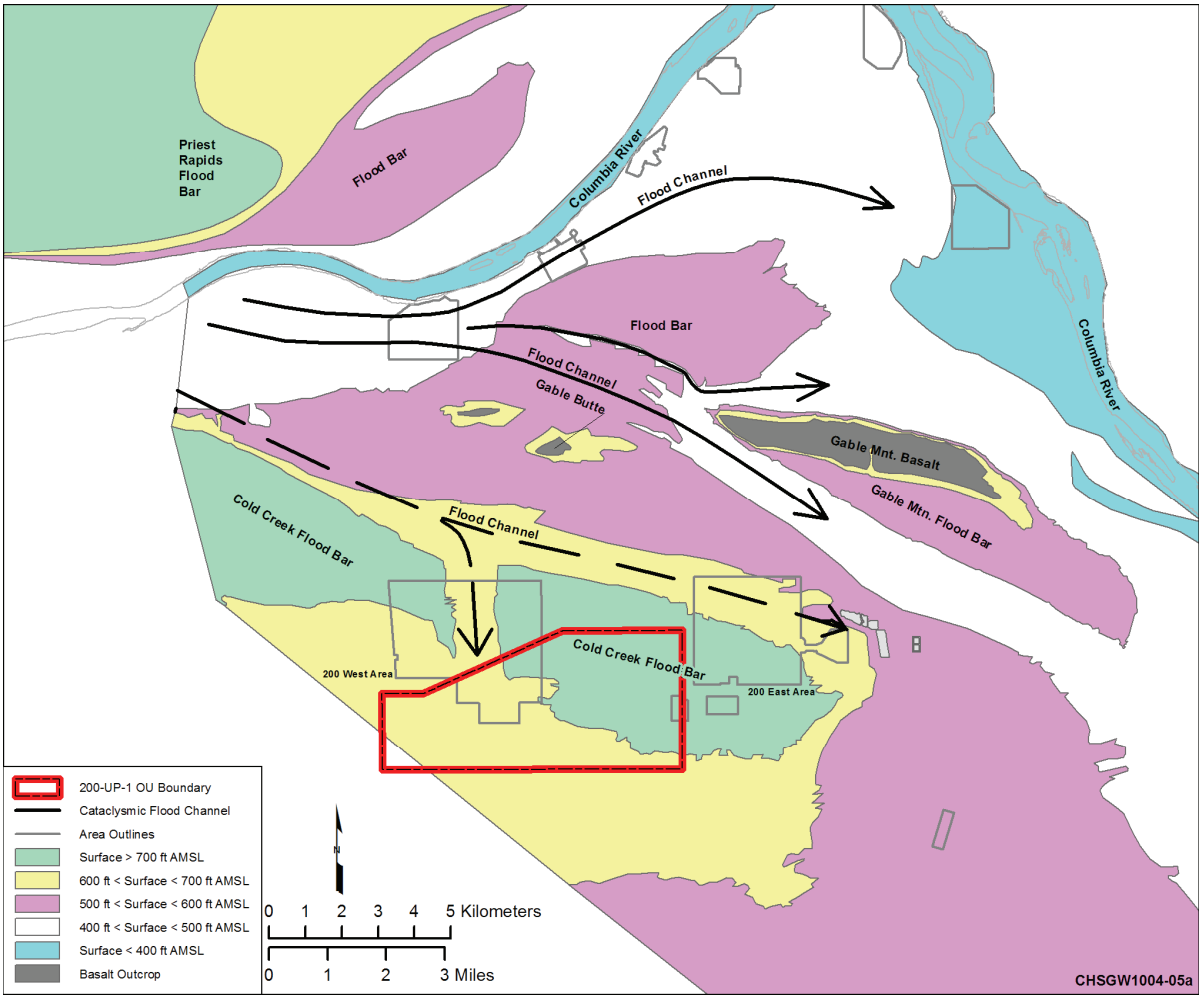


Figure 3-3. Topography of the 200-UP-1 OU and Surrounding Area

Man-made features visible on the ground surface of 200-UP-1 OU are limited to industrial structures related to the historical nuclear material production activities at the Site, the Environmental Restoration Disposal Facility (ERDF), and the U.S. Ecology Site. The 200-UP-1 OU includes the following major historical structures:

- 221-U Building (U Plant), used historically for recovery of uranium from high-level radioactive waste
- 224-U Building (UO_3 Plant), used historically for production of uranium tri-oxide from reactor fuel reprocessing wastes
- Various associated cribs, ponds, ditches used historically for waste disposal, and the S-SX and U Tank Farms
- 202-S (S Plant, REDOX) used historically to extract plutonium and uranium from fuel rods irradiated by Site reactors

3.2 Meteorology

The Pacific Ocean moderates temperatures throughout the Pacific Northwest, and the Cascade Range (approximately 113 km [70 mi] west of the Site) generates a rain shadow that limits rain and snowfall in the eastern half of Washington State. The Cascade Range also serves as a source of cold air drainage, which has a considerable effect on the wind regime of the Site. The Rocky Mountains to the north and east of the region shield the area from the severe winter storms and frigid air masses that move southward across Canada.

Climatological data for the Site are compiled at Hanford Meteorology Station (HMS), Number 21, which is located on the Central Plateau just outside the northeast corner of the 200 West Area. To characterize meteorological differences accurately across the Site, the HMS operates a network that currently contains 30 different monitoring stations recording data every 15 minutes. This monitoring network has been in full operation since the early 1980s, but site meteorological data has been collected as far back as 1944. Before the HMS was established, local observations were made at the old Hanford Townsite (1912 through late 1943) and in Richland (1943–1944). Historical and statistical Hanford meteorological data are compiled and reported in PNNL-14242.

3.2.1 Wind

The prevailing surface winds on the Hanford Site's Central Plateau are generally from the northwest and southwest and are the strongest during the winter and summer months. The Cascade Mountains have a considerable effect on the wind regime at the Site by serving as a source of cold and dense air drainage. This drainage results in a northwest to west-northwest prevailing wind direction that averages 2.7 to 3.1 m/s (6 to 7 mph), and faster during the spring and summer, averaging 3.6 to 4.0 m/s (8 to 9 mph). The fastest wind speeds are usually associated with flow from the southwest; however, summertime drainage winds from the northwest frequently exceed speeds of 13 m/s (30 mph).

3.2.2 Temperature and Humidity

Temperatures in the winter average about 0°C (31°F) in January to 25°C (77°F) in July, The Daily maximum temperatures vary from about 2°C (35°F) in late December and early January to 36°C (96°F) in late July. On average, 52 days during the summer months have maximum temperatures greater than 32°C (90°F) and 12 days with maximums greater than 38°C (100°F). The largest number of consecutive days on record with maximum daily temperatures greater than 32°C (90°F) is 32 days. The record maximum temperature of 45°C (113°F) occurred three times (July 23, 2006, July 13, 2002, and August 4, 1961).

On average the daily minimum temperature of less than -18°C (about 0°F) occurs 3 days per year; however, only about one winter in two experiences such low temperatures. The annual average relative humidity is 55 percent, averaging about 76 percent in the winter and 36 percent in the summer.

3.2.3 Precipitation

Average annual precipitation at the HMS is 17 cm (6.8 in.). Most precipitation occurs during the late autumn and winter, with more than 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, decreasing to 1.3 cm (0.5 in.) during March. Snowfall accounts for about 38 percent of all precipitation from December through February.

3.3 Surface Water Hydrology

There are no natural surface water bodies on the land surface above the 200-UP-1 OU. Ponds are north and east of the OU and include West Lake, the SALDS, and the 200 Area Treated Effluent Disposal Facility (TEDF) disposal ponds. West Lake is north of the 200 East Area and is a natural feature recharged occasionally from groundwater (ARH-CD-775, *Geohydrologic Study of the West Lake Basin*; PNL-7662, *An Evaluation of the Chemical, Radiological, and Ecological Conditions of West Lake on the Hanford Site*). West Lake has not received direct effluent discharges from Site facilities; rather, its existence is caused by the intersection of the elevated water table with the land surface in the topographically low area.

TEDF is east of the 200 East Area and consists of two disposal ponds. These ponds are each 0.02 km^2 (0.008 mi^2) in size and receive industrial wastewater permitted in accordance with WAC 173-216, "State Waste Discharge Permit Program." Limited permitted effluent releases still occur at the 200 Area SALDS north of the 200 West Area within the adjacent 200-ZP-1 OU. The wastewater evaporates or percolates into the ground from the disposal ponds. As a result of the arid climate, and rapidly draining surface sediment, no surface drainage pattern was developed for 200-UP-1.

From a precipitation and surface water run-on/run-off perspective, the OU is not in a designated floodplain, and calculations of probable maximum floods for the Columbia River indicate the area is not expected to be inundated under maximum flood conditions (RHO-BWI-C-120/PNL-4219, *Flood Risk Analysis of Cold Creek near the Hanford Site*). Total estimated precipitation over the Pasco Basin is about 9×10^8 m^3 (3.2×10^{10} ft^3) annually (DOE/RW-0164, *Site Characterization Plan: Reference Repository Location, Hanford Site, Washington*). Normal annual precipitation in the Central Plateau (PNNL-20548, *Hanford Site Environmental Report for Calendar Year 2010*) is 17.7 cm (6.98 in.). Precipitation varies spatially and temporally with higher amounts generally falling at higher elevations within the Basin. Mean annual run-off from the Pasco Basin is estimated at 3.1×10^7 m^3/yr (1.1×10^9 ft^3/yr), or approximately 3 percent of the total precipitation (DOE/RW-0164). Most of the remaining precipitation is lost through evapotranspiration; however, a portion of the precipitation that infiltrates the soil eventually recharges the groundwater flow system. The amount of recharge varies spatially based on soil texture and vegetation (Gee et al., 1992, "Variations in Recharge at the Hanford Site"). Natural recharge also varies temporally with the majority occurring in the winter and spring. Some evidence suggests that most significant recharge events are associated with rapid melting of relatively large snowpacks, which may only occur a few times in a decade (PNNL-14744, *Recharge Data Package for the 2005 Integrated Disposal Facility Performance Assessment*). Estimates of groundwater recharge to the area are discussed in Section 3.6.7 of this report.

3.4 Geology

The subsurface geology forms the framework that affects the locations of aquifers and the release and subsurface movement of contaminants and groundwater. The physiographic setting, stratigraphy, and geologic structure of the 200-UP-1 OU are described in this section. Hydrostratigraphic cross sections and descriptions of unconsolidated sediments and basalt bedrock are included to illustrate the nature of the aquifer sediment and the lateral continuity or variations that occur across the 200-UP-1 OU.

The geology of the Site has been extensively characterized as a result of various past investigation activities. These activities have included the siting of nuclear reactors (WPPSS, 1981, *Final Safety Analysis Report*; PSPL, 1982, *Preliminary Safety Analysis for Skagit/Hanford Nuclear Project*), the site characterization efforts of the Basalt Waste Isolation Project (DOE/RW-0164), support for waste management operations (DOE/EIS-0113, *Final Environmental Impact Statement Disposal of Hanford*

Defense High-Level, Transuranic and Tank Wastes: Hanford Site Richland, Washington), and the recent environmental remediation activities. Geologic and geophysical investigations within the 200-UP-1 OU have included regional and Site surface mapping, borehole/well sediment logging, field and laboratory sediment classification, surface and borehole geophysical studies (including radiological borehole logging and various seismic and electromagnetic surveys), and in situ and laboratory hydrogeologic properties testing.

3.4.1 General Geologic Setting of the OU

The 200-UP-1 OU is in the central part of the Pasco Basin. Figure 3-2 presents a generalized structural geologic map of the Pasco Basin, showing the broad structural and topographic basin. Over the last 16 million years, the basin filled with materials that form bedrock (volcanic lava flows) and unconsolidated sediments (silt, sand, and gravel). Beneath the ground surface, major geologic units of interest (from oldest to youngest) include the following: (1) the Elephant Mountain Member basalt of the Saddle Mountains Basalt Formation and related interbeds within the Columbia River Basalt Group, (2) the Ringold Formation, (3) the Cold Creek Unit (CCU), (4) the Hanford formation, and (5) Holocene surficial deposits.

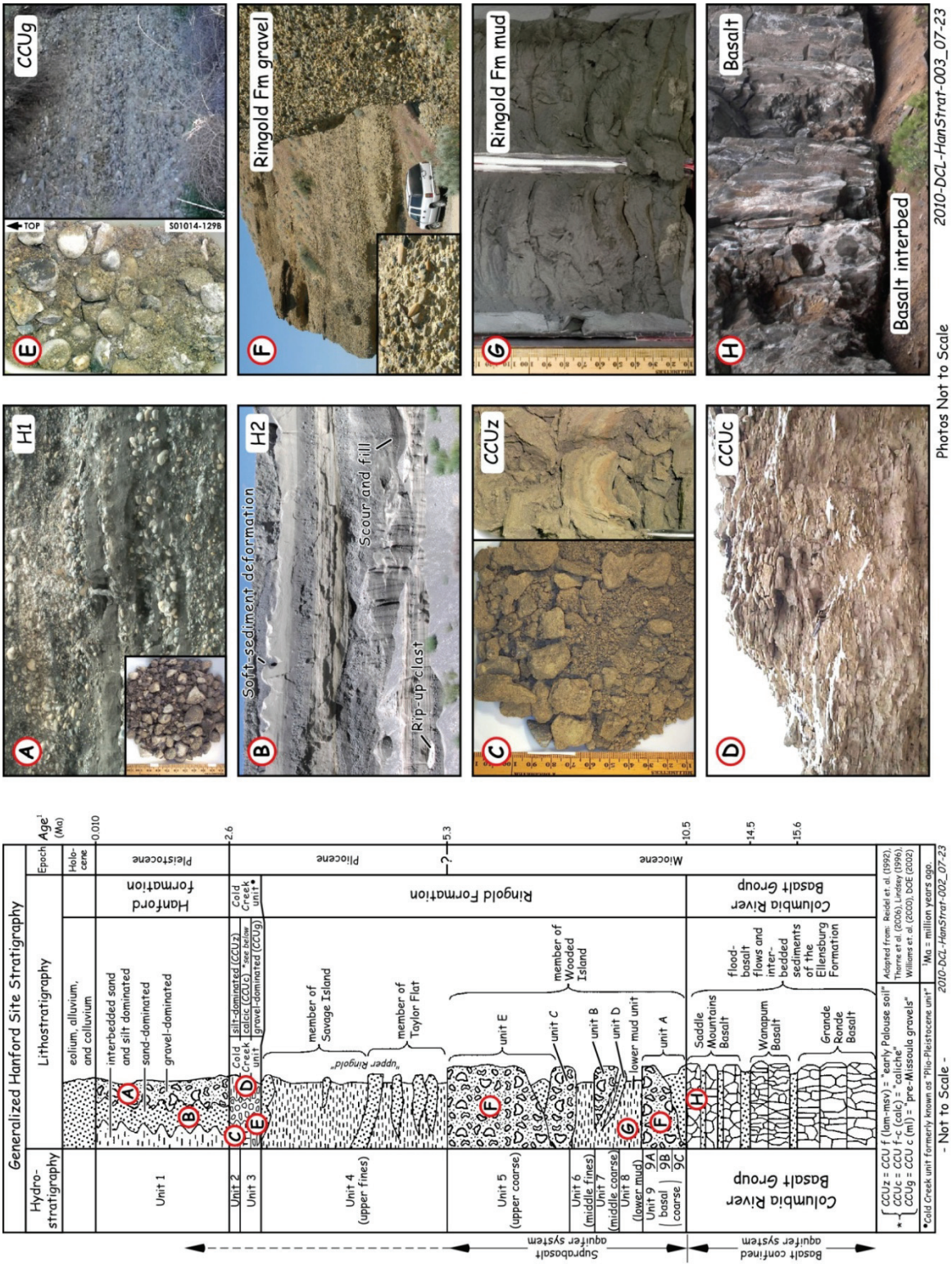
Previous studies containing geologic interpretations and related maps and cross sections pertaining to the 200-UP-1 OU include the 200 West AAMSR (DOE/RL-92-16) and the 200-PO-1 RCRA facility investigation (DOE/RL-95-100, *RCRA Facility Investigation Report for the 200-PO-1 Operable Unit*), which included cross sections from BHI-00184, *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington*. The updated hydrogeology is based on the revised hydrogeology of the 200 West Area (PNNL-13858, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington*).

Unconsolidated and partly consolidated fluvial (river-derived), lacustrine (lake), and cataclysmic flood sediments of the Miocene through Holocene ages (approximately 8.5 million years to the present) overlie the basalts. The 200-UP-1 OU is focused on these sedimentary suprabasalt units above the basalt bedrock because this sediment contains the uppermost unconfined aquifer system within the region. Figure 3-4 presents a generalized stratigraphic column for the area.

3.4.2 Elephant Mountain Member Basalt

Basalt is an igneous rock ejected from the earth during volcanic events. The basalt flows of the Columbia River Basalt Group were deposited during the Miocene from source vents in southeastern Washington, northern Oregon, and western Idaho. These basalt flows form the basement for overlying sedimentary deposits (Figure 3-4). Beneath the 200-UP-1 OU, the youngest and uppermost basalts are members of the Saddle Mountains Basalt Formation (RHO-BWI-ST-4, *Geologic Studies of the Columbia Plateau: A Status Report*). The Saddle Mountains Basalt Formation is divided into the Ice Harbor, Elephant Mountain, Pomona, Esquatzel, Asotin, Wilbur Creek, and Umatilla Members. The Elephant Mountain Member is the uppermost basalt unit and is approximately 35 m (115 ft) thick beneath most of the Site, except in the vicinity of the 300 Area, where the overlying Ice Harbor Member forms the top of the Saddle Mountains Basalt. The Rattlesnake Ridge interbed of the Ellensburg Formation is between the Elephant Mountain Member and the underlying Pomona Member and comprises the uppermost basalt confined aquifer beneath the 200-UP-1 OU.

In the central portion of the Pasco Basin (200-UP-1), the Ellensburg Formation interbed ranges from 1.5 to 15 m (5 to 50 ft) thick and is composed of clayey basalt conglomerates, fluvial floodplain deposits, and ash tuffs and tuffites (RHO-RE-ST-12P, *An Assessment of Aquifer Intercommunication in the B Pond-Gable Mountain Pond Area of the Hanford Site*). Within the 200-UP-1 OU, the basalt surface is interpreted as the basal hydrogeologic boundary for the overlying (suprabasalt) aquifer system that has been affected by past Site liquid effluent disposal practices (Figure 3-4).



Source: PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization.*

Figure 3-4. Generalized Stratigraphy of the Hanford Site Including the Central Plateau

3.4.3 Suprabasalt Geology

Unconsolidated and partly consolidated sediments of the Miocene through Holocene (approximately 8.5 million years to the present) ages overlie the basalts (DOE/RL-95-100). The 200-UP-1 OU RI/FS is focused on the suprabasalt sedimentary units because these sediments contain the vadose interval and uppermost unconfined aquifer system within the region. Figure 3-4 presents a generalized geologic column of the Hanford Site, including the 200-UP-1 OU.

The geology of the suprabasalt sediments is well defined in the 200 East Area and 200 West Area because of characterization data obtained from many closely spaced wells across the Central Plateau. The suprabasalt sediments beneath the 200-UP-1 OU are dominated by extensive fluvial and lacustrine deposits, assigned to the Miocene to Pliocene age Ringold Formation, which are deposited on top of the basalt surface. The Ringold Formation is overlain by the CCU (which includes the formerly named early Palouse soil), which is overlain with coarse-grained Pleistocene age paleo-flood deposits of the Hanford formation. The suprabasalt sedimentary sequence ranges up to 215 m (700 ft) thick in the center of the basin and contains the uppermost unconfined aquifer, which controls groundwater contaminant migration across the 200-UP-1 OU.

The Ringold Formation comprises the oldest suprabasalt sediment, is deposited unconformably on the basalt surface, and is the primary sequence of units making up the suprabasalt aquifer system (Figure 3-4). The Ringold Formation is a semiconsolidated to unconsolidated sedimentary sequence composed of fluvially deposited conglomeratic gravel-dominated units, designated as units A, B/D, C, and E (from oldest to youngest). These high-energy deposits may be separated by fine-grained lacustrine or overbank deposits designated as the Ringold lower mud unit, Ringold upper mud unit, and upper Ringold unit. Within the 200-UP-1 OU, only four Ringold Formation units are present (from oldest to youngest): the fluvial gravel unit A, lower mud unit, fluvial gravel unit E, and upper Ringold unit. These geologic units have been designated in ascending order as hydrostratigraphic units (HSUs) 9, 8, 5, and 4, respectively (Figure 3-5). A detailed lithologic description of these units can be found in PNNL-13858 and is discussed further in Section 3.6.2.

Ringold fluvial gravel unit A (HSU 9) directly overlies the Saddle Mountains Basalt (Figure 3-5) and displays a relatively flat surface that dips toward the axis of the Cold Creek syncline (south-southwesterly). Unit A ranges in thickness up to about 30 m (100 ft) beneath the OU. Cross sections (Figures 3-6 and 3-7) depict the hydrogeology and general structural and depositional relationships of the Ringold Formation and overlying CCU and Hanford formation sediment. The Ringold lower mud unit (HSU 8) is a relatively thick, low-permeability fine-grained sequence of overbank, paleosol, and lacustrine silt and clay with minor sand and gravel (Figures 3-4 and 3-5). Where the Ringold lower mud unit (HSU 8) occurs below the water table, it forms a confining unit within the suprabasalt aquifer system, separating the lower saturated Ringold unit A gravel (HSU 9) from the overlying saturated Ringold unit E (HSU 5) (Figures 3-6 and 3-7). Where the Ringold lower mud unit is at or above the water table, it creates a relative aquitard—a no-flow groundwater boundary. The uppermost unconfined aquifer within the suprabasalt sedimentary sequence is contained within the geologic units overlying the Ringold lower mud unit (Ringold unit E) where it is present, or the top of basalt where the Ringold lower mud unit is missing.

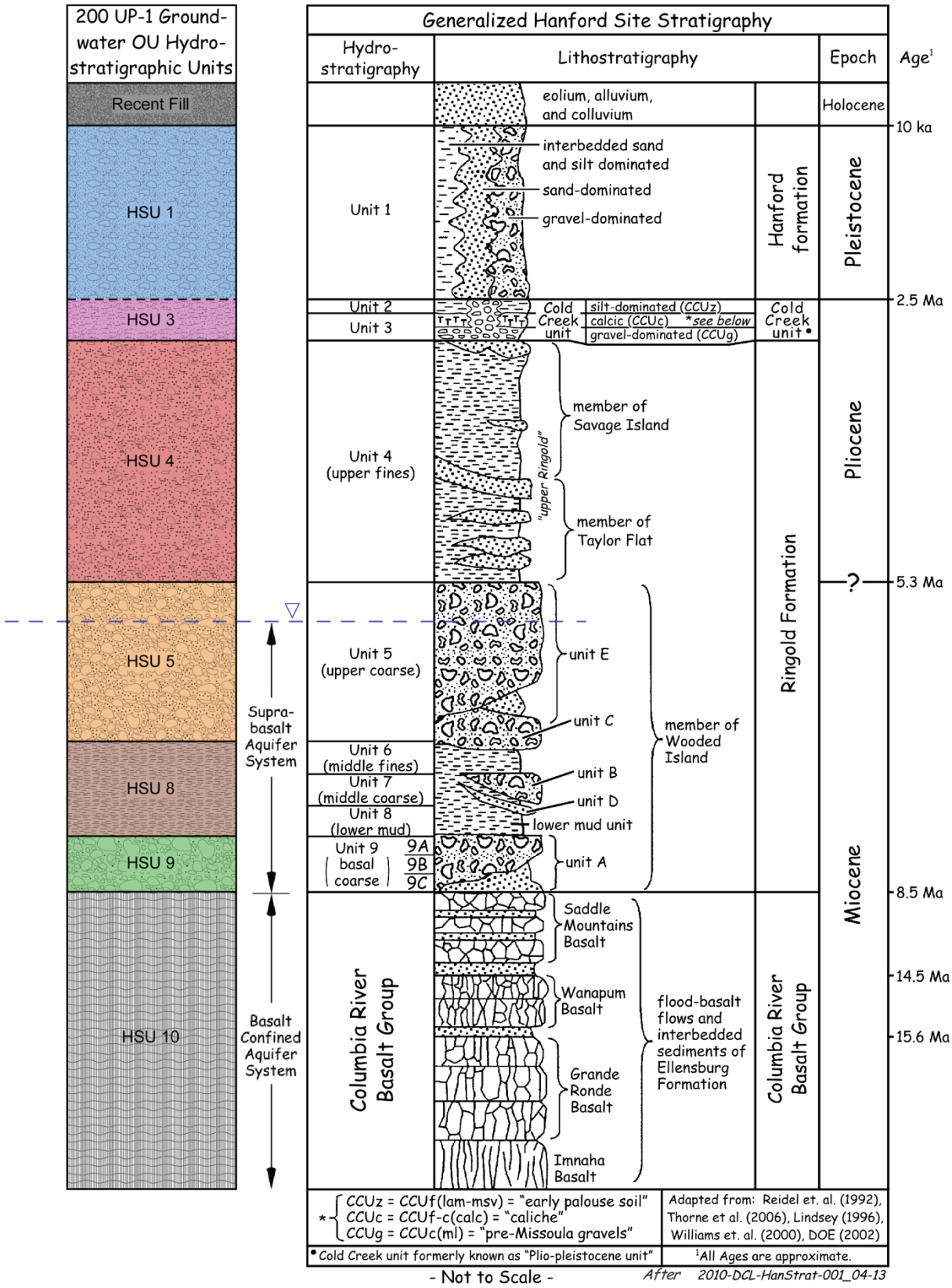


Figure 3-5. Hydrogeologic Nomenclature Comparison for the 200-UP-1 OU

Well data suggest the Ringold lower mud unit is present beneath the entire 200-UP-1 OU (Figures 3-6 and 3-7). The Ringold lower mud unit sequence thickens and dips to the south into the Cold Creek syncline, similar to the underlying Ringold unit A. The Ringold lower mud unit sequence is very thin to absent through the very northernmost portion of the 200 West Area (within the 200-ZP-1 OU). The Ringold lower mud unit sequence ranges in thickness from about 8 m (26 ft) to more than 26 m (85 ft) in the 200-UP-1 OU. Northeast of the 200-UP-1 OU near the 200 East Area boundary, well data suggest that a portion of the Ringold lower mud unit is elevated at or above the water table, creating a hydraulic barrier to groundwater movement eastward out of the northern portion of the 200 West Area. The presence of the Ringold lower mud unit near the water table in this area is believed to create a groundwater diversion, splitting groundwater (and any constrained contamination) into two main flow paths: one north to northeast near the Gable Gap (within 200-ZP-1 OU), and the other more easterly (within the 200-UP-1 OU).

Within the 200 West Area, the Ringold unit E (HSU 5) is the uppermost geologic unit within the unconfined aquifer and is composed of fluvial silty, sandy gravel. Ringold unit E overlies the Ringold lower mud unit (Figures 3-4 and 3-5). The Ringold unit E is present throughout the OU (Figures 3-6 and 3-7). Most known contaminant plumes that emanate from the 200 West Area migrate eastward through this unit and into the adjacent and overlying Hanford formation sediment near the 200 East Area erosional truncation (Figure 3-8). The Ringold unit E is thickest near the southwestern portion of the 200-UP-1 OU and gradually thins to the east until it is truncated within the 200 East Area (Figure 3-8). The Ringold unit E ranges in thickness to more than 90 m (295 ft) (PNNL-13858) near the western margin of the 200-UP-1 OU.

The Ringold unit E (HSU 5) grades upward into interbedded fluvial sand and silt of the overlying upper Ringold unit (HSU 4). The upper Ringold unit (HSU 4) is within the vadose zone and is only locally present in the 200-UP-1 OU. Detailed descriptions of this unit are provided in BHI-00184 and BHI-01311, *Hydrogeologic Conceptual Model for the Carbon Tetrachloride and Uranium/Technetium Plumes in the 200 West Area: 1994 Through 1999 Update*.

3.5 Cold Creek Unit

The CCU (HSU 3) includes several post-Ringold Formation and pre-Hanford formation units beneath portions 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 side stream alluvial facies in previous site reports. Beneath the 200 West area, the CCU comprises fluvial, eolian (wind derived), and paleosol (soil) deposits that are divided into two separate units designated the lower caliche unit (CCU_c or Unit 3) and the overlying silt unit (former early Palouse soil) (CCU_z or Unit 2) (Figure 3-4). The Caliche layer formed during subareal exposure of the upper portions of the underlying sediment (Ringold unit E or the upper Ringold unit) and extended into overlying CCU_z sediment. The CCU_c caliche deposit is composed of precipitated calcium carbonate that accumulated in available pore spaces between sediment grains (sand, silt, or gravel). The caliche forms a secondary mineral coating or cement that binds the sediment grains together, forming one or more “hardpan” layers. The stratigraphic location and amount of calcium carbonate cement are variable, so the physical properties of this unit vary from “soil-like” to “rock-like.” For the purpose of this report, these two intervals (Unit 2 and Unit 3) are grouped together on cross sections, maps, and model layers and designated as HSU 3 (Figure 3-5).

The CCU is present in the vadose zone beneath the 200 West Area (Figures 3-6 and 3-8). The CCU is an important unit because these cemented deposits are extensive, relatively impermeable, deeply buried, and impede or perch the downward migration of liquid and contaminants in the vadose zone beneath the waste sites.

3.5.1 Hanford Formation

The Hanford formation (HSU 1) is the informal stratigraphic name given to the Pleistocene cataclysmic flood deposits in the Pasco Basin (DOE/RL-2002-39). The cataclysmic flood waters eroded or reworked much of the pre-existing Ringold Formation and CCU sediment across the Gable Gap area, and unconformably deposited sediments of the Hanford formation, locally reshaping the topography of the Pasco Basin (Figure 3-3). The floodwaters deposited a thick sand and gravel bar (Cold Creek Bar) that constitutes the Central Plateau and includes the 200-UP-1 OU. Remnant erosional channels, preserved during the waning stages of the paleo-floods, remain north of the 200 Areas in the area currently occupied by West Lake and the former Gable Mountain Pond.

The Hanford formation (Figure 3-4) consists predominantly of unconsolidated sediments that range from boulder-size gravel to sand, silty sand, and silt. The sorting ranges from poorly sorted (for gravel facies) to well sorted (for fine sand and silt facies). The Hanford formation is divided into three main facies associations: interbedded sand- to silt-dominated (formerly called the Touchet beds or slack water facies), sand-dominated (formerly called the sand-dominated flood facies), and gravel-dominated (formerly called the Pasco gravels) (DOE/RL-2002-39). These units vary vertically and laterally across the region and are difficult to correlate. The gravel-dominated facies are cross-stratified, coarse-grained sands and granule-to-boulder gravel. 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 sand. Where the sand and silt content is low in the gravel-dominated facies, an open-framework texture is common. The Hanford formation sediment exhibits extremely high permeability and hydraulic conductivity.

Beneath the 200-UP-1 OU, the Hanford formation sediments were deposited on the older CCU or Ringold units (unit E, Ringold lower mud unit, and unit A) and may comprise the uppermost portion of the unconfined aquifer at the very eastern margins of the OU (Figure 3-8). Within the 200 West Area, the Hanford formation overlies the CCU, and is entirely within the vadose zone (Figure 3-8).

The Hanford formation is important because it is the thickest geologic unit (comprising most of the vadose zone thickness) and lies directly beneath the waste sites through which contamination passed to reach the CCU and groundwater.

Clastic dikes are common discontinuities in the Hanford formation but are rare in the Ringold Formation (DOE/RL-2002-39). They normally appear as crosscutting, vertically oriented cracks, or fissures that are filled with sand, silt, clay, and minor coarser debris (Figure 3-9). Their origin is likely associated with natural hydraulic injection during or immediately following Pleistocene cataclysmic flooding, mass wasting, earthquakes, and other geologic processes. Clastic dikes occurring in vadose zone sediments have the potential to influence soil moisture and contaminant movement (BHI-01103, *Clastic Injection Dikes of the Pasco Basin and Vicinity*). No data exist regarding the potential influence of clastic dikes within the aquifer.

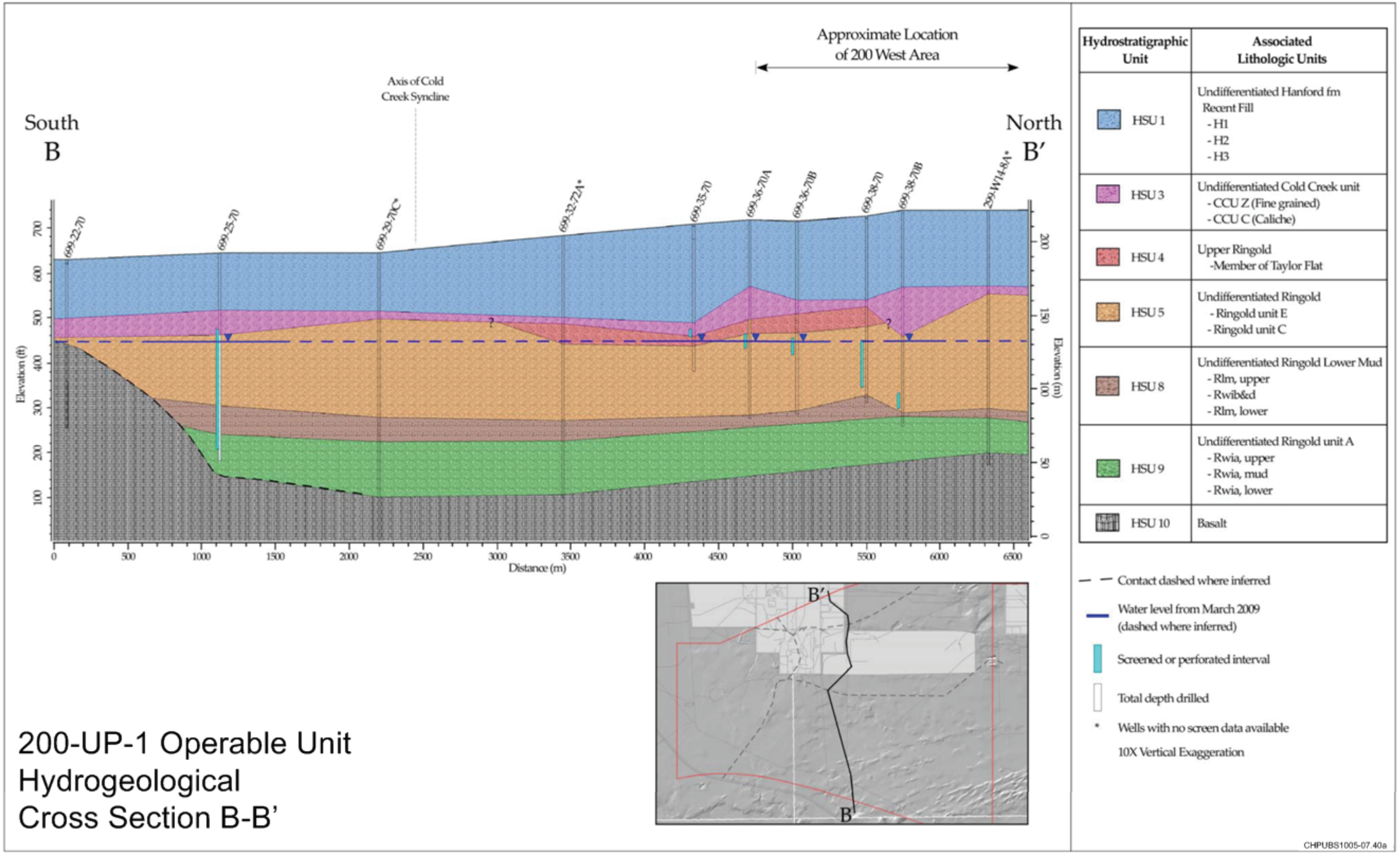


Figure 3-6. Cross Section B-B' Illustrating Hydrogeology beneath the 200-UP-1 OU

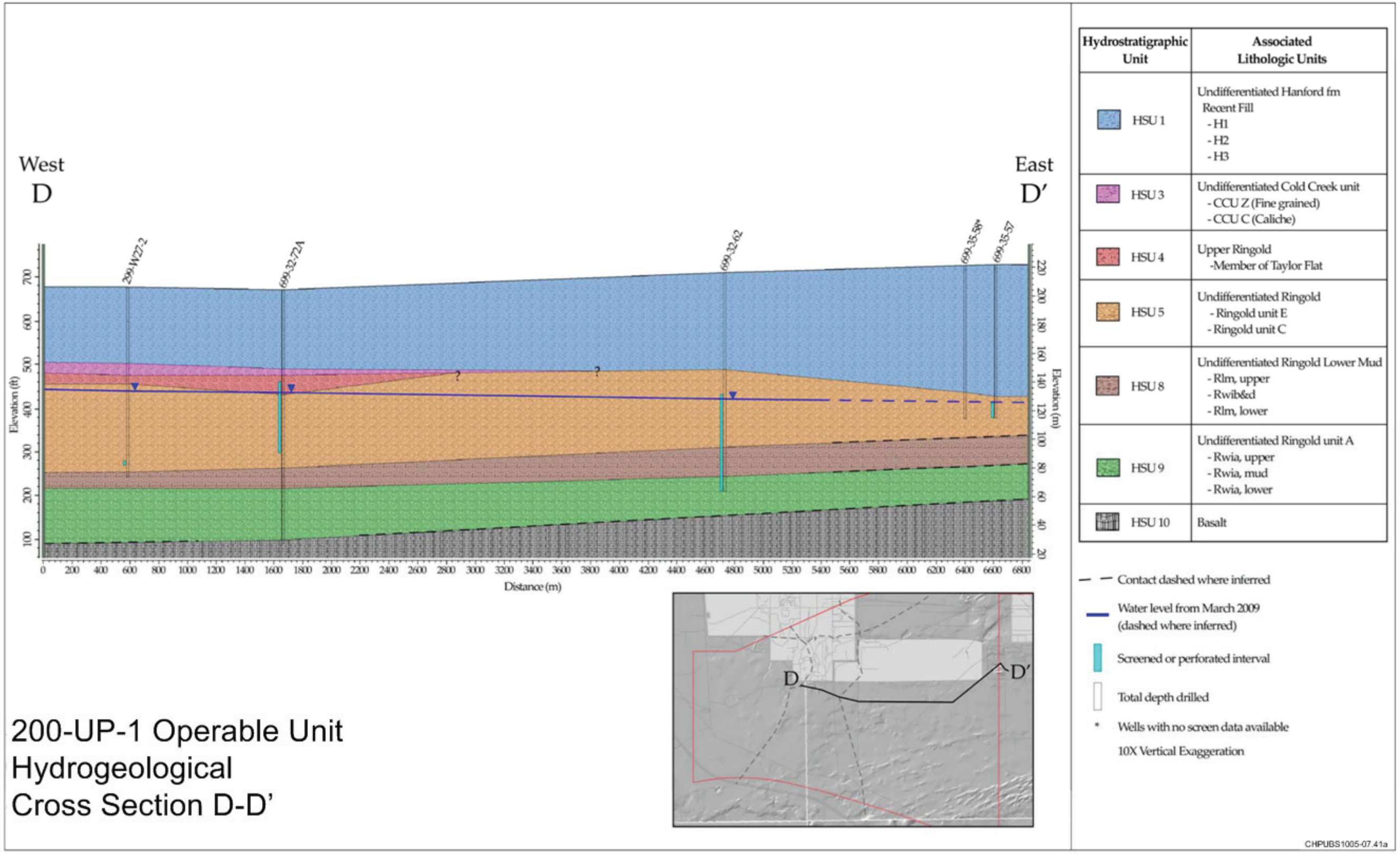


Figure 3-7. Cross Section D-D' Illustrating Hydrogeology beneath the 200-UP-1 OU

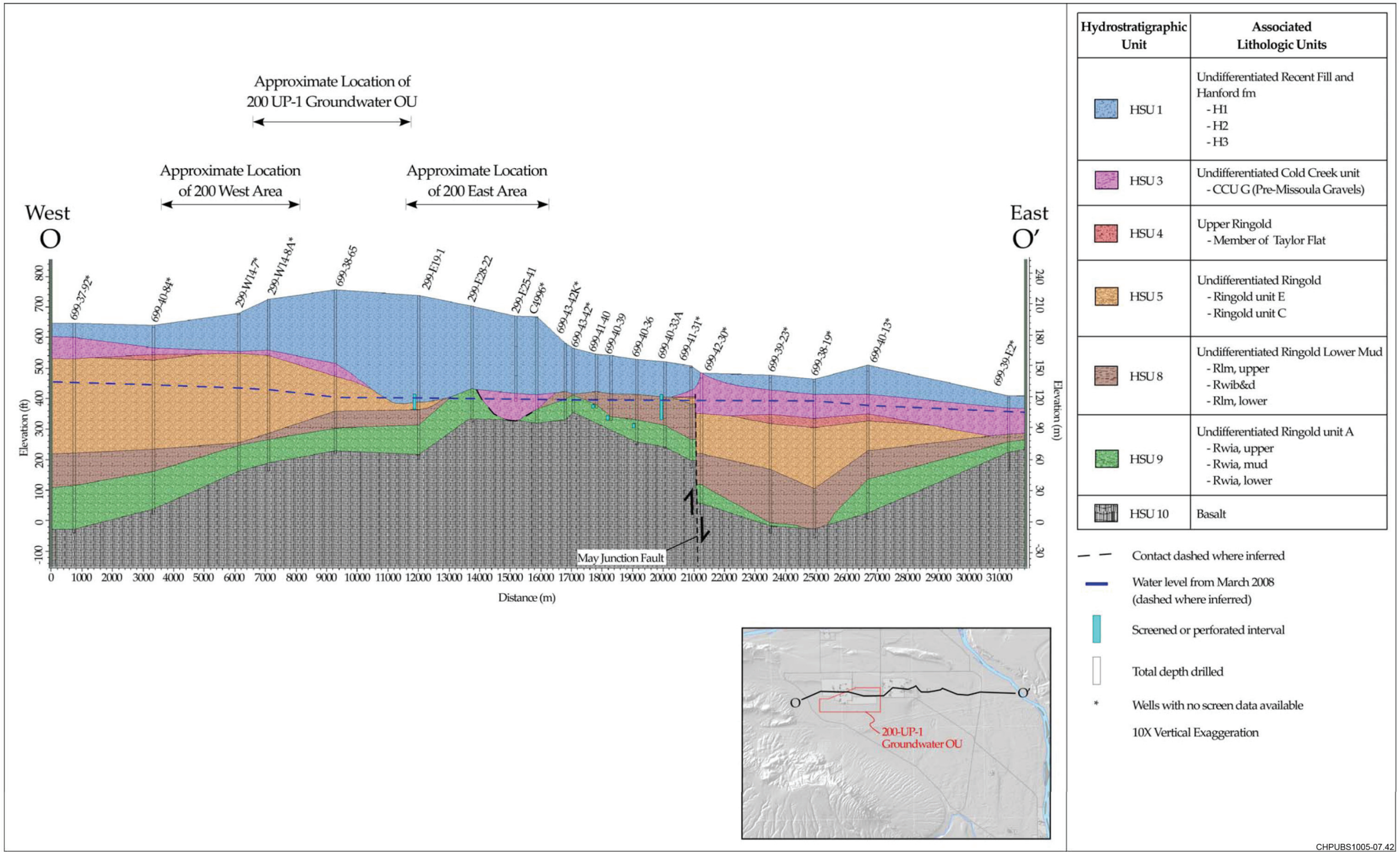


Figure 3-8. Hydrogeology across the Central Plateau Illustrating Various Aquifer Boundaries

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Figure 3-9. Clastic Dike in the Hanford Formation

3.5.2 Holocene Surficial Deposits

Recently deposited surficial deposits that mostly comprise eolian (windblown) silt and sand overlie the Hanford formation. Only about 6 percent of Hanford Site land has been disturbed or is actively used by DOE for waste disposal and storage. Most of the land area is relatively undisturbed because of long-standing DOE management practices. However, these deposits were removed or reworked extensively over much of the 200 Area by construction activities.

3.6 Soils

Groundwater OUs at the Site are administratively separated from vadose zone OUs where contaminant sources are located. This RI/FS report discusses groundwater in the saturated zone of the 200-UP-1 OU. The unconsolidated sediments of the vadose zone that overlie the 200-UP-1 OU saturated zone are addressed in detail in documents for the overlying source OUs.

3.7 Hydrogeology

Groundwater migration is the primary contaminant transport pathway for this OU. Because the groundwater OUs at the Site are administratively segregated from the overlying source OUs, including related vadose zone contamination, this hydrogeologic discussion is focused primarily on the aquifer systems.

3.7.1 Summary of Aquifer Systems in the 200-UP-1 OU

This section describes the hydrostratigraphic and groundwater flow characteristics of the 200-UP-1 OU. Specifically, this section addresses the confined basalt aquifers, semiconfined to unconfined suprabasalt aquifer system, and overlying vadose zone. Groundwater contamination moves within the uppermost (suprabasalt) aquifer system of the 200-UP-1 OU. The suprabasalt aquifer system beneath the Site is unconfined to semi-confined, depending on the depth below the water table. This aquifer system is within the unconsolidated to indurated sand and gravel that may include the Hanford formation, CCU, and Ringold Formation, which overlie basalt bedrock. In some areas, layers of silt and clay confine and separate portions of the suprabasalt aquifer. In the 200-UP-1 OU, the suprabasalt aquifer system is almost entirely within Ringold Formation sediment (Figure 3-5).

Confined aquifers occur within the underlying basalt flows and their sedimentary interbeds. These interbed aquifers are confined by the overlying competent basalt layers and the Ringold lower mud unit where this unit is directly on top of basalt (300 Area).

The vadose zone overlying the 200-UP-1 OU is composed primarily of laterally discontinuous, highly permeable Hanford formation sediment, the CCU, the upper Ringold unit, and upper portions of the Ringold unit E.

Groundwater beneath the Site flows primarily from recharge areas along the elevated western and southwestern margins of the Site to the east and north toward the Columbia River (watershed sink). Groundwater flow patterns historically were modified by groundwater mounds created by the discharge of large volumes of wastewater to the ground. Figure 3-10 summarizes liquid waste discharged to 200 West Area waste sites over time. The water table near the former U Pond, within increased to more than 25 m (82 ft) above background conditions during the pond's peak discharge period (1965 to 1985) (WHC-EP-0707, *216-U-10 Pond and 216-Z-19 Ditch Characterization Studies*). Because large discharges no longer occur at most of the liquid waste disposal sites, the water table in the affected areas is returning to pre-Hanford conditions (DOE/RL-97-36, Rev. 3). Within the 200-UP-1 OU, the 200 West Area recharge mound is dropping, leaving many monitoring wells dry, and changing groundwater flow

patterns and gradients across the Central Plateau. Subsequently, the water table in the 200 West Area has a relatively lower gradient than during years of peak liquid discharge to the ground.

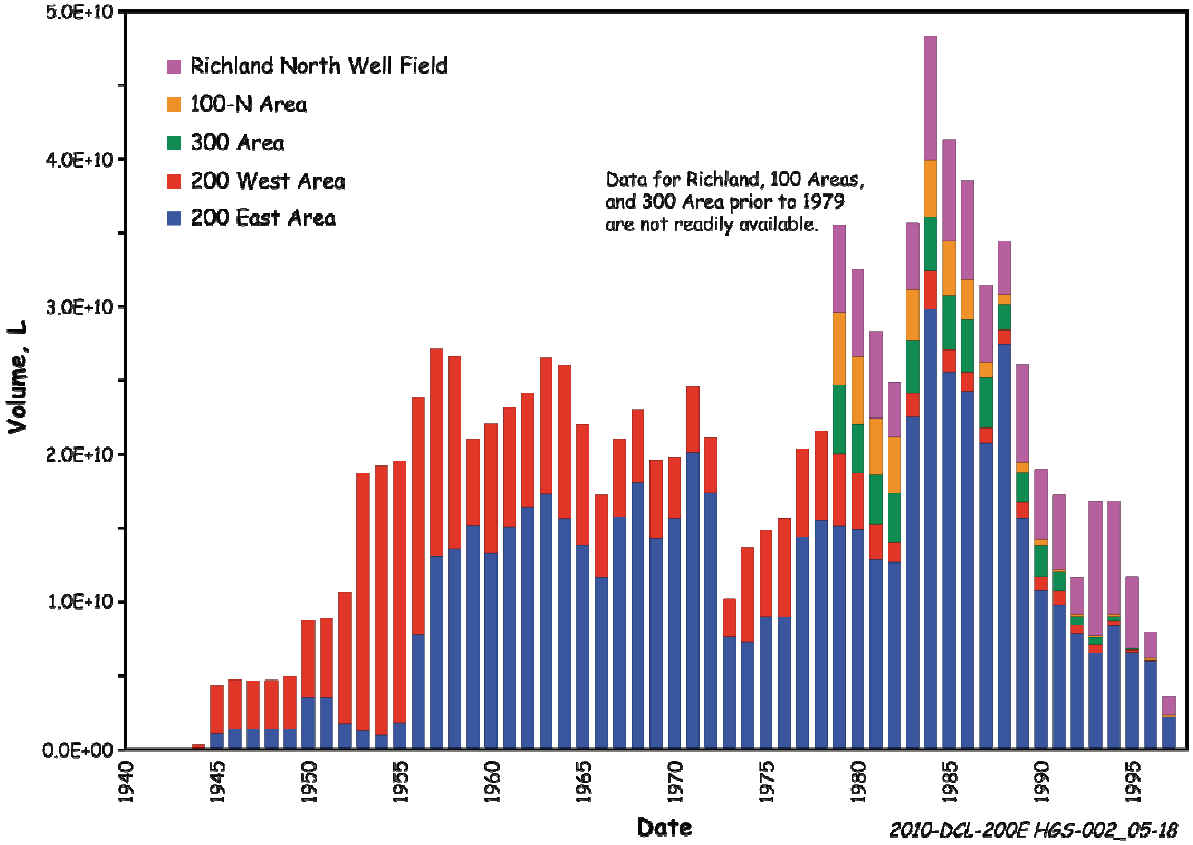


Figure 3-10. Liquid Effluent Disposal Activities Across the Hanford Site

Within the 200-UP-1 OU, the water table still remains several meters above pre-Hanford conditions (Figure 3-11). Limited permitted effluent releases still occur at the 200 Area SALDS, north of the 200 West Area within the adjacent 200-ZP-1 OU. In addition, injection wells that operated as part of the 200-ZP-1 OU P&T system (to remove carbon tetrachloride and other contaminants via groundwater extraction) affected groundwater conditions within the 200-ZP-1 OU and the northern part of the 200-UP-1 OU. It is expected that operation of the 200-ZP-1 OU remedy (the 200 West P&T facility) will affect groundwater and contaminant migration in the 200-UP-1 OU.

3.7.2 200-UP-1 Hydrostratigraphy

Within the 200-UP-1 OU, the geologic units that form the hydrogeologic framework for the area are re-defined as HSUs, which are used for groundwater modeling and contaminant fate and transport modeling. In some cases, the geologic units may be combined based on similarities in hydraulic properties or in areas where uncertainty exists about the correlation and extent of the geologic units. The primary HSUs within the 200-UP-1 OU are, from oldest to youngest (Figure 3-5), defined as follows:

- **Columbia River Basalt**—The Rattlesnake Ridge interbed and deeper interbeds of the Ellensburg Formation, which form confined aquifer flow zones (HSU 10). HSU 10 also includes the Elephant Mountain Member basalt and deeper lava flows of the Saddle Mountains Basalt, which form the basalt-confining horizons.

- **Ringold Formation**—From oldest to youngest, Ringold unit A (HSU 9) is a silty, sandy gravel, which contains locally confined to unconfined aquifer flow zones and directly overlies HSU 10. HSU 9 is confined and separated by the Ringold lower mud unit (or HSU 8) from the overlying Ringold unit E (HSU 5) that makes up most of the unconfined suprabasalt aquifer system. The upper Ringold unit (HSU 4), located within the vadose zone, overlies HSU 5.
- **CCU (HSU 3)**—This unit is only present in the vadose zone, within the boundary of the 200-UP-1 OU. It is undifferentiated and defined as a combination of HSU 2 and HSU 3 (Figure 3-4).
- **Hanford Formation (HSU 1)**—The Hanford formation unconsolidated silt, sand, and gravel (HSU 1) is only in the vadose zone, except near the very eastern, downgradient boundary of the OU where HSU 1 is a highly permeable, unconfined aquifer flow zone when saturated.

3.7.3 Basalt Aquifers

Several regional confined aquifers exist within the Saddle Mountains Basalt-Ellensburg Formation HSU 10 in the 200-UP-1 OU. The confined water-bearing zones occur in the sedimentary interbeds of the Ellensburg Formation and in interflow and fractured intraflow intervals within the basalts. The uppermost regional confined aquifer in the vicinity is generally within the Rattlesnake Ridge interbed (Ellensburg Formation), but may also include the fractured flow top and bottom of the enclosing basalt flows. This aquifer is referred to as the upper basalt-confined aquifer. Within the 200-UP-1 OU, the basalt surface is interpreted as the basal hydrogeologic boundary for the overlying (suprabasalt) aquifer system that has been affected by past liquid effluent disposal practices.

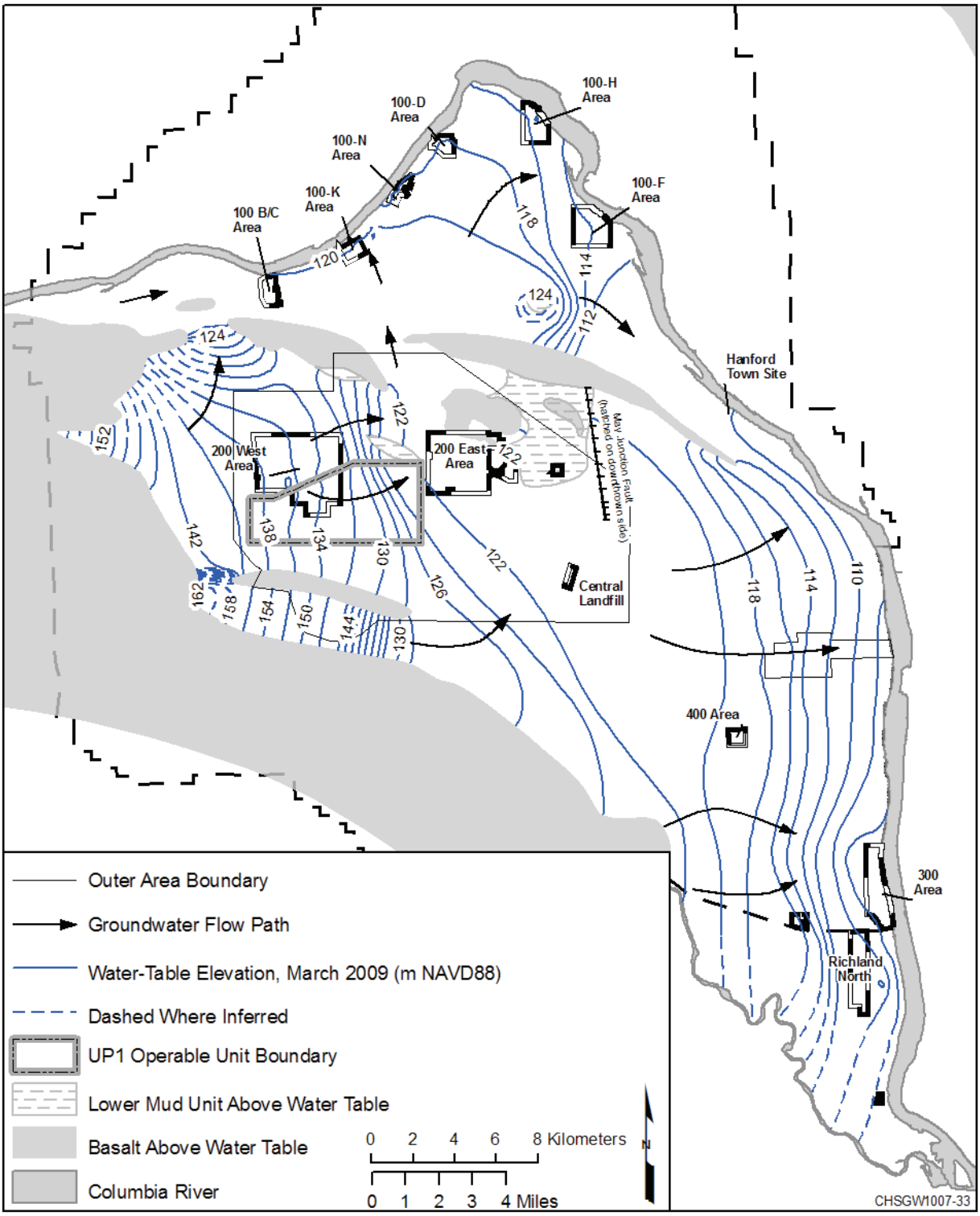
The confining unit for the upper basalt-confined aquifer within the 200-UP-1 OU is the Elephant Mountain basalt. Figure 3-12 shows a potentiometric surface map of the upper basalt-confined aquifer. Groundwater within this aquifer generally moves to the east-northeast beneath the OU.

Water level measurements within the upper basalt-confined aquifer and the overlying unconfined and Ringold confined aquifers near the 200 West Area indicate a downward hydraulic gradient, as illustrated on Figure 3-13 and described in DOE/RL-2008-66. The downward gradient occurs between the Ringold Formation confined aquifer (HSU 9) and the upper basalt-confined aquifer system (HSU 10), and between the unconfined aquifer (HSU 5) and the Ringold Formation confined aquifer. The confining units are interpreted to be laterally continuous within the 200-UP-1 OU, preventing communication between the aquifers (see Section 3.6.5).

3.7.4 Suprabasalt Aquifer System

The suprabasalt aquifer system comprises the uppermost aquifer system in the 200-UP-1 OU, which controls groundwater contaminant migration across the 200-UP-1 OU. This aquifer system is defined primarily by two intervals: the uppermost unconfined interval contained within HSU 5 and the deeper semiconfined to confined interval within the basal Ringold HSU 9. These two aquifer intervals are separated and isolated within the 200-UP-1 OU by the Ringold lower mud unit (HSU 8) confining unit. HSU 5 and HSU 9 are composed of semi-indurated and partially cemented silty sandy gravel.

The depth to the uppermost unconfined aquifer (the thickness of the vadose zone) ranges from approximately 53 m (175 ft) within the 200 West Area source area, to more than 106.7 m (300 ft) near the southeastern boundary of the 200-UP-1 OU. This variation in vadose zone thickness reflects the relative relief of the large paleo-flood-deposited Cold Creek Bar that forms the elevated Central Plateau.



Source: DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*.

Figure 3-11. Hanford Site Groundwater Elevations and Flow Patterns

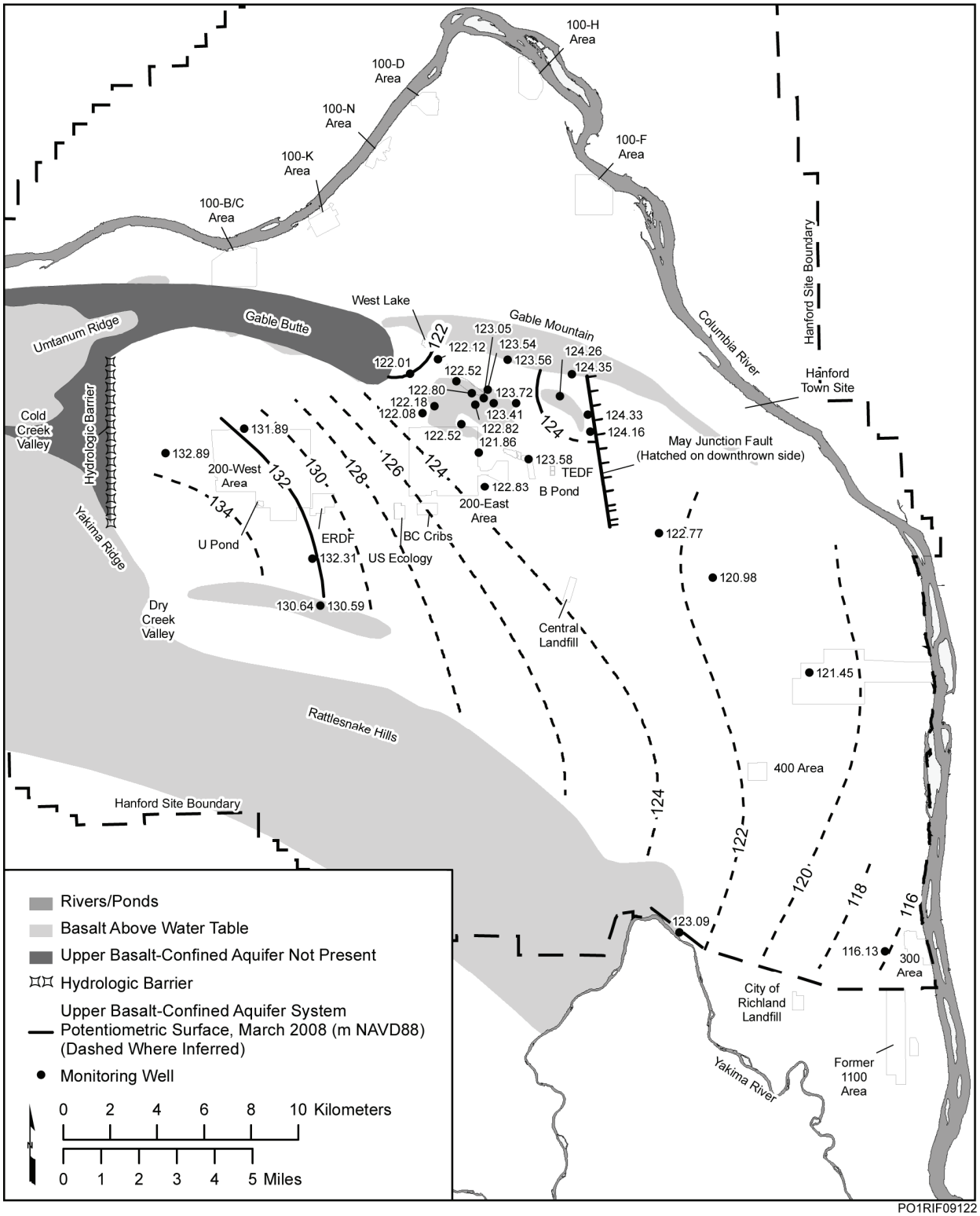


Figure 3-12. Potentiometric Map of the Basalt Confined Aquifer (Rattlesnake-ridge Interbed)

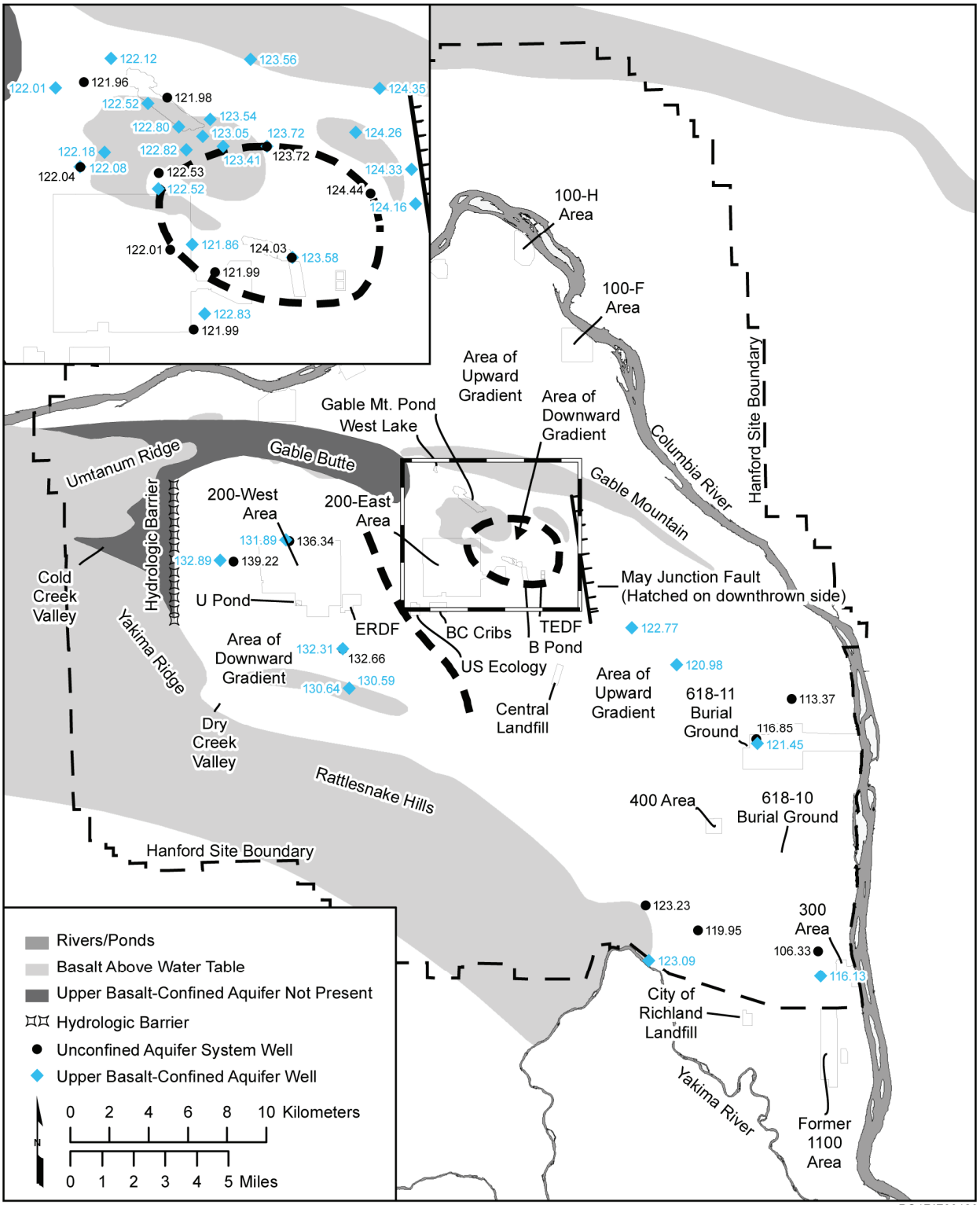


Figure 3-13. Comparison of Head Measurements, in Meters, between the Unconfined and Basalt Confined Aquifer Systems

Regional Miocene-Pliocene age basalt uplift along the Umtanum-Gable structural axis (north of the 200-UP-1 OU) and subsequent depositional thinning or paleo-flood erosion have created a sequence of uplifted Ringold sediment within the east-northeastern 200-UP-1 OU, which results in older and presumably less-permeable sediment (of HSU 5) comprising the uppermost aquifer near the downgradient margin of the OU (Figures 3-8 and 3-14). Therefore, groundwater flowing eastward and downgradient across the 200-UP-1 OU moves through progressively older HSU 5 sediment until it emerges at the erosional boundary within the 200 East Area. The reduced hydraulic conductivity of the older sediment, as well as the reduction in the aquifer's thickness because of the shallower confining sediment (HSU 8), creates physical restrictions in groundwater flow at the eastern edge of the 200-UP-1 OU (Figure 3-8); however, the very uppermost portion of the unconfined aquifer encounters the lower portion of the Hanford formation or CCU (HSU 1 or HSU 3), which unconformably overlies the Ringold Formation (HSU 9 or HSU 5). The younger, more-permeable HSU 1 or HSU 3 provides opportunity for preferential groundwater flow within the very uppermost portion of the unconfined aquifer because of the higher hydraulic conductivity of the younger HSU 1 or HSU 3 relative to the adjacent and underlying HSU 5. These unconfined aquifer conditions are manifested by the historical increase in water table elevation and gradient created by the low-permeability Ringold (HSU 9-5) sediments and the abrupt steepening (elevation drop) in the water table gradient in the region where saturated younger and highly permeable sediment (HSU 1 or HSU 3) occupies the uppermost aquifer interval (near the 200 East Area) (Figures 3-8 and 3-11). A suprabasalt aquifer thickness map is shown on Figure 3-15.

3.7.5 Aquifer Intercommunication

Throughout most of the 200-UP-1 OU, groundwater in the uppermost unconfined aquifer (HSU 5) is isolated from groundwater in the lower confined interval (HSU 9) and the lower basalt confined aquifers by the Ringold lower mud unit (HSU 8) because the confining units are laterally continuous within the 200-UP-1 OU, preventing communication.

The hydraulic head within the Ringold Formation confined aquifer (HSU 9) is lower than in the unconfined aquifer system (HSU 5) above the Ringold lower mud unit (HSU 8), thereby resulting in a downward hydraulic gradient between the two aquifers. A downward gradient also exists between the Ringold Formation confined aquifer and the underlying upper basalt confined aquifer. Data supporting this conclusion are presented on Figure 3-13, which compares water level elevations in adjacent wells open to the upper basalt confined aquifer and the overlying aquifers. Flow across aquifers is constrained by the confining layers, which are laterally continuous within the 200-UP-1 OU, based on well data.

Outside of the 200-UP-1 OU, to the north and northeast, depositional thinning or erosion has removed HSU 8, resulting in exposure of the lower confined aquifer system (HSU 9 or HSU 10) to the uppermost unconfined aquifer system in some areas (HSU 9, HSU 5, and/or HSU 1). This northern region is known to have intercommunication based on the vertical distribution of contamination within the aquifer system. As illustrated on Figure 3-16, carbon tetrachloride has migrated deep into HSU 9, where HSU 8 is not present. No apparent intercommunication occurs between the lower confined (the basalt HSU 10 or HSU 9 intervals) and the upper unconfined HSU 5 beneath the 200-UP-1 OU because of the continuous nature of the basalt confining layer.

The distribution (position and extent) of hydrogeologic units at or near the water table is a result of Miocene-Pliocene age (Ringold Formation) geologic uplift, and subsequent Pleistocene cataclysmic flood and ancestral Columbia River erosion. Figure 3-17 depicts the distribution of hydrogeologic units at the water table during 2006. Figure 3-17 illustrates that Ringold Formation HSU 5 in 200 West is the primary hydrogeologic unit that comprises the unconfined aquifer. Near the eastern border of the OU, the Hanford formation HSU 1 is the uppermost hydrogeologic unit defined at the water table. This region of change between HSU 5 and HSU 1 is the area coincident with the steep water table gradient reflective of

groundwater flow from upgradient within the lower-permeability HSU 5 into the higher-permeability HSU 1.

Subsequently, two geologic features are believed to influence the observed behavior of groundwater plumes across the 200-UP-1 OU. These geologic features limit the thickness of the unconfined aquifer and constrain the movement of groundwater and contaminants at the downgradient edge near the eastern border of the 200-UP-1 OU.

Within the 200-UP-1 OU, the relative thickness and geometric shape of the unconfined aquifer can be described as a basin or wedge that reflects the dipping surface of HSU 8. HSU 8 forms the base of the unconfined aquifer and dips gently into the Cold Creek syncline south and southwest of 200-UP-1 OU (upgradient direction), forming a thick wedge of saturated HSU 5 sediment above HSU 8. Downgradient, toward the east-northeastern margin of the OU, HSU 8 has been uplifted on tilted basalt beds, which creates thinning of the overlying saturated HSU 5 sediment interval (forming the conceptual lip of the basin). The structural rise in HSU 8 across this area is more than 50 m (164 ft), as shown on Figure 3-18. In 2002 (PNNL-13858), the uppermost unconfined aquifer thickness (the saturated thickness of HSU 5) ranged from more than 72 m (236 ft) near U Pond (upgradient) to less than 10 m (33 ft) at the northeastern boundary of the OU (downgradient). The thickest portion of the uppermost contaminated aquifer is beneath the 200 West Area sources, where HSU 8 is structurally the deepest and the water table mound is the highest. Depth-discrete groundwater samples from multiple wells indicate that some contamination extends throughout the saturated interval to the bottom of the unconfined aquifer (top of HSU 8) (Figure 3-18).

At the eastern, downgradient margin of 200-UP-1 OU, the Hanford-Ringold contact forms the second significant hydrogeologic interface related to the distribution and movement of groundwater contaminants across the 200 Central Plateau. Fluvial erosion and paleo-flooding have shaped the contact between the Hanford formation and underlying Ringold Formation sediments (Hanford-Ringold contact). Regionally, this Hanford-Ringold contact is fairly flat relative to the underlying geologic units (Figure 3-7), with exceptions where fluvial or paleo-flooding eroded into the underlying Ringold Formation and scoured larger channels (Figure 3-19).

The results of hydraulic testing from many boreholes across the Site have revealed a significant permeability (hydraulic conductivity) difference between the Hanford formation (HSU 1), the CCU (HSU 3), and the underlying Ringold Formation (HSU 5 and HSU 9) sediments. This hydraulic conductivity contrast creates preferential groundwater flow through the very uppermost portion of the unconfined aquifer within the younger Hanford formation or CCU sediments where they occur at or below the water table.

During operational years at the Site, when artificial groundwater mounds were the dominant cause of high gradients across the Central Plateau, groundwater and dissolved contaminants were driven much faster across the 200-UP-1 OU. These contaminants dispersed eastward across the 200 East Area (into the adjacent 200-PO-1 Groundwater OU) or north and northeastward through the 200 East Area Gable Gap area (into the adjacent 200-BP-5 Groundwater OU). The resultant flow paths of contaminants in groundwater were influenced by artificial gradients in the 200 East Area and the location of the sources in the 200 West Area.

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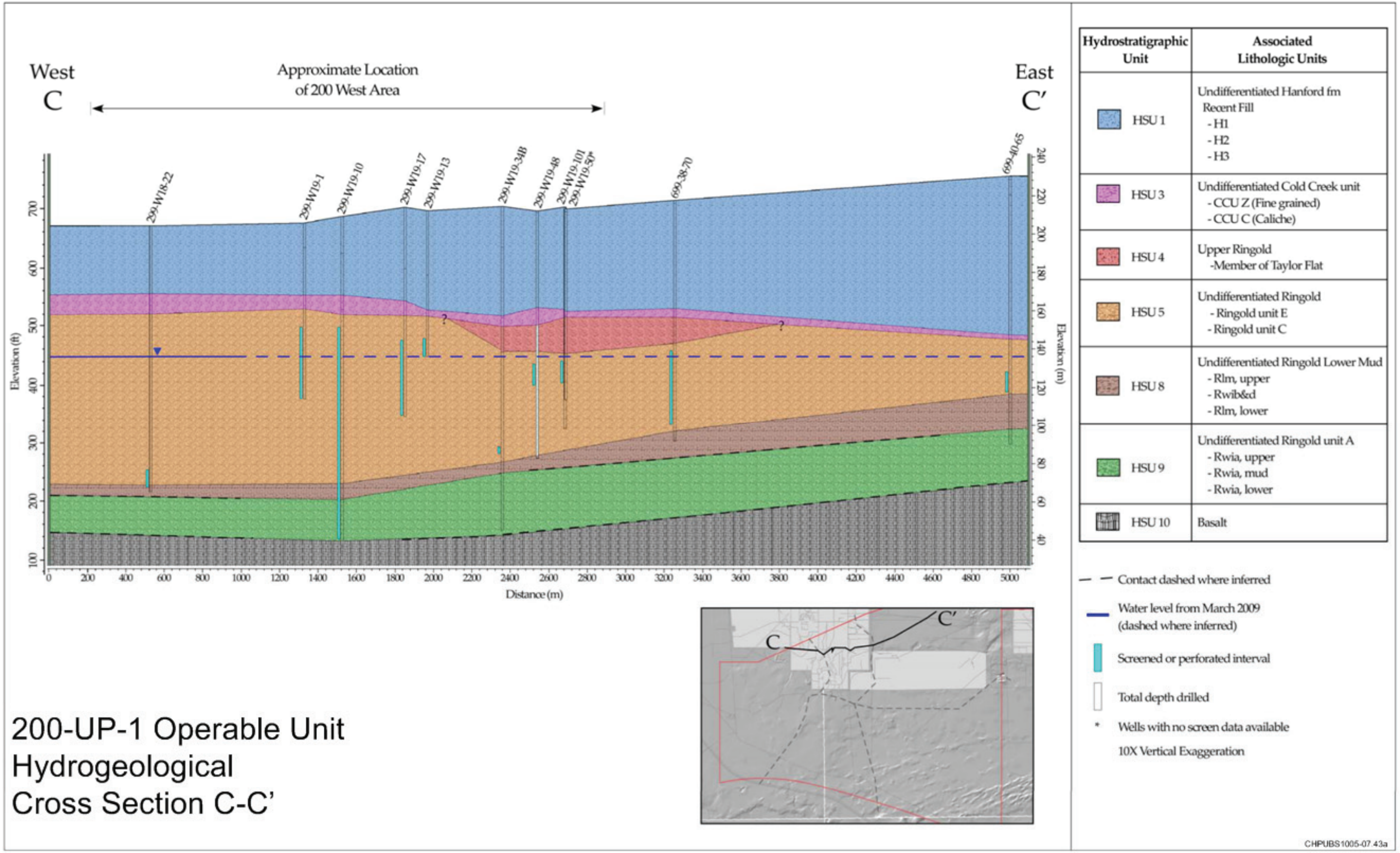

Figure 3-14. Suprabasalt Aquifer System within the 200-UP-1 OU

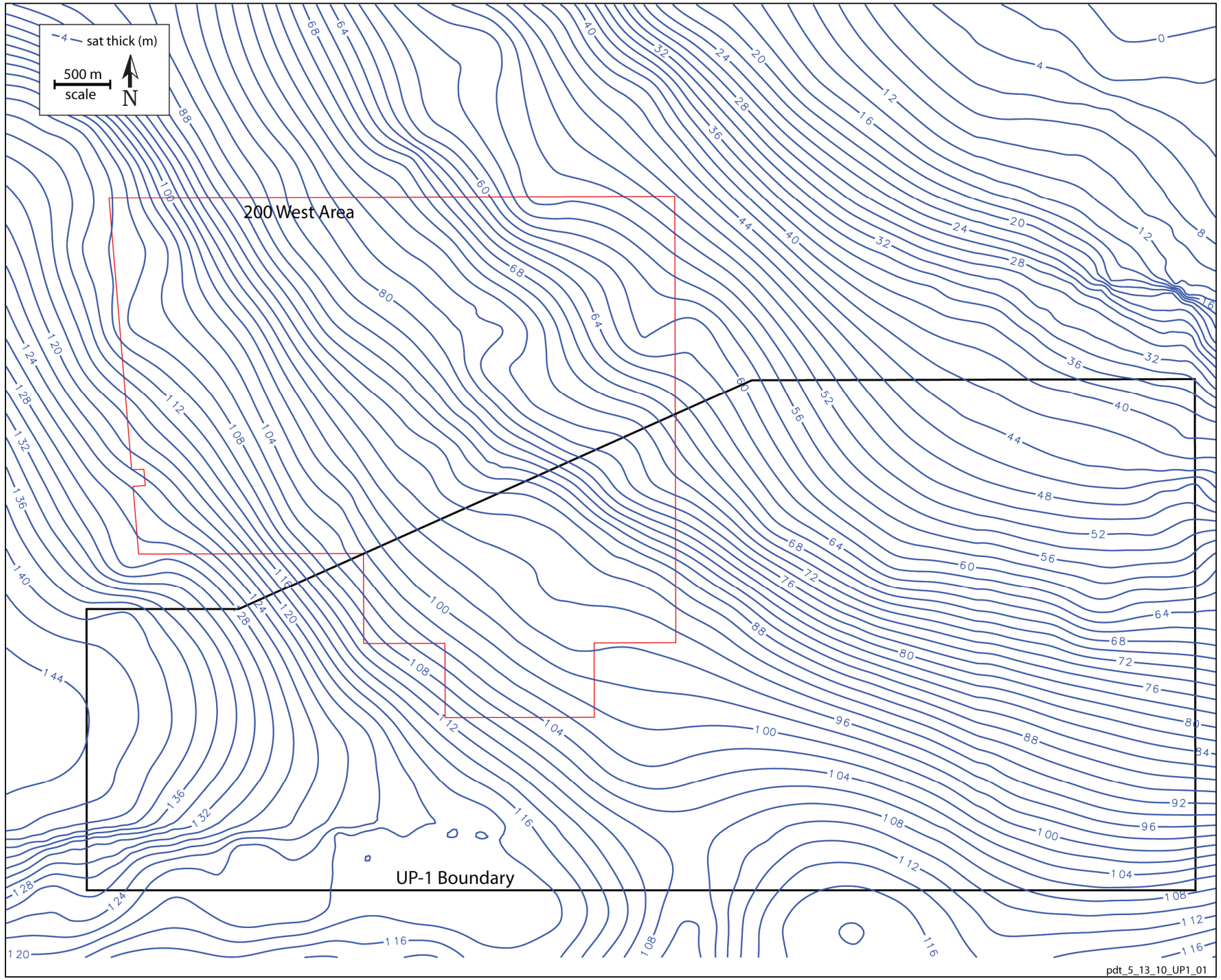

Figure 3-15. Suprabasalt Aquifer Thickness Map, 200-UP-1 OU

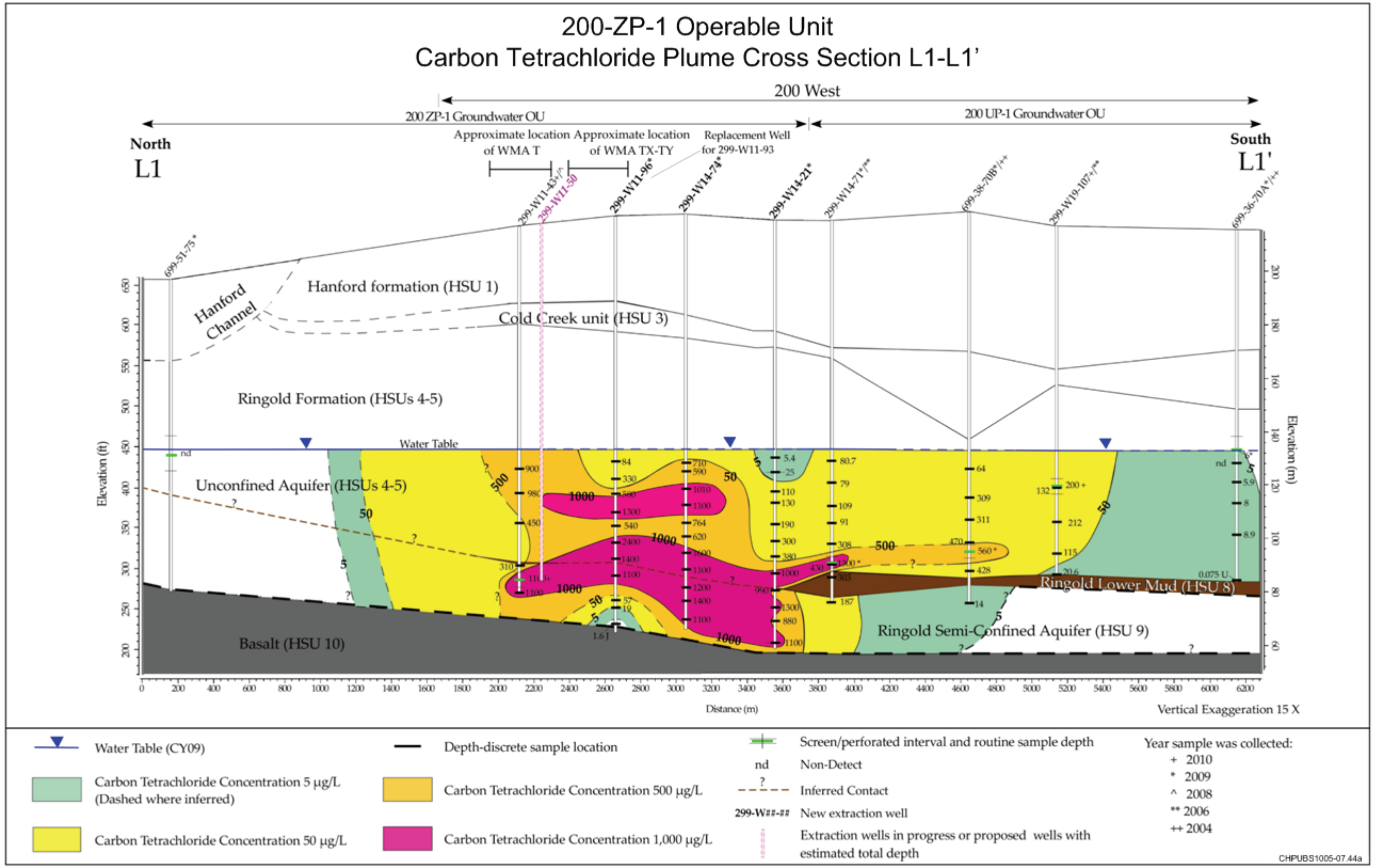

Figure 3-16. 200 West Area Groundwater Cross Section Illustrating Suprabasalt Aquifer Intercommunication and Distribution of Carbon Tetrachloride

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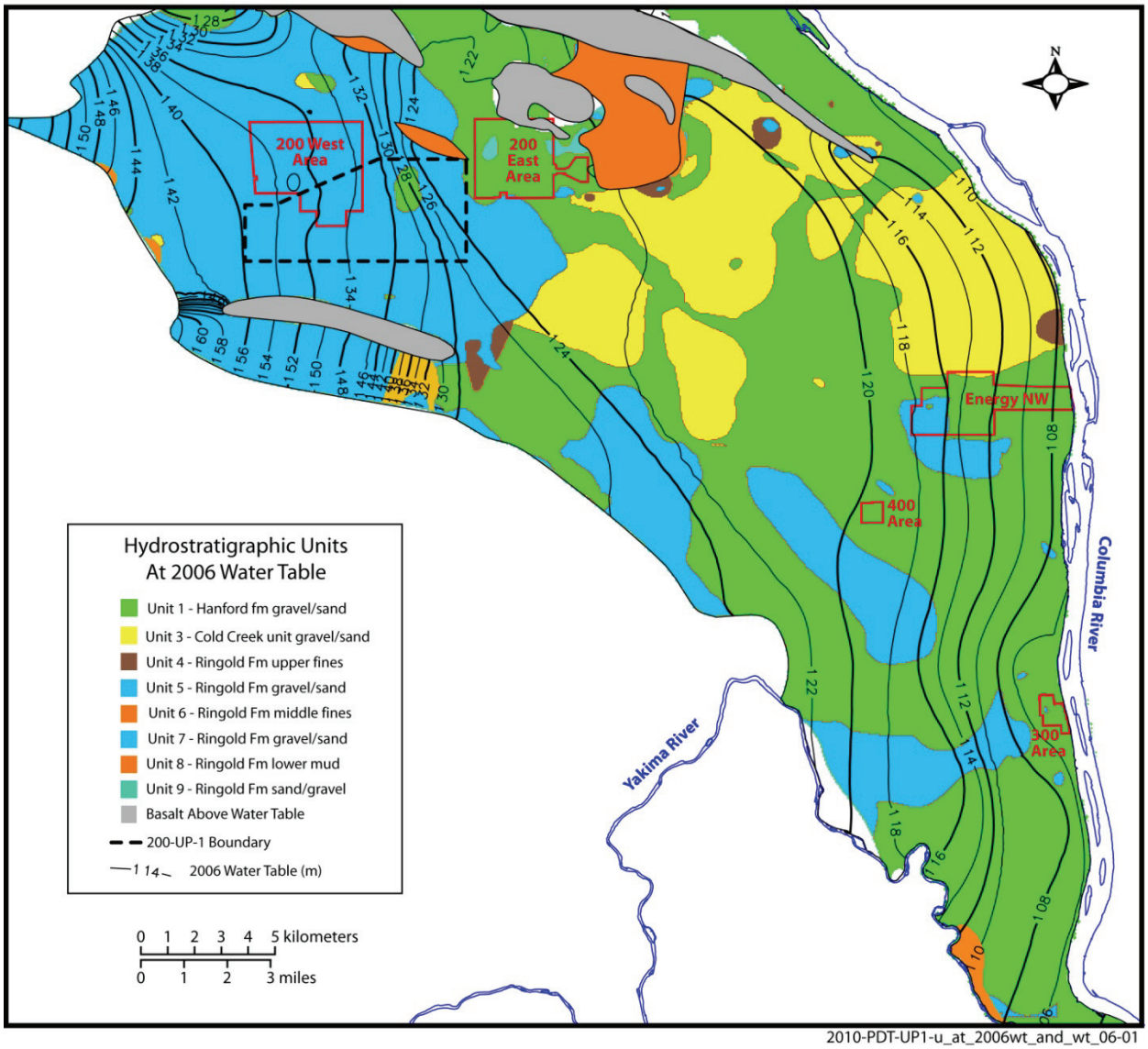

Figure 3-17. Distribution of Hydrogeologic Units at the Water Table, 200-UP-1 OU

Because of the general shape of the water table mound that exists beneath the 200 West Area, contamination from sources in the southern half of the 200 West Area track eastward toward the 200-PO-1 Groundwater OU, and contamination from sources in the northern half of the 200 West Area track more north to northeasterly into the 200-BP-5 Groundwater OU. Today, there is no measureable remnant groundwater mound within the 200 East Area. Within the 200 West Area, the water table still reflects remnant mounding and remains elevated above that of the 200 East Area. The variation between the elevation of the residual mound in the 200 West Area and the elevation of the water table within the 200 East Area (200-PO-1 and BP-5 Groundwater OUs) is partly because of the difference in aquifer properties between the saturated HSU 5 and HSU 1 and HSU 3, respectively (Figure 3-17).

The groundwater mound that existed beneath the 200 East Area, dominated by saturated high-permeability HSU 1 and HSU 3 sediment, declined and re-equilibrated at a much faster rate than the mound in the 200 West Area. The older, lower-permeability units within the 200-UP-1 OU coupled with the lower to flat water table gradient between the 200-UP-1 OU and the downgradient 200-PO-1 Groundwater OU will result in a dramatic slowing of groundwater and contaminant movement beyond the

200-UP-1 OU. In other words, the rapidly falling heads within the 200 West Area and subsequent lowering of the water table into older, less-permeable HSU 5 sediment will result in slower movement and increasing lateral constraint on the remaining groundwater and contamination within that portion of the aquifer. In addition, groundwater that flows beyond the Hanford-Ringold contact boundary at the eastern edge of the 200-UP-1 OU will be slowed dramatically because of the flat gradient in this region (200-PO-1 Groundwater OU). Combined, these effects may result in increased residence time for residual contaminants emanating from the 200-UP-1 OU.

3.7.6 Conceptual Site Model

The 200-UP-1 OU CSM consists of the Site's hydrogeology and known distribution of groundwater contamination combined with the conceptual exposure model. This section discusses the physical aspects of the CSM, including the geologic and hydrogeologic features comprising the suprabasalt aquifer system and this system's control of groundwater contaminants migrating across the area. The conceptual exposure model component identifies the means by which human or ecological receptors may contact contaminants in groundwater and is developed in Section 6.2.4. The CSM of the hydrogeology of the 200-UP-1 OU is described in PNNL-13858. This study concluded that two aquifers exist within the suprabasalt sediment of the 200 West Area. The upper unconfined aquifer occurs in the sediment of HSU 5 (unit E of the Ringold Formation), and in the lower portion of HSU 1or HSU 3. Currently, groundwater in the unconfined portion of the suprabasalt aquifer (HSU 5) generally flows easterly across the Central Plateau toward the Columbia River (Figures 3-8 and 3-9).

An underlying confined aquifer consists of HSU 9 sediment separated from the overlying unconfined aquifer by HSU 8. The resulting fluvial silty, sandy gravel aquifer forms the lower suprabasalt (Ringold Formation) confined aquifer. Within the 200-UP-1 OU, groundwater flow in the Ringold Formation confined aquifer (HSU 9) is isolated from the overlying HSU 5 (Figure 3-7). At the eastern boundary of the 200-UP-1 OU, however, groundwater from HSU 9 and groundwater within HSU 5 converge from the west and south (Figure 3-8), potentially upwelling and mixing with the unconfined aquifer where Hanford formation sediments (HSU 1) juxtapose Ringold Formation sediments exposed within erosional channels that trend across the 200 East Area.

A deeper confined aquifer system also exists in the Columbia River Basalt Group (HSU 10) underlying the Ringold Formation (PNNL-13858). The upper basalt confined aquifer occurs within fractured basalt and sedimentary interbeds of the Upper Saddle Mountains Basalt, which directly underlies the Ringold Formation confined aquifer. Groundwater generally flows from west to east within the upper basalt confined aquifer (Figure 3-12). Vertical gradients are downward within this confined aquifer system beneath the 200-UP-1 OU (Figure 3-13). Groundwater within the basalt confined aquifer is isolated from groundwater in the overlying suprabasalt aquifer beneath the 200-UP-1 OU because the confining basalt layer is laterally continuous, preventing communication between the aquifers.

All of the groundwater contamination in the 200-UP-1 OU originated within the 200 West Area and vicinity. The primary contributors to groundwater contamination originating from within the 200-UP-1 OU include S Plant and U Plant Ponds, cribs and trenches, and SST WMA S-SX. The carbon tetrachloride plume originated from the PFP (Z-Plant) waste sites overlying the 200-ZP-1 OU.

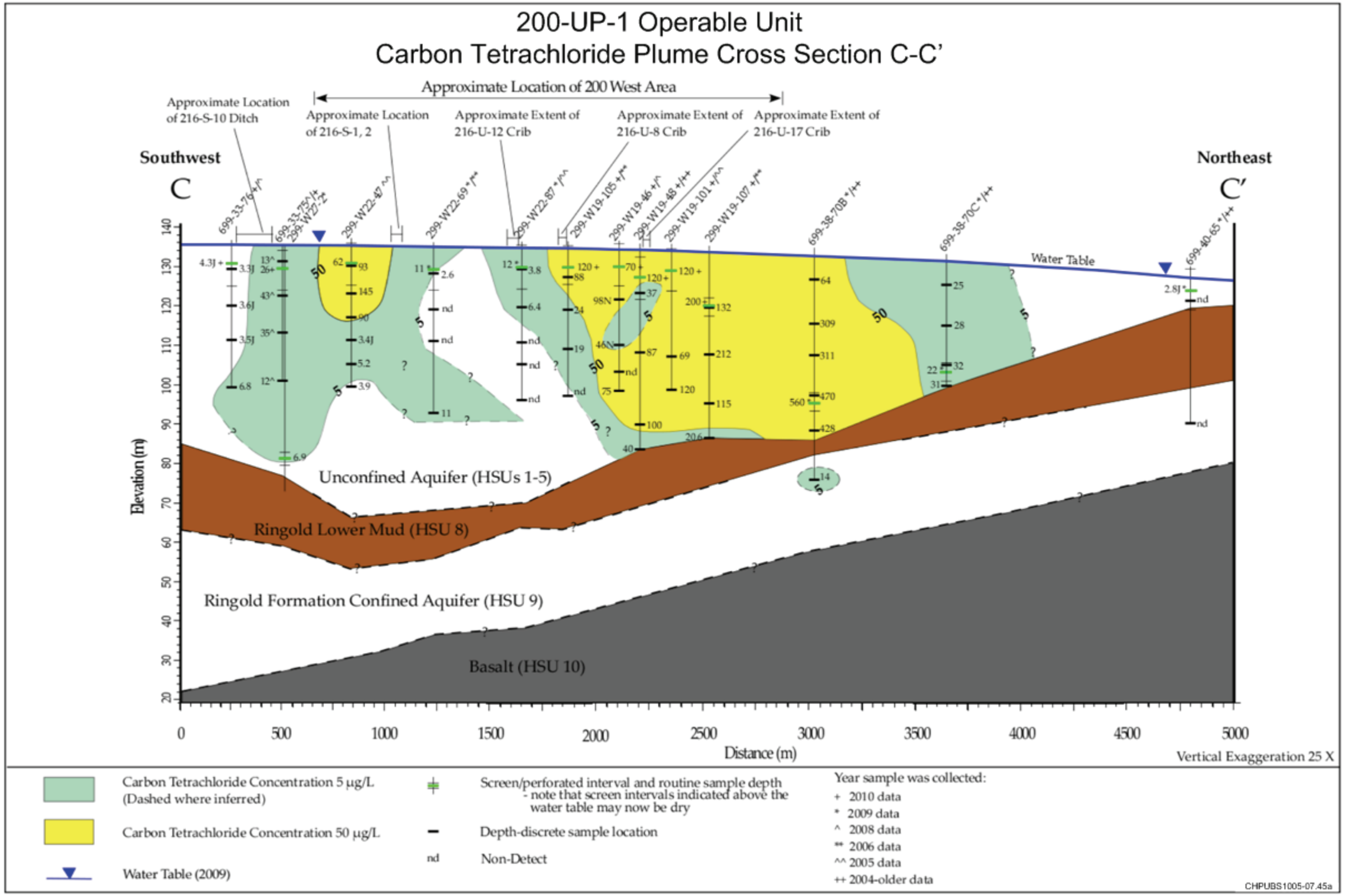

Figure 3-18. Hydrogeologic Cross Section of the 200-UP-1 OU Illustrating the Dipping Nature of the Ringold Lower Mud Unit (HSU 8) and the Depth Distribution of Carbon Tetrachloride Contamination within the Unconfined Aquifer

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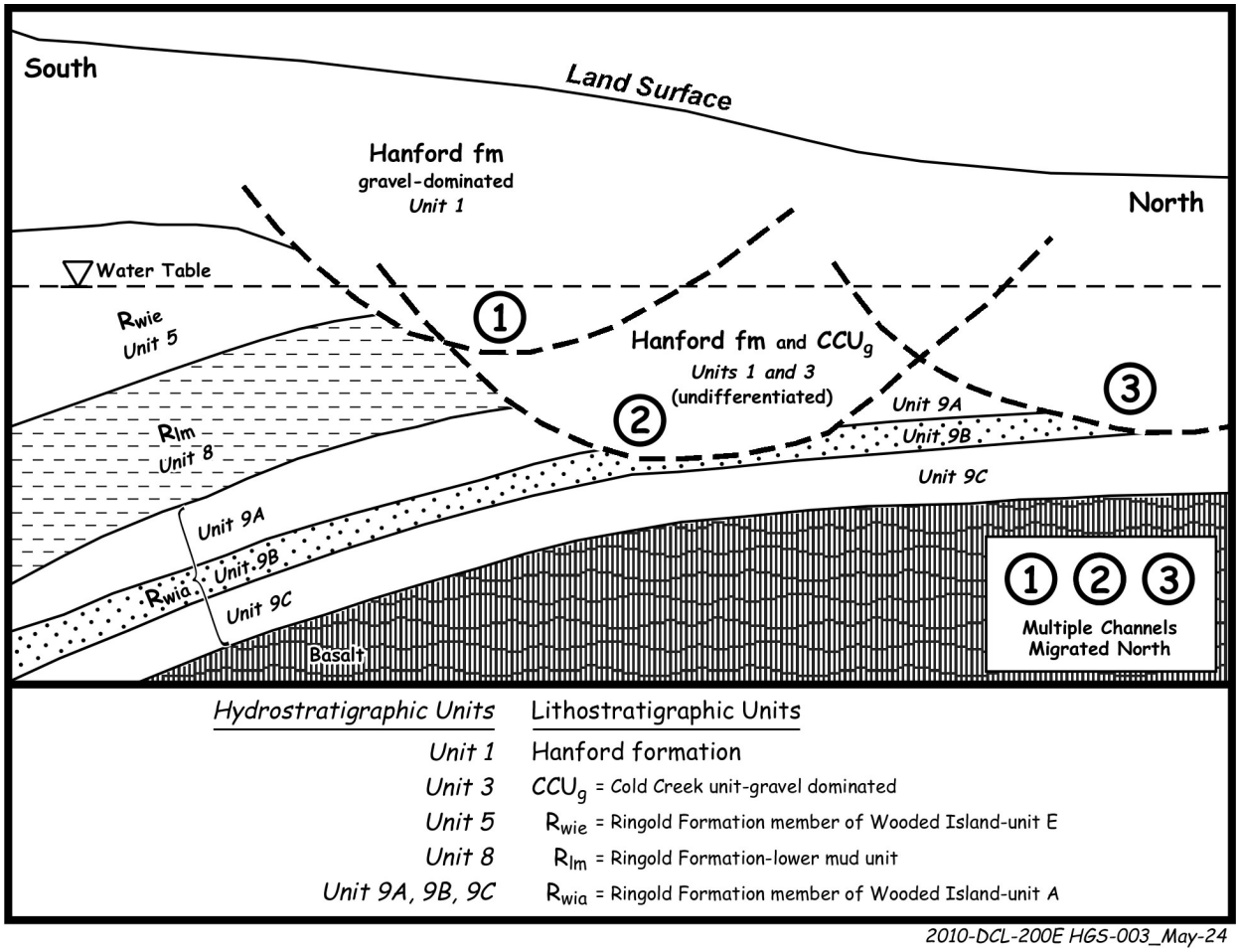

Figure 3-19. Conceptualization of Paleo-Flood Erosion and Channeling into Older Ringold Formation Sediment

Sufficient effluent volumes were disposed of at U Pond and other waste sites, resulting in a persistently elevated water table, providing the gradient to move contaminants away from the sources. Liquid effluent initially migrated vertically downward beneath the waste sites through the thick vadose sediments composed primarily of permeable Hanford formation sand and gravel (HSU 1) until they contacted the CCU (HSU 3). Many less mobile contaminants reacted and sorbed to the sediment above or within HSU 3 and do not present a hazard to groundwater. The more mobile contaminants (tritium, I-129, and nitrate) were dispersed across HSU 3 as the liquid effluent accumulated or perched on top of and within the unit, until sufficient hydraulic head or pathways through HSU 3 were presented. HSU 3 created a natural vertical barrier that spread perched water from multiple nearby disposal sources and contributed to the mixing and commingling of contaminants within the vadose zone before the effluent reached groundwater, making the identification of sources problematic.

Contaminated effluent eventually reached the water table and affected the aquifer below several liquid waste disposal areas within the 200-UP-1 OU. The resulting groundwater mound has influenced groundwater flow rate and direction over the entire 200 West Area and vicinity for more than four decades. During peak disposal, the groundwater mound under U Pond caused an estimated additional 25 m (82 ft) of hydraulic head. The resulting downward gradient and radial flow pattern increased the rate of groundwater flow toward the 200 East Area. Groundwater monitoring data indicate that downward

gradients were generated during disposal operations, which resulted in a more extensive vertical distribution of contaminants beneath the pond (PNNL-SA-38387, *Multi-Source Influence on Vertical Contaminant Distribution and Transport in a Thick Unconfined Aquifer Beneath the Hanford Site at Richland, Washington*), forcing contaminants lower within the thick uppermost suprabasalt aquifer (HSU 5). As effluent and groundwater encountered the underlying and relatively impermeable HSU 8, they were diverted laterally and spread downgradient (easterly and southeasterly) through HSU 5 sediment. Farther east, near the boundary of the 200-UP-1 OU, the Ringold Formation sediments (HSU 5) are replaced with Hanford formation or CCU (HSU 1 or HSU 3) sediments located at or near the water table. The contaminated groundwater is expected to continue to move downgradient within the upper Ringold sediment (HSU 5) and into the adjacent Hanford formation or CCU (HSU 1 or HSU 3) sediment beyond the boundary of the 200-UP-1 OU.

Figure 3-20 identifies 200-UP-1 OU waste sites. Figure 3-21 conceptually illustrates the hydrologic units identified beneath the 200-UP-1 OU, the artificial recharge and mounding, and the groundwater contaminant plumes from the 200 West Area sources. Figure 3-21 shows the period of highest liquid waste disposal to the ground. All liquid effluent disposal to the ground beneath the 200-UP-1 OU and most of the associated artificial groundwater recharge to the 200 West Area ceased by the early 1990s. Since that time, much of the groundwater mound within the unconfined aquifer that was beneath the 200 West Area has declined. Figure 3-22 provides the CSM under current conditions within 200-UP-1 OU.

3.7.7 Groundwater Recharge

Movement of contaminants in groundwater at the Site depends heavily on recharge to the unconfined aquifer. As the effects of past artificial discharges dissipate, the water table is expected to return to more natural conditions, and natural recharge will become the driving force when evaluating future groundwater flow conditions and related contaminant transport. Previous work on the relationship of natural recharge to groundwater movement at the Site has focused on direct recharge from infiltrating rainfall and snowmelt within the area, as discussed in PNNL-14717, *Natural Recharge to the Unconfined Aquifer System on the Hanford Site from the Greater Cold Creek Watershed: Progress Report 2004*.

Except for the SALDS, the 200 Area TEDF, and septic drain fields, substantial artificial recharge to the vadose zone ended in the mid-1990s. The recharge to the aquifer from the septic systems is considered small compared to other liquid waste disposal sites within 200-UP-1 OU. At the Hanford Site, natural recharge from the deep infiltration of precipitation varies spatially and temporally and ranges from near-zero to more than 111 mm/yr depending on vegetative cover, climate, and soil type (G. W. Gee, J. M. Keller, and A. L. Ward, 2005, *Measurement and Prediction of Deep Drainage from Bare Sediments at a Semiarid Site, Vadose Zone Journal*, 4:32-40). Recharge is greatest in areas with nonvegetated coarse-textured surface soil (gravel) and is also generally higher near the basalt ridges because of greater precipitation and run-off. Recharge rates are lowest in areas of fine-textured soil (silt loam) with shrubs. Hanford field studies have been performed to evaluate the natural water balance and groundwater recharge conditions on the site (Gee et al., 1992; Fayer et al., 1996, "Estimating Recharge Rates for a Groundwater Model Using a GIS;" PNNL-14753, *Groundwater Data Package for Hanford Assessments*). Natural and artificial, recharge rates applied for groundwater modeling (Section 5.0) were acquired from PNNL-14753.

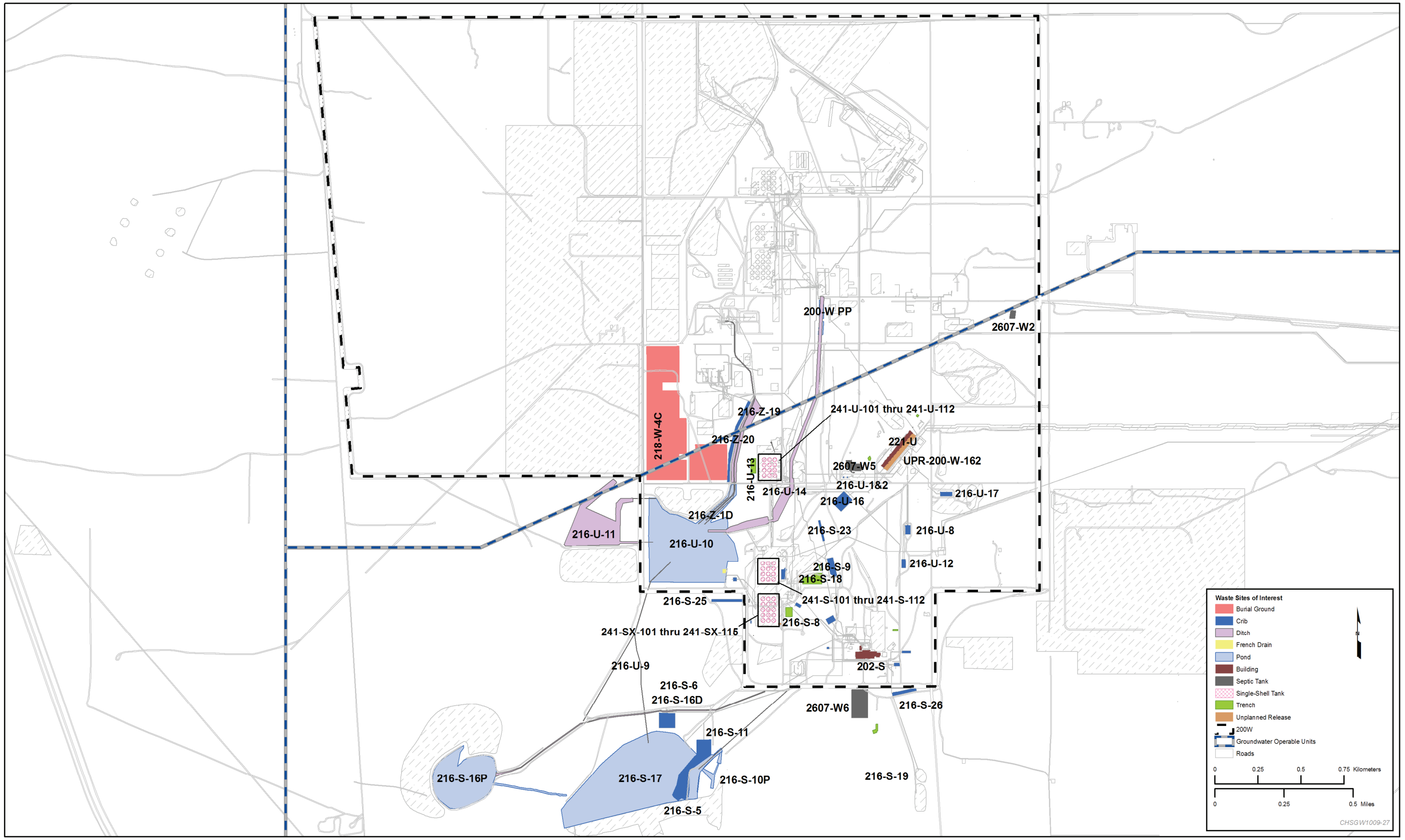

Figure 3-20. 200-UP-1 OU Waste Sites

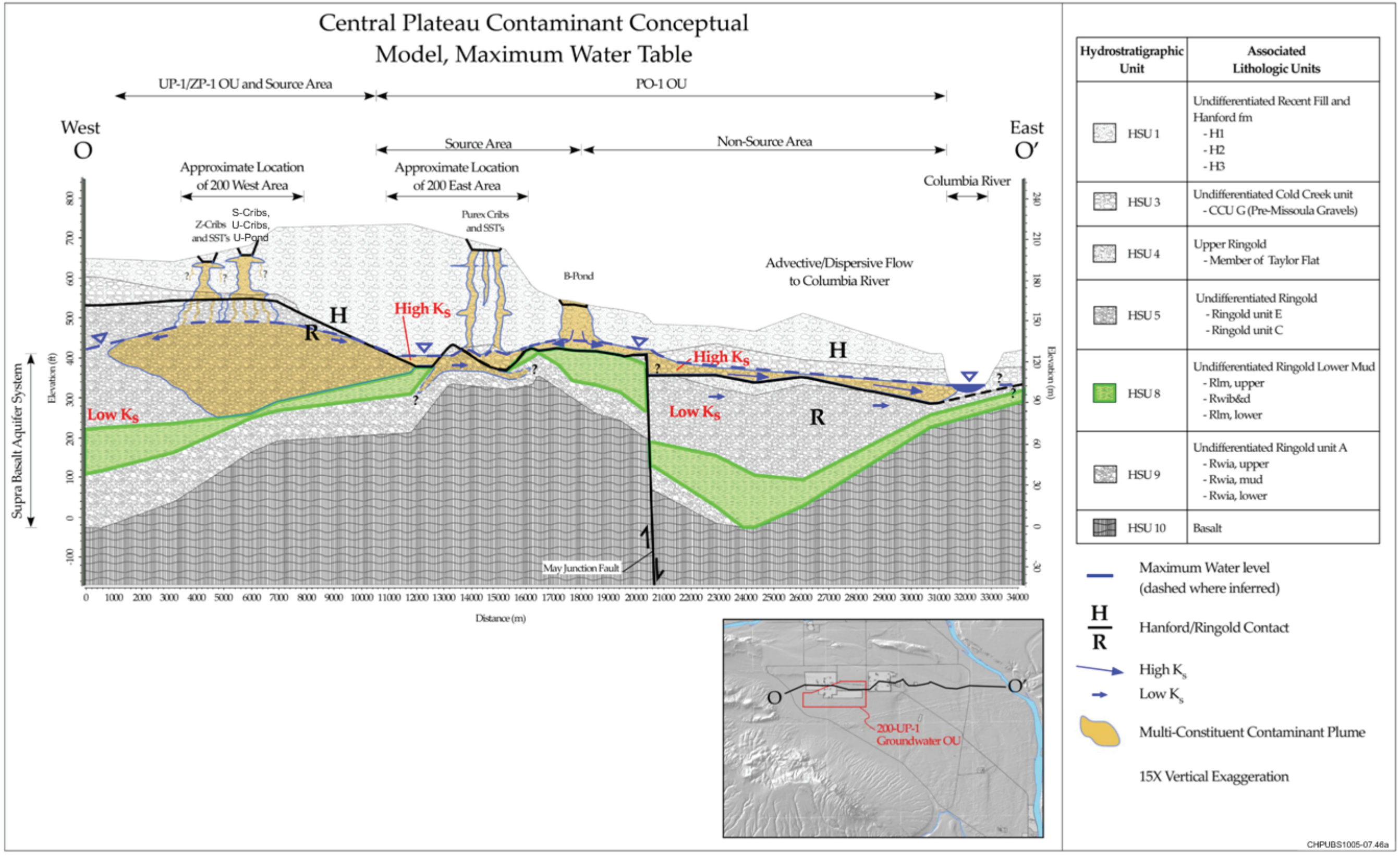

Figure 3-21. Conceptual Site Model Representing Past Peak Liquid Effluent Disposal, 200-UP-1 OU

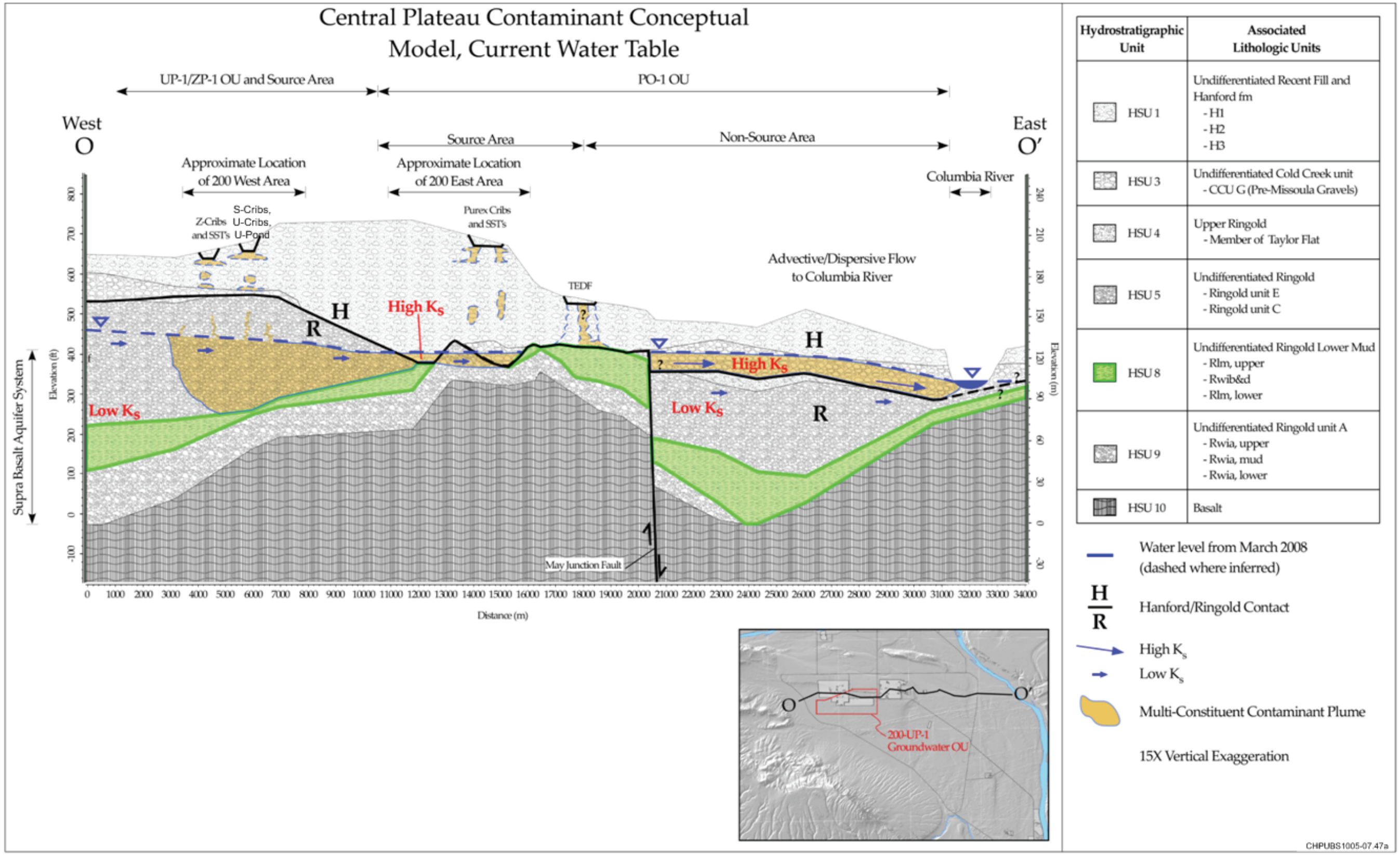

Figure 3-22. Conceptual Site Model Representing Current Groundwater Conditions, 200-UP-1 OU

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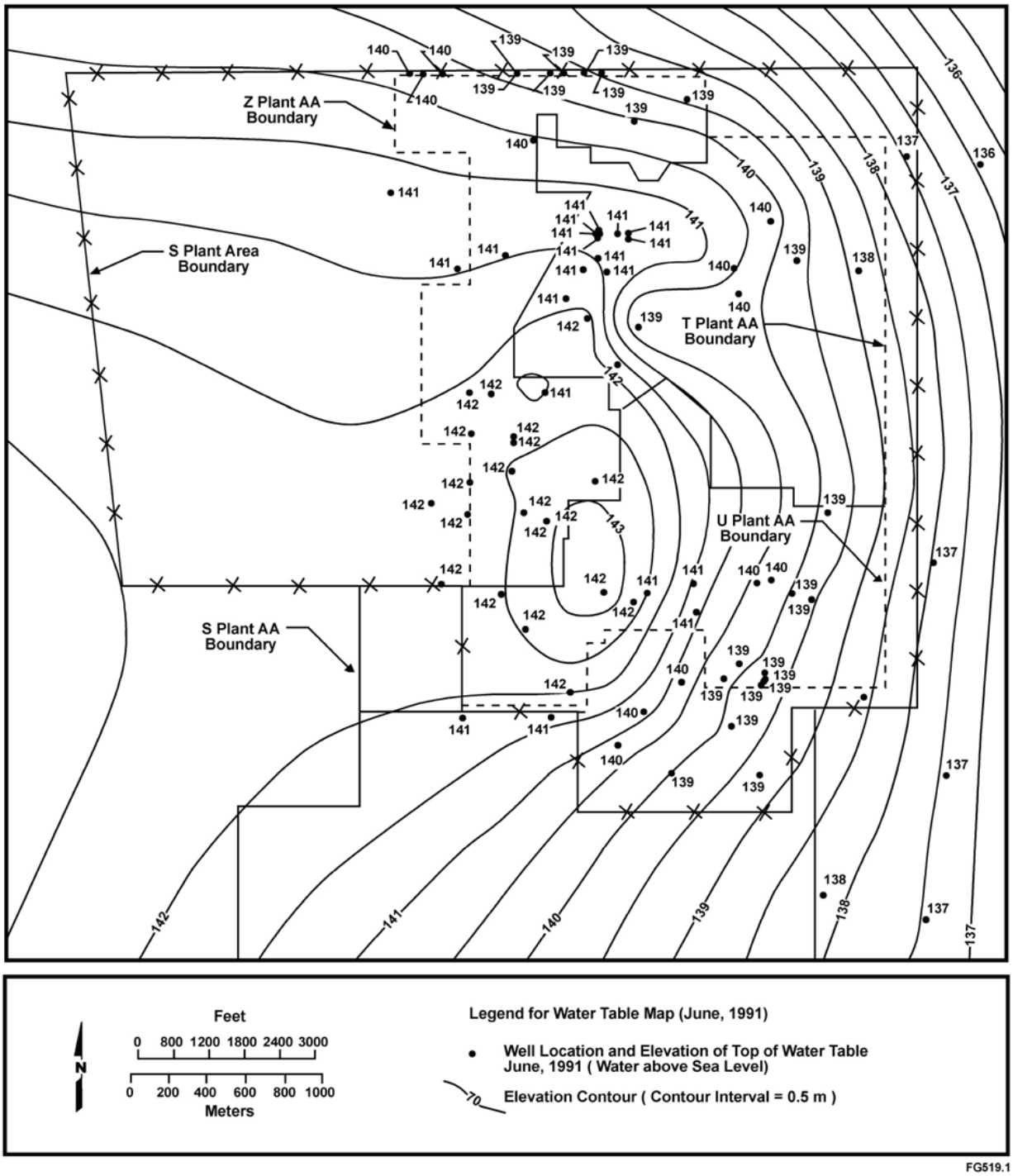
Currently, the principal sources of natural recharge are precipitation and run-off infiltration along the periphery of the Pasco Basin. Part of the groundwater recharge at the Site is provided by flow from the Greater Cold Creek watershed, a large drainage area on the western boundary of the Site that includes Cold Creek Valley, Dry Creek Valley, and the Hanford side of Rattlesnake Mountain. Small ephemeral streams such as Cold Creek and Dry Creek also lose water to the ground as they spread out on the valley plain.

Between 1944 and the mid-1990s, the volume of artificial recharge from Site wastewater disposal was significantly greater than recharge from precipitation. An estimated 1.68×10^{12} L (4.44×10^{11} gal) of liquid was discharged to disposal ponds, trenches, and cribs during this period. Wastewater discharge has decreased since 1984 and currently contributes a volume of recharge in the same range as the estimated natural recharge from precipitation. Because of the reduction in discharges, groundwater levels are falling, particularly around the operational areas (PNNL-16346).

After the beginning of Site operations during 1943, the water table rose about 25 m (82 ft) under the U Pond disposal area and about 9.1 m (30 ft) under disposal ponds near the 200 East Area. The volume of water that was discharged to the ground at the 200 West Area was actually less than that discharged at the 200 East Area. The lower hydraulic conductivity of the aquifer near the 200 West Area inhibited groundwater movement in this area, resulting in a higher groundwater mound. The presence of the groundwater mounds locally affected the direction of groundwater movement, causing radial flow from the discharge areas. Changes in water table elevations were documented between 1950 and 1980 in PNL-5506, *Hanford Site Water Table Changes 1950 Through 1980: Data Observations and Evaluation*. Until about 1980, the edge of the mounds migrated outward from the sources over time. Although the reduction of wastewater discharges has caused water levels to drop significantly, a residual groundwater mound remains beneath the 200 West Area.

The depth to groundwater beneath liquid disposal sites within the 200 West Area and throughout most of the 200-UP-1 OU is approximately 91 m (300 ft) below ground surface. Liquid disposal was the driving force for contaminant migration from the disposal sites. In 1992, the 200 West Groundwater AAMSR (DOE/RL-92-16) evaluated surface sites for potential contaminant migration to groundwater. This evaluation estimated possible groundwater impact by comparing vadose zone moisture retention capacity to the volume of liquid disposed of. Those sites receiving liquid volumes greater than the retention capacity were identified as having the potential to affect groundwater. Since 1992, RIs have progressed by source OU and are being evaluated for contributions and recharge to groundwater.

Figures 3-23 and 3-24 show the changes in groundwater elevation at the 200-UP-1 OU because of artificial recharge. The selected wells illustrated on Figure 3-24 represent a west-to-east cross section of water table elevations in wells extending from the immediate vicinity of 216-U-10 Pond (Well 699-35-78A) in the downgradient direction, ending with Well 699-32-62, approximately 5,000 m (16,405 ft) to the east. The hydrographs illustrate the dramatic extent of the groundwater mound associated with discharges to 216-U-10 Pond and the temporal variations in hydraulic gradient between wells across the width of 200-UP-1 OU.



Source: DOE/RL-92-76, Rev. 1, *Remedial Investigation/Feasibility Study Work Plan for the 200-UP-1 Groundwater Operable Unit*.

Figure 3-23. 200 West Area Water Table Elevation Map, June 1991

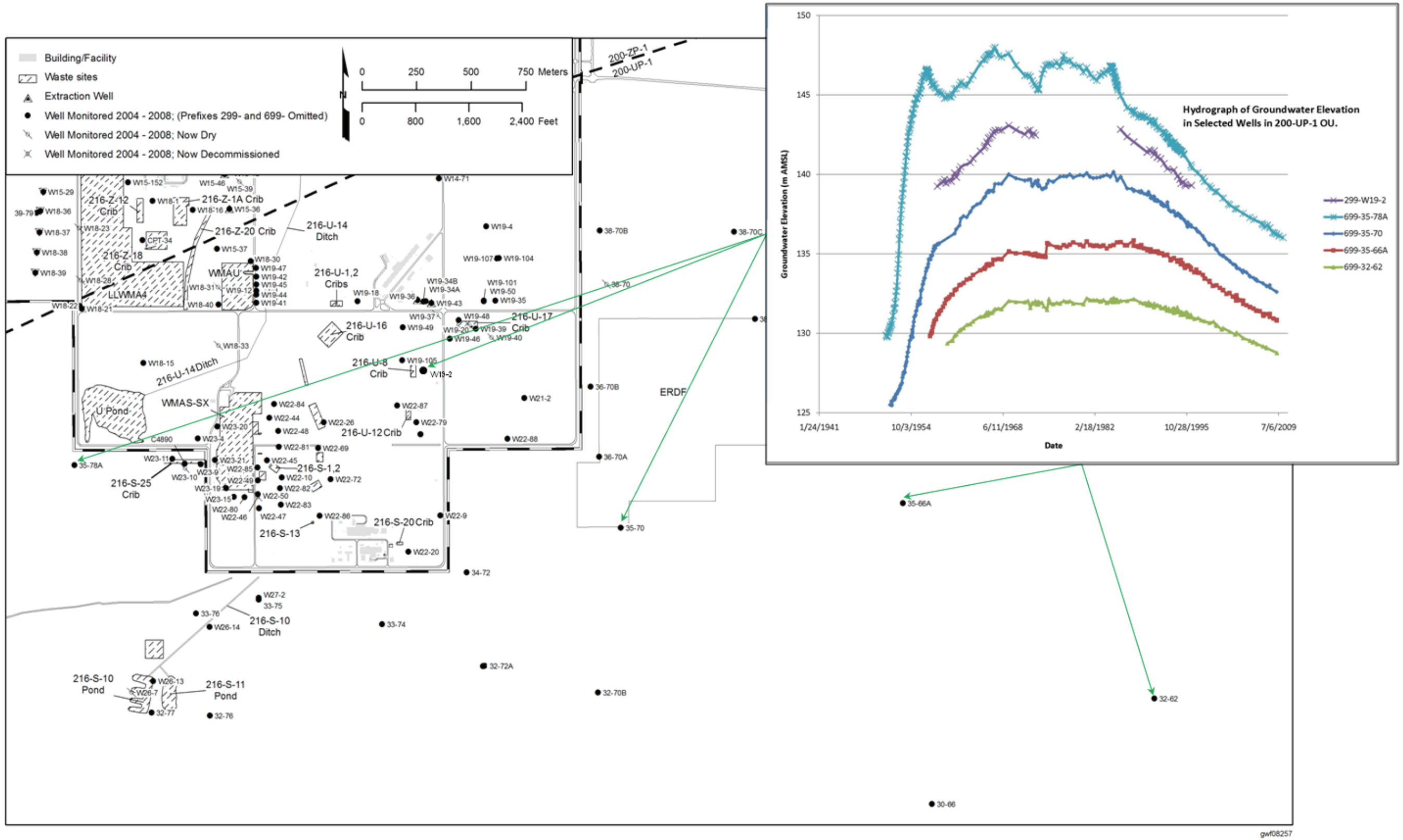


Figure 3-24. Changes in Groundwater Elevation over Time in Selected Wells within the 200-UP-1 OU

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3.7.8 Groundwater Velocity and Travel Time

Large liquid volumes were discharged to the vadose zone overlying the 200-UP-1 OU during Hanford Site operations (Figure 3-25). The impact of substantial artificial recharge on the 200-UP-1 OU unconfined aquifer system can be seen by inspecting the hydrographs for selected wells within the OU (Figure 3-24).

Historical groundwater velocities based on the movement of the tritum plume over time ranged from about 79 m/yr (259 ft/yr) to 105 m/yr (344 ft/yr), with an average velocity of about 90 m/yr (295 ft/yr) within the shallow, unconfined aquifer. This average velocity was estimated by inspection of arrival times of tritium concentration peaks at monitoring wells along an identified flow pathway downgradient from the source areas (Figure 3-26 and Table 3-1). More recent groundwater flow rates in the areas of WMA U and WMA S-SX were determined to be 28 m/yr and 34 m/yr, respectively (DOE/RL-2008-66), which reflects a decrease in velocity from historical rates. Groundwater flow velocity over the area of the 200-UP-1 OU is expected to continue to decline as the historic 200 West Area groundwater mound (U Pond) continues to decay, the shallow aquifer returns to historic recharge and flow patterns, and the gradient decreases across the OU.

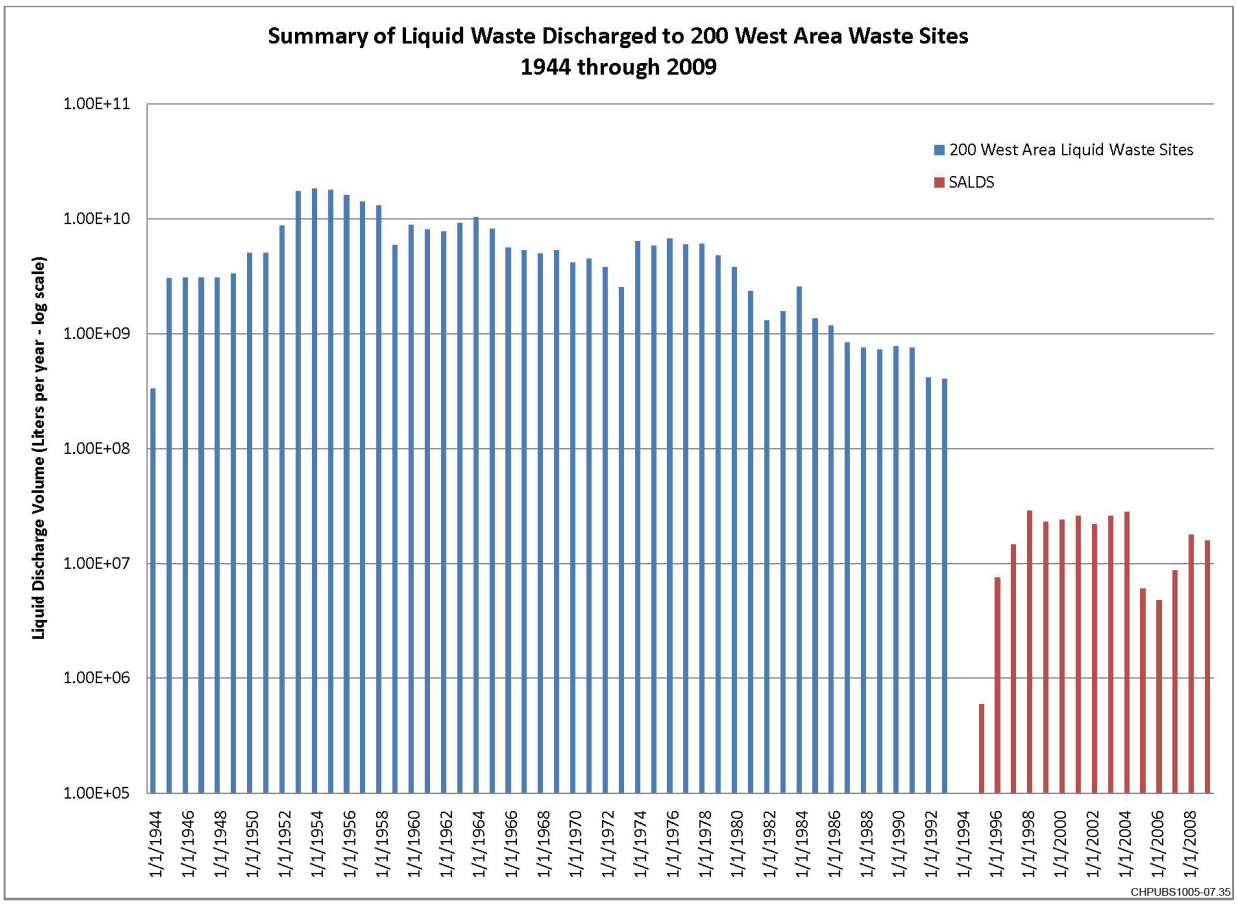

Figure 3-25. Annual Waste Discharged to the Ground in the 200 West Area

Table 3-1. Historical Estimates of Groundwater Velocity over Time for the 200-UP-1 OU Unconfined Aquifer, Based on Arrival of Tritium Concentration Peaks in Select Wells

Wells Inspected for Tritium Peaks and Time Period	Time Period, years	Estimated Groundwater Velocity
MW 299-W19-2 and MW-699-35-70	1962 to 1975	~79 m/yr (~259 ft/yr)
MW 699-35-70 and MW 699-35-66A	1975 to 1986	~105 m/yr (~344 ft/yr)
MW 699-35-66A and MW 699-32-62	1986 to 2005	~83 m/yr (272 ft/yr)
MW 699-32-62 and MW 699-36-61A	1986 to 2005	~92 m/yr (302 ft/yr)

3.7.9 Water Use

Groundwater is contaminated and not currently used in the 200-UP-1 OU for drinking water purposes. The source of water used in the 200 Areas (for fire protection, potable water, and so forth) is from the Columbia River.

3.8 Ecology

The Site has a mid-latitude semiarid climate. Terrestrial portions of the Site are characterized as a shrub-steppe ecosystem, composed of a shrub overstory and grass understory, interspersed with areas of disturbed ground (PNNL-6415). Only about 6 percent of Site land has been disturbed or is actively used by DOE for waste disposal and storage. The last free-flowing section of the Columbia River within the United States is above McNary Dam and flows through the Site, providing a unique habitat.

Although plumes in the 200-UP-1 OU are not a direct risk to terrestrial receptors, terrestrial ecology is being considered because future potential groundwater remediation processes may have direct impacts to local ecology. The discussion is general to the Central Plateau because the 200-UP-1 OU is an arbitrarily defined area on the Central Plateau used to describe groundwater plumes and is not based on natural physical or ecological boundaries.

3.8.1 Vegetation

In the native shrub-steppe habitat, the most prevalent shrub is big sagebrush (*Artemisia tridentata*). The understory is dominated by the native perennial Sandberg bluegrass (*Poa secunda* formerly *sandbergii*) and the introduced annual cheatgrass (*Bromus tectorum*). Of the native species observed during the Ecological Compliance Assessment Program survey conducted in 2001 (DOE/RL-2001-54, *Ecological Evaluation of the Hanford 200 Areas – Phase I: Compilation of Existing 200 Areas Ecological Data*), Sandberg bluegrass (*Poa secunda* formerly *sandbergii*), hoary aster (*Machaeranthera canescens*), and rabbitbrush (*Chrysothamnus* sp. and *Ericameria* sp.) were the most widely distributed. Areas of disturbed habitat include bare ground, gravel, or asphalt areas that may have sparse vegetation, and areas planted with nonnative wheatgrasses. The disturbed habitat communities are primarily the result of range fires or mechanical disturbance (from road clearing or construction).

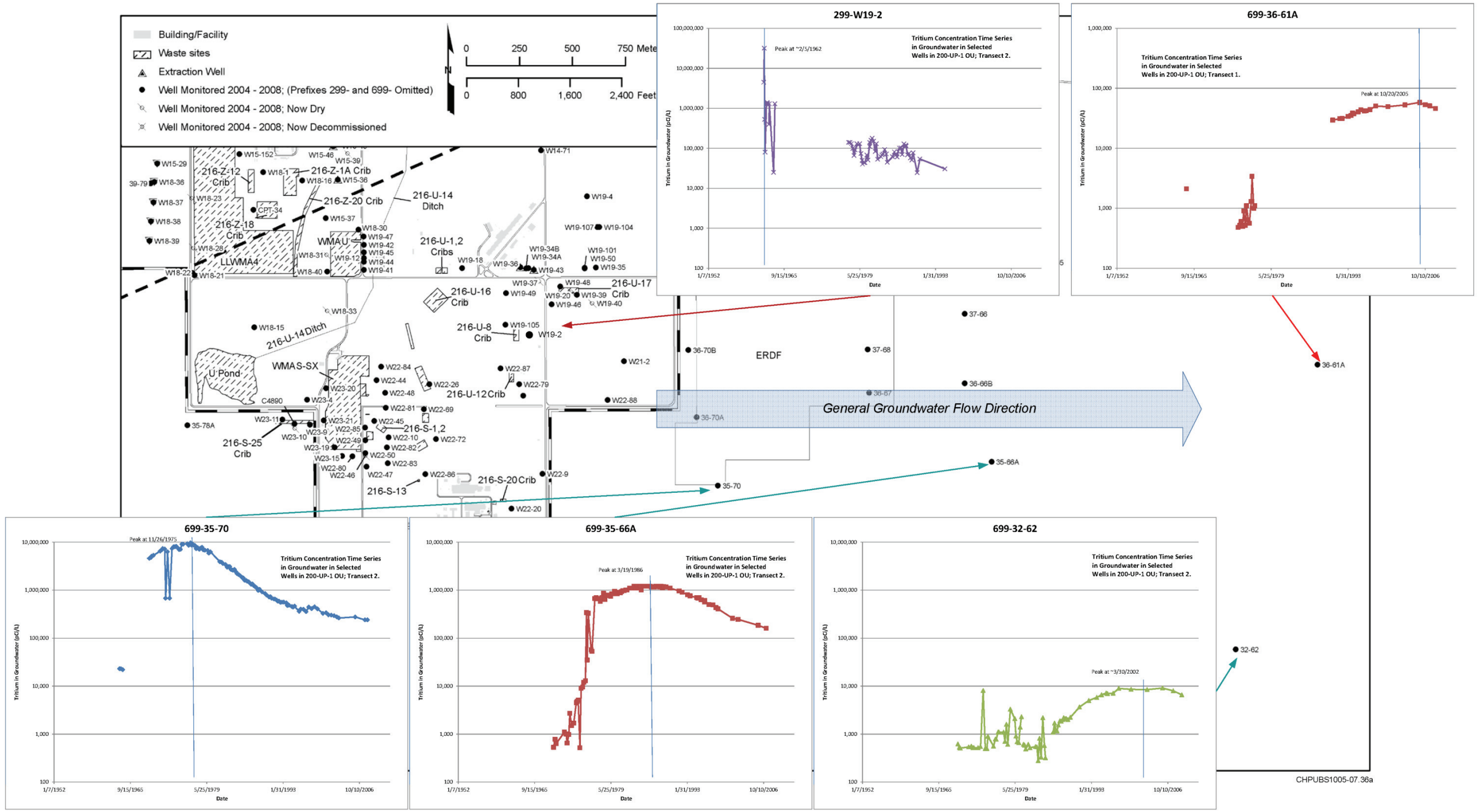

Figure 3-26. Arrival Peaks for Tritium in Selected Groundwater Monitoring Wells in the 200-UP-1 OU

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Other disturbed and gravel or asphalt areas have minimal vegetative cover and are primarily colonized by nonnative annual species, such as Russian thistle (*Salsola kali*), tumble mustard (*Sisymbrium altissimum*), and cheatgrass (*Bromus tectorum*) (DOE/RL-2001-54). The vegetation around former waste ponds and ditches has mostly died off because of stabilization activities.

3.8.2 Animal Species Inhabiting the Native Shrub-Steppe Habitat

Species lists have been compiled for the major classes of vertebrates that have been observed on the Site or within the Hanford Reach of the Columbia River and include 46 species of mammals, 145 species of birds, 10 species of reptiles, 5 species of amphibians, and 45 species of fish (PNNL-6415). The shrub and grassland habitat of the Site supports many groups of terrestrial wildlife. Table 3-2 presents some of the more common and representative species with associated habitat found at or near the Central Plateau. The most abundant mammal is the Great Basin pocket mouse (*Perognathus parvus*). Many of the rodent species and some predators (badgers [*Taxidea taxus*]) construct burrows on the Site. In addition, other nonburrowing animals that may use abandoned burrows include Nuttall's cottontail (*Sylvilagus nuttallii*), black-tailed jackrabbits (*Lepus californicus*), and snakes. The burrowing owl (*Athene cunicularia*) has been known to do both.

3.8.3 Bird Species Inhabiting the Native Shrub-Steppe Habitat

Shrub-steppe and grassland provide nesting and foraging habitat for many passerine bird species, including 41 species that depend on undisturbed habitat. The most common species include the western meadowlarks (*Sturnella neglecta*) and horned larks (*Eremophila alpestris*) (PNNL-6415). Long-billed curlews (*Numenius americanus*) and vesper sparrows (*Pooecetes gramineus*) were the most commonly occurring species in shrub-steppe habitat. Species that depend on undisturbed habitat include sage sparrows (*Amphispiza belli*), sage thrashers (*Oreoscoptes montanus*), and loggerhead shrikes (*Lanius ludovicianus*). Common upland gamebird species that occur in shrub and grassland habitat include chukar (*Alectoris chukar*), partridge (*Perdix perdix*), California quail (*Callipepla californica*), and ring-necked pheasant (*Phasianus colchicus*). Among the more common raptor species that use shrub and grassland habitat are the ferruginous hawk (*Buteo regalis*)—a state threatened species—Swainson's hawk (*Buteo swainsoni*), and the red-tailed hawk (*Buteo jamaicensis*). Table 3-3 presents representative avian species associated with specific habitat type.

3.8.4 Amphibians, Reptiles, and Insect Species Inhabiting the Native Shrub-Steppe Habitat

The side-blotched lizard (*Uta stansburiana*) is the most abundant reptile species occurring on the Site (PNNL-6415). The most common snake species include gopher snake (*Pituophis catenifer*), eastern racer (*Coluber constrictor*), and western rattlesnake (*Crotalus viridis*). Many species of insects are found throughout all habitats of the Site—butterflies, grasshoppers, and darkling beetles (*Eleodes* sp.) being among the most conspicuous. A total of 1,509 species-level identifications have been completed, and the collection of 40,000 specimens has resulted in the identification of 43 new taxa and 142 new findings in the State of Washington (TNC, 1999, *Biodiversity Inventory and Analysis of the Hanford Site Final Report 1994-1999*). The high diversity of insect species on the Site reflects the size, complexity, and relatively undisturbed quality of the shrub-steppe habitat. Table 3-4 shows the representative species associated with specific habitat types.

Table 3-2. Representative Mammals with Associated Central Plateau Habitat

Feeding Guilds	Scientific Name	Shrub	Grass/ Forbs	Disturbed/ Revegetated[a]	Disturbed Other[b]
Herbivores					
Black-tailed jackrabbit	*Lepus californicus*	X	X	X	
Bushy-tailed woodrat	*Neotoma cinerea*	X	X	X	X
Elk	*Cervus elaphus*	X	X	X	
Great Basin pocket mouse	*Perognathus parvus*	X	X	X	
Ground squirrel	*Spermophilus* sp.	X	X	X	
Mule deer	*Odocoileus hemionus*	X	X	X	
Northern pocket gopher	*Thomomys talpoides*		X	X	
Nuttall's cottontail	*Sylvilagus nuttallii*	X	X	X	
Sagebrush vole	*Lemmiscus curtatus*	X			
Omnivores					
Deer mouse	*Peromyscus maniculatus*	X	X	X	X
House mouse	*Mus musculus*			X	X
Insectivores					
Little brown bat	*Myotis lucifugus*				X
Long-legged myotis	*Myotis volans*				X
Northern grasshopper mouse	*Onychomys leucogaster*	X			
Pallid bat	*Antrozous pallidus*				X
Silver-haired bat	*Lasionycteris noctivagans*				X
Western pipistrelle	*Pipistrellus hesperus*				X
Carnivores					
Badger	*Taxidea taxus*	X	X	X	
Bobcat	*Lynx rufus*	X	X	X	
Coyote	*Canis latrans*	X	X	X	

Source: DOE/RL-2001-54, *Ecological Evaluation of the Hanford 200 Areas – Phase I: Compilation of Existing 200 Areas Ecological Data*.

a. Revegetated annuals and grasses.

b. Planted trees, power lines, buildings, fences, gravel, and asphalt.

Table 3-3. Representative Birds with Associated Central Plateau Habitat

Feeding Guilds	Scientific Name	Shrub	Grass/Forbs	Disturbed/ Revegetated[a]	Disturbed Other[b]
Herbivores					
American goldfinch	*Carduelis tristis*				X
California quail	*Callipepla californica*		X		
Chukar	*Alectoris chukar*	X	X	X	
House finch	*Carpodacus mexicanus*		X		X
House sparrow	*Passer domesticus*	X	X	X	X
Mourning dove	*Zenaida macroura*	X	X		X
Rock dove	*Columbia livia*				X
Sage sparrow	*Amphispiza belli*	X			
Vesper sparrow	*Pooecetes gramineus*	X	X		
Omnivores					
American robin	*Turdus migratorius*	X	X	X	X
Brown-headed cowbird	*Molothrus ater*		X	X	
Dark-eyed junco	*Junco hyemalis*	X	X	X	
Eastern kingbird	*Tyrannus tyrannus*	X	X	X	
European starling	*Sturnus vulgaris*				X
Horned lark	*Eremophila alpestris*	X	X		X
Northern flicker	*Colaptes auratus*				X
Ring-billed gull	*Larus delawarensis*				X
Ring-necked pheasant	*Phasianus colchicus*		X		
Ruby-crowned kinglet	*Regulus calendula*				X
Sage thrasher	*Oreoscoptes montanus*	X			
Varied thrush	*Ixoreus naevius*	X			X
Western kingbird	*Tyrannus verticalis*	X	X	X	X
Western meadowlark	*Sturnella neglecta*	X	X	X	
Insectivores					
Barn swallow	*Hirundo rustica*		X	X	X
Common nighthawk	*Chordeiles minor*				X
Killdeer	*Charadrius vociferous*		X	X	X

Table 3-3. Representative Birds with Associated Central Plateau Habitat

Feeding Guilds	Scientific Name	Shrub	Grass/Forbs	Disturbed/ Revegetated[a]	Disturbed Other[b]
Loggerhead shrike	*Lanius ludovicianus*	X			X
Long-billed curlew	*Numenius americanus*		X	X	
Red-winged blackbird	*Agelaius phoeniceus*		X		X
Rock wren	*Salpinctes obsoletus*				X
Yellow warbler	*Dendroica petechia*				X
Carnivores					
American kestrel	*Falco sparverius*	X			X
Barn owl	*Tyto alba*				X
Burrowing owl	*Athene cunicularia*	X			X
Common raven	*Corvus corax*	X	X	X	X
Long-eared owl	*Asio otus*				X
Northern harrier	*Circus cyaneus*	X	X	X	
Red-tailed hawk	*Buteo jamaicensis*	X			X
Sharp-shinned hawk	*Accipiter striatus*	X			X

Source: DOE/RL-2001-54, *Ecological Evaluation of the Hanford 200 Areas – Phase I: Compilation of Existing 200 Areas Ecological Data*.

a. Revegetated annuals and grasses.

b. Planted trees, power lines, buildings, fences, gravel, and asphalt

3.8.5 Special Status Species

Multiple species of concern (state endangered, threatened, sensitive, review group 1, or review group 2 by the Washington National Heritage Program [WNHP] or the Washington Department of Fish and Wildlife [WDFW]) may occur on the Central Plateau (Table 3-5) (WDFW, 2009, "Species of Concern in Washington State;" WNHP, 2009, "List of Plants Tracked by the Washington Natural Heritage Program;" and PNNL, 2009, "Ecological Monitoring & Compliance, Hanford Site, Species List"). Species that are associated with specific localities and altitudes, species not within the Central Plateau, and riparian and river habitat species are omitted from this list, with the exceptions of the bald eagle (*Haliaeetus leucocephalus*), the peregrine falcon (*Falco peregrinus*), and the golden eagle (*Aquila chrysaetos*). While these species depend on the river corridor, they are occasionally observed on the Central Plateau. Additionally, although the pygmy rabbit (*Brachylagus idahoensis*), a federal and state endangered species, has not been observed on the Central Plateau, it has been seen on the Arid Lands Ecology Reserve and is included in Table 3-5.

Table 3-4. Representative Amphibians and Reptiles with Associated Central Plateau Habitat

Feeding Guilds	Scientific Name	Shrub	Grass/ Forbs	Disturbed/ Revegetated[a]	Disturbed Otherb
Insectivores					
Great Basin spadefoot toad	*Scaphiopus intermontana*				X
Sagebrush lizard	*Sceloporus graciosus*	X			
Side-blotched lizard	*Uta stansburiana*	X	X	X	
Woodhouse's toad	*Anaxyrus woodhousii*				X
Carnivores					
Eastern racer	*Coluber constrictor*	X	X	X	
Gopher snake	*Pituophis catenifer*	X	X	X	
Western rattlesnake	*Crotalus viridis*	X			X

Source: DOE/RL-2001-54, *Ecological Evaluation of the Hanford 200 Areas – Phase I: Compilation of Existing 200 Areas Ecological Data*.

a. Re-vegetated annuals and grasses.

b. Planted trees, power lines, buildings, fences, gravel, and asphalt.

Fauna are managed by the WDFW, and all migratory birds are protected by the *Migratory Bird Treaty Act of 1918* (WNHIS, 2009, "Washington Natural Heritage Information System List of Known Occurrences of Rare Plants and Animals in Washington February 2009"). The species of concern were determined by comparison of the flora list from WNHP, 2009; the fauna list from WDFW, 2009; and the lists of species that were identified on the Hanford Site according to PNNL, 2009. The flora and fauna from these lists were then screened for the Central Plateau based on their habitat, their past locations, and input from subject matter experts.

Table 3-5. Species of Concern That May Occur on the Central Plateau

Common Name(s)	Scientific Name(s)	State Classification	Federal Classification
Plants			
Great Basin gilia	*Aliciella leptomeria*	Threatened	None
Geyer's milk-vetch	*Astragalus geyeri*	Threatened	None
Rosy pussypaws/rosy calyptridium	*Cistanthe rosea*	Threatened	None
Desert dodder	*Cuscuta denticulata*	Threatened	None
Loeflingia	*Loeflingia squarrosa* var. *squarossa*	Threatened	None
Small-flowered evening primrose/small-flowered desert primrose	*Camissonia minor*	Sensitive	None

Table 3-5. Species of Concern That May Occur on the Central Plateau

Common Name(s)	Scientific Name(s)	State Classification	Federal Classification
Dwarf evening-primrose/dwarf desert primrose	*Camissonia pygmaea*	Sensitive	None
Gray cryptantha	*Cryptantha leucophaea*	Sensitive	None
Piper's daisy	*Erigeron piperianus*	Sensitive	None
Suksdorf's monkey-flower	*Mimulus suksdorfii*	Sensitive	None
Coyote tobacco	*Nicotiana attenuata*	Sensitive	None
Birds			
Sage sparrow	*Amphispiza belli*	Endangered	None
Sandhill crane	*Grus canadensis*	Endangered	None
Ferruginous hawk	*Buteo regalis*	Threatened	Species of concern
Greater sage grouse	*Centrocercus urophasianus*	Threatened	Candidate
Burrowing owl	*Athene cunicularia*	Candidate	Species of concern
Golden eagle	*Aquila chrysaetos*	Candidate	None
Loggerhead shrike	*Lanius ludovicianus*	Candidate	Species of concern
Sage thrasher	*Oreoscoptes montanus*	Candidate	None
Bald eagle	*Haliaeetus leucocephalus*	Sensitive	Species of concern
Peregrine falcon	*Falco peregrinus*	Sensitive	Species of concern
Mammals			
Pygmy rabbit	*Brachylagus idahoensis*	Endangered	Endangered
Black-tailed jackrabbit	*Lepus californicus*	Candidate	None
White-tailed jackrabbit	*Lepus townsendii*	Candidate	None
Merriam's shrew	*Sorex merriami*	Candidate	None
Townsend's ground squirrel	*Spermophilus townsendii*	Candidate	Species of concern
Washington's ground squirrel	*Spermophilus washingtoni*	Candidate	Candidate

Table 3-5. Species of Concern That May Occur on the Central Plateau

Common Name(s)	Scientific Name(s)	State Classification	Federal Classification
Amphibians and Reptiles			
Striped whipsnake	*Masticophis taeniatus*	Candidate	None
Northern sagebrush lizard	*Sceloporus graciosus*	Candidate	Species of concern

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Table 3-1. Historical Estimates of Groundwater Velocity over Time for the 200-UP-1 OU Unconfined Aquifer, Based on Arrival of Tritium Concentration Peaks in Select Wells 3-46
Table 3-2. Representative Mammals with Associated Central Plateau Habitat.....3-50
Table 3-3. Representative Birds with Associated Central Plateau Habitat.....3-51
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4 Nature and Extent of Contamination

This chapter presents a comprehensive interpretation of the spatial distribution of groundwater contamination within the 200-UP-1 OU. The data used for this interpretation consist of the results of groundwater sampling conducted to support the RI (DOE/RL-92-76, Rev. 1), additional sampling conducted under RCRA, and additional groundwater monitoring performed under CERCLA for the Environmental Restoration Disposal Facility (ERDF).

The monitoring program for the 200-UP-1 RI/FS was guided by an extensive list of COPCs, which were presented in the RI/FS Work Plan, (DOE/RL-92-76, Rev. 1). These constituents were grouped into two categories: high priority COPCs identified during a previous DQO process (BHI-01576, *DQO Summary Report for Establishing a 200-ZP-1 and 200-UP-1 Groundwater Monitoring Well Network*) and additional COPCs identified specifically for the RI (CP-15315, *Data Quality Objectives Summary Report Supporting the 200-UP-1 Operable Unit Remedial Investigation/Feasibility Study Process*; DOE/RL-92-76, Rev. 1).[1] The high priority COPCs are arsenic, cadmium, carbon tetrachloride, chloroform, chromium (total and hexavalent), I-129, nitrate, Sr-90, Tc-99, TCE, tritium, and uranium (total). The additional COPCs included an extensive list of VOCs, metals, anions, ammonium ion, ammonia, cyanide, sulfide, cresols, phenols, total petroleum hydrocarbons (kerosene range), and several radionuclides: beta emitters carbon-14 and selenium-79; alpha emitters neptunium-237, protactinium-231, uranium-234, -235, and -238; and gamma emitters Cs-137 and cobalt-60. The high priority constituents were sampled for extensively in wells throughout much of the OU, while sampling for the additional constituents was largely focused on the newly installed wells. Much of the groundwater sampling performed for the RI was directed toward identifying whether the COPCs were present in groundwater, and if so, to determine their concentration levels and spatial extent.

The following subsections provide information on background concentrations for the COPCs (Section 4.1), the current spatial distribution of contamination within the OU (Section 4.2), and a summary of the IRAs (Section 4.3). Potential sources of groundwater contamination within the OU are discussed in Section 1.2. Specific sources of groundwater contamination are also described in the following subsections.

4.1 Background Concentrations

Information on background concentrations of the COPCs are needed for two purposes. First, comparison of groundwater sampling results with background concentration levels is fundamental to determining whether a particular constituent in the groundwater is a result of waste disposal operations. If a constituent occurs in groundwater at concentrations above the range of background values, and there is sufficient process knowledge, it may be concluded that the constituent is a contaminant. Second, background concentrations are used as a lower bound on cleanup levels. For example, if a cleanup level determined under WAC 173-340, “Model Toxics Control Act—Cleanup” also known as the MTCA, is below the natural background concentration, the cleanup level will be adjusted upward to the natural background concentration (or the practical quantitation limit, whichever is higher).

Natural background concentrations of inorganic chemicals and radionuclides for the Hanford Site were presented in DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*, and were determined by evaluating historical sample results and analysis of new sample results collected from a network of Site monitoring wells. The monitoring wells were chosen through a systematic process of identifying wells in the unconfined aquifer not affected by contaminants originating from the Hanford Site. Because the sample results from these wells exhibited a range of values and a skewed right distribution, the background concentration levels were statistically specified by the geometric mean, geometric standard deviation, and

[1] A third category consists of six constituents that were added as COPCs during preparation of this RI/FS: aluminum, bromodichloromethane, chloromethane, styrene, thallium, and trans-1,3-dichloropropene.

minimum, maximum, 90th, and 95th percentiles. Table 4-1 shows these values for the inorganic and radionuclide COPCs. Organic compounds that are not naturally present in the environment, such as carbon tetrachloride, are assumed to have natural background concentrations of zero. The maximum, 90th, and 95th percentile natural background concentrations for nitrate are relatively high at 28, 27, and 42 mg/L, respectively (Table 4-1) in wells located in parts of the aquifer not affected by Hanford operations. The high nitrate concentrations are the result of nitrate migrating onto the Hanford Site from offsite sources. Because this nitrate did not originate from local activities (Hanford Site activities), it was considered part of the upgradient source in DOE/RL-96-61.

4.2 Well Locations and Distribution of Contaminants

Table 4-2 summarizes the results of groundwater sampling within the 200-UP-1 OU during the RI. For each COPC, Table 4-2 shows the total number of analyses performed, the number of detections, the median and maximum values of the detections, the number of detections that exceeded the natural background concentration (where available), and the number of detections that exceeded a federal DWS (where applicable). For the high priority COPCs, all are present in groundwater above background levels except for arsenic and cadmium. Arsenic occurs naturally in groundwater at concentrations above the laboratory detection limit, so this constituent was frequently detected. Only a few detections of cadmium were found, and these may have been false-positive analytical results. Additional COPCs that occur in the groundwater at concentrations above the natural background level are 1,4-dioxane, bromodichloromethane, carbon-14, chloromethane, hexavalent chromium, magnesium, methylene chloride, selenium-79, tetrachloroethene (PCE), and uranium-234, -235, and -238.

The detailed results of groundwater sampling performed during the RI for the high priority COPCs are presented in Sections 4.2.1 through 4.2.8. The groundwater sampling results for the additional COPCs are presented in Section 4.2.9. Unless otherwise noted, the groundwater plume maps show constituent concentrations in the upper part of the unconfined aquifer, based on average concentrations for samples collected during fiscal year (FY) 2008. They are the same as those presented in DOE/RL-2008-66, except the chromium plume east-southeast from the 200 West Area was re-interpreted as part of this RI. The federal DWS plume contours for the high priority COPCs are shown collectively on Plate 1 (Appendix A).

Cross-sectional plume interpretations are based on depth-discrete sampling during drilling of newly installed monitoring wells. In addition, more recent sample results from each well are shown. Thus, the data shown on these cross sections were collected over several years and may not be representative of current conditions because of plume concentration changes over time. The cross sections are consistent with the FY 2008 plume maps, which show the plume distribution at the water table. Table 4-3 lists the depth-discrete sampling results obtained during drilling. Well and cross section locations are shown on Figure 4-1 and on Plate 1 (Appendix A).

NOTE: Because of the large number of figures in this section, the figures for each contaminant discussed are grouped at the end of each subsection where the individual contaminants are discussed.

Table 4-1. Natural Background Concentrations for Inorganic and Radionuclide Contaminants of Potential Concern[a]

Constituent	Units	Number of Samples	Geometric Mean	Geometric Standard Deviation	Minimum	Maximum	90th Percentile	95th Percentile
Aluminum (filtered)	µg/L	32	1.23	3.92	0.5	187	7.11	11.7
Ammonia	µg/L	32	26.2	3,120	5	882	113	170
Antimony (filtered)	µg/L	15	23.8	1.92	9.47	53.9	55.1	69.8
Arsenic (filtered)	µg/L	29	1.83	3.11	0.5	8.81	7.85	11.8
Cadmium (filtered)	µg/L	32	0.274	2.57	0.05	0.5	0.916	1.29
Cesium-137	pCi/L	17	2.26	0.00226	0.000643	0.0295	0.00843	0.0122
Chromium (total, filtered)	µg/L	27	0.893	2.16	0.5	4.41	2.4	3.17
Cobalt (filtered)	µg/L	32	0.274	2.57	0.05	0.5	0.916	1.29
Cobalt-60	pCi/L	17	0.00109	0.00243	0.000404	0.023	0.0225	0.0447
Cyanide	µg/L	25	5.43	1,407	5	26.7	8.41	9.52
Fluoride	mg/L	28	0.491	0.0018	0.267	5.85	1.047	1.298
Iodine-129	pCi/L	9	0.0000288	0.00000251	0.0000063	0.0000961	0.0000939	0.000131
Iron (filtered)	µg/L	22	55.3	6.17	6	7,225	570	1,104
Lead (filtered)	µg/L	31	0.271	2.59	0.05	0.5	0.917	1.3
Magnesium (filtered)	µg/L	25	11,245	1.85	825	39,600	24,816	31,051
Manganese (filtered)	µg/L	32	2.22	9.25	0.05	94.4	38.5	86.4
Mercury (filtered)	µg/L	27	0	5.34	0	0.012	0.003	0.006
Nitrate	mg/L	26	5.681	3.361	0.085	28.063	26.871	41.723
Strontium-90	pCi/L	14	0.00478	0.00239	0.000641	0.0156	0.0146	0.02
Sulfide	mg/L	32	0.00171	0.00121	0.0016	0.00321	0.00219	0.00235

Table 4-1. Natural Background Concentrations for Inorganic and Radionuclide Contaminants of Potential Concern[a]

Constituent	Units	Number of Samples	Geometric Mean	Geometric Standard Deviation	Minimum	Maximum	90th Percentile	95th Percentile
Technetium-99	pCi/L	5	0.447	1.62	0.271	0.752	0.83	0.988
Thallium (filtered)	µg/L	4	1.14	1.35	0.883	1.73	1.67	1.87
Tritium	pCi/L	15	63.9	1.63	27.8	131	119	142
Uranium	µg/L	25	2.57	2.85	0.5	12.8	9.85	14.4
Uranium-234	pCi/L	2	0.75	1.1	0.7	0.803	0.849	0.88
Uranium-235	pCi/L	17	0.0231	0.00334	0.00155	0.114	0.108	0.167
Uranium-238	pCi/L	17	0.721	0.00189	0.15	2.44	1.63	2.05
Vanadium (filtered)[b]	µg/L	32	1.83	4.19	0.5	16.7	11.5	19.3

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

a. The organic COPCs 1,1-dichloroethene, 1,2-dichloroethane, 1,4-dioxane, bromodichloromethane, carbon tetrachloride, chloroform, chloromethane, styrene, PCE, trans-1, 3-dichloropropene, and TCE are assumed to have natural background concentrations of zero.

b. Sample results during the RI suggest that the vanadium natural background values presented in this table are too low to be representative of the natural background for the 200-UP-1 OU.

Table 4-2. Sample Results for 200-UP-1 Contaminants of Potential Concern[a]

Constituent	Number of Analyses	Number of Detections	Median of Detections[b]	Maximum of Detections[b]	Natural Background (95th Percentile)	Number of Results Above Background[b]	Drinking Water Standard	Number of Results Above Drinking Water Standard[b]	Comment
High Priority Contaminants of Potential Concern									
Arsenic (filtered), µg/L	222	149	3.36	27.5	11.8	1	10	1	Maximum result is likely a false positive.
Arsenic (unfiltered), µg/L	125	87	3.31	6.9	--	--	10	0	
Cadmium (filtered), µg/L	909	3	2.2	4.5	1.29	2	5	0	
Cadmium (unfiltered), µg/L	364	1	N/A	N/A	--	--	5	0	Single detection flagged as "suspect."
Carbon tetrachloride, µg/L	693	639	57	1,600	0	614	5	529	
Chloroform, µg/L	696	581	2.6	35	0	562	80	0	
Chromium (filtered), µg/L	922	567	9.15	1,750	3.17	511	100	90	
Chromium (unfiltered), µg/L	376	237	20.7	1,100	--	--	100[e]	39	
Iodine-129, pCi/L	540	193[c]	2.42	38.7	0.000131	191	1	180	
Nitrate, mg/L	1,248	1,248	42.2	1,740	41.723	565	45	538	
Strontium-90, pCi/L	157	13	1.04	32	0.02	11	8	2	
Technetium-99, pCi/L	1,245	1,122	292	137,000	0.988	1,098	900	351	
Trichloroethene, µg/L	696	295	1.1	13	0	291	5	52	
Tritium, pCi/L	540	401	13,000	1,020,000	142	398	20,000	143	

Table 4-2. Sample Results for 200-UP-1 Contaminants of Potential Concern[a]

Constituent	Number of Analyses	Number of Detections	Median of Detections[b]	Maximum of Detections[b]	Natural Background (95th Percentile)	Number of Results Above Background[b]	Drinking Water Standard	Number of Results Above Drinking Water Standard[b]	Comment
Uranium (total), µg/L	940	891	4.79	613	14.4	304	30	260	
Additional Contaminants of Potential Concern Identified in the RI/FS Work Plan (DOE/RL-92-76, Rev. 1)									
1,1,1-Trichloroethane, µg/L	695	0	N/A	N/A	0	0	200	0	
1,1-Dichloroethene, µg/L	636	1	0.11	0.11	0	1	--	--	Single detection is most likely a false-positive result.
1,2-Dichloroethane, µg/L	695	2	0.66	0.66	0	1	--	--	One detection flagged to indicate a QC problem.
1,4-Dioxane, µg/L	390	1	120	120	0	1	--	--	
4-methyl-2-Pentanone, µg/L	695	1	4.3	4.3	0	1	--	--	Single detection is most likely a false-positive result.
Acetone, µg/L	695	63	1.8	29	0	53	--	--	Common laboratory contaminant.
Ammonia, µg/L	37	6	N/A	N/A	170	0	--	--	All six detections flagged to indicate a QC problem
Ammonium ion, µg/L	49	21	15.7	42.6	--	--	--	--	
Antimony (filtered), µg/L	909	16	3.7	41	69.8	0	6	3	Results above the federal DWS are most likely false positives.
Antimony (unfiltered), µg/L	364	13	3.3	3.7	--	--	6	0	

Table 4-2. Sample Results for 200-UP-1 Contaminants of Potential Concern[a]

Constituent	Number of Analyses	Number of Detections	Median of Detections[b]	Maximum of Detections[b]	Natural Background (95th Percentile)	Number of Results Above Background[b]	Drinking Water Standard	Number of Results Above Drinking Water Standard[b]	Comment
Butanol (1-butanol), µg/L	574	1	N/A	N/A	0	0	--	--	Single detection flagged as "suspect."
Carbon Disulfide, µg/L	695	23	0.46	3.1	--	--	--	--	
Carbon-14, pCi/L	135	17	12.1	32.9	--	--	2,000	0	
Cesium-137, pCi/L	146	0	N/A	N/A	0.0122	0	200	0	
Chromium (hexavalent, filtered, and unfiltered), µg/L	144	89	10	236	--	--	100	5	
Cobalt (filtered), µg/L	909	90	4.35	16.3	1.29	57	--	--	
Cobalt (unfiltered), µg/L	364	30	6.0	15.5	--	--	--	--	
Cobalt-60, pCi/L	146	0	N/A	N/A	0.0447	0	100	0	
Cresols (total), µg/L	49	0	N/A	N/A	0	0	--	--	
Cyanide, µg/L	81	3	6.5	25.1	9.52	1	200	0	
Ethyl Acetate, µg/L	73	0	N/A	N/A	0	0	--	--	
Fluoride, mg/L[d]	1,248	1,231	0.35	0.69	1.298	0	2	0	
Iron (filtered), µg/L	909	443	30.1	314	1,104	0	300	1	
Iron (unfiltered), µg/L	364	303	89	3,780	--	--	300	46	High concentrations generally associated with high turbidity samples.
Kerosene, µg/L	75	0	N/A	N/A	0	0	--	--	

Table 4-2. Sample Results for 200-UP-1 Contaminants of Potential Concern[a]

Constituent	Number of Analyses	Number of Detections	Median of Detections[b]	Maximum of Detections[b]	Natural Background (95th Percentile)	Number of Results Above Background[b]	Drinking Water Standard	Number of Results Above Drinking Water Standard[b]	Comment
Lead (filtered), µg/L	143	5	2.0	3.3	1.3	4	15	0	
Lead (unfiltered), µg/L	100	7	2.0	37.7	--	--	15	1	Single result above the federal DWS is likely a false positive.
Lithium (filtered), µg/L	89	46	5.3	12.8	--	--	--	--	
Lithium (unfiltered), µg/L	66	48	5.5	13.5	--	--	--	--	
Magnesium (filtered), µg/L	909	909	9,900	98,600	31,051	23	--	--	
Magnesium (unfiltered), µg/L	364	364	10,250	44,700	--	--	--	--	
Manganese (filtered), µg/L	909	453	3.6	372	86.4	6	50	11	
Manganese (unfiltered), µg/L	364	139	7.3	88.5	--	--	50	6	
Mercury (filtered), µg/L	106	7	0.07	0.08	0.006	4	2	0	
Mercury (unfiltered), µg/L	63	3	0.06	0.08	--	--	2	0	
Methyl Ethyl Ketone (2-Butanone), µg/L	695	4	2	2	0	4	--	--	Common laboratory contaminant.
Methylene chloride, µg/L	695	69	2	16	0	66	5	8 (?)	Common laboratory contaminant.
Neptunium-237, pCi/L	82	4	0.028	0.033	--	--	--	--	

Table 4-2. Sample Results for 200-UP-1 Contaminants of Potential Concern[a]

Constituent	Number of Analyses	Number of Detections	Median of Detections[b]	Maximum of Detections[b]	Natural Background (95th Percentile)	Number of Results Above Background[b]	Drinking Water Standard	Number of Results Above Drinking Water Standard[b]	Comment
Nitrite, mg/L	1,248	120	0.164	1.61	--	--	3.3	0	About 68 percent of the detections flagged as outliers or have QC problems.
Phenols, µg/L	67	7	N/A	N/A	0	0	--	--	All detections flagged to indicate a QC problem.
Protactinium-231, pCi/L	64	0	N/A	N/A	--	--	--	--	
Selenium-79, pCi/L	156	38	51.2	2,080	--	--	--	--	
Sulfide, mg/L	70	4	1.4	1.6	0.00235	4	--	--	
Tetrachloroethene, µg/L	695	54	0.34	3.8	0	49	5	0	
Toluene, µg/L	695	0	N/A	N/A	0	0	--	--	Common laboratory contaminant.
Uranium-234, pCi/L	42	42	0.81	166	0.88	18	--	--	
Uranium-235, pCi/L	42	7	0.54	7.14	0.167	7	--	--	
Uranium-238, pCi/L	42	39	0.52	170	2.05	8	--	--	
Vanadium (filtered), µg/L	921	910	25.7	45.5	19.3	725	--	--	
Vanadium (unfiltered), µg/L	376	374	26.2	45.8	--	--	--	--	
Xylene, µg/L	695	4	0.36	0.45	0	4	--	--	

Table 4-2. Sample Results for 200-UP-1 Contaminants of Potential Concern[a]

Constituent	Number of Analyses	Number of Detections	Median of Detections[b]	Maximum of Detections[b]	Natural Background (95th Percentile)	Number of Results Above Background[b]	Drinking Water Standard	Number of Results Above Drinking Water Standard[b]	Comment
Additional Contaminants of Potential Concern Identified for This RI/FS Report									
Aluminum (filtered), µg/L	374	192	41.1	114	11.7	47	50	8	Many results are probably false positives.
Aluminum (unfiltered), µg/L	71	44	48.6	109	--	--	50	12	Many results are probably false positives.
Bromodichloromethane, µg/L	189	32	0.2	1.1	0	32	80	0	
Chloromethane, µg/L	189	25	0.34	1.3	0	22	--	--	
Styrene, µg/L	189	2	0.20	0.23	0	2	--	--	
Thallium (filtered), µg/L	22	3	9.2	9.2	1.87	1	2	1	Two of the detections flagged to indicate a QC problem.
Thallium (unfiltered), µg/L	22	2	N/A	N/A	--	--	2	0	Both detections flagged to indicate a QC problem.
trans-1,3-Dichloropropene, µg/L	189	1	0.1	0.1	0	1	--	--	

a. Does not include samples collected for characterization purposes during well drilling.
b. Excludes results flagged as "suspect" or "reject" or otherwise flagged to indicate a laboratory QC problem.
c. All results greater than or equal to 1 pCi/L counted as detections.
d. Fluoride was added as a COPC by Ecology in the RI/FS work plan approval letter.
e. Federal DWS is 100 ug/L, but the State MTCA B value of 48 ug/L is used throughout this report.
General note -- = not applicable

Table 4-3. Depth-discrete Sampling Results during Well Drilling within the 200-UP-1 OU

Well Name and Sample Date Range	Sample Depth		Sample Results										
			Field Parameters					Other Chemicals			Radionuclides		
	Below Land Surface (ft)	Below Water Table (m)	Specific Conductance (µS/cm)	Dissolved Oxygen (µg/L)	Carbon Tetrachloride (µg/L)	Chloroform (µg/L)	Trichloroethene (µg/L)	Chromium (µg/L)	Nitrate (mg/L)	Uranium (µg/L)	Technetium-99 (pCi/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)
299-W14-71	284	2.2	N/A	N/A	N/A	(2)	(ND)	N/A	N/A	N/A	N/A	N/A	N/A
9/14/06-10/13/06	296	5.8	N/A	6,700	(80.7)	(4.76)	(ND)	N/A	12.8 (13)	0.716	ND	ND	ND
	322	13.8	N/A	8,000	(77.9)	(5.5)	(ND)	N/A	10.9 (12)	0.654	17.1	ND	ND
	347	21.4	N/A	7,250	(100)	(3.3)	(ND)	N/A	4.07 (10.5)	0.354	49.6	ND	ND
	367	27.5	N/A	8,200	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	396	36.4	N/A	7,100	(308)	(6.16)	(2.4)	N/A	(6)	0.593	ND	N/A	N/A
	418	43.1	N/A	N/A	1,600	33	13	N/A	8.9	N/A	ND	ND	ND
	421	44	N/A	7,400	(421)	(10)	(3.27)	N/A	6.6 (7)	0.632	ND	ND	ND
	435	48.2	N/A	5,300	(303)	(27)	(2.88)	N/A	(6)	0.466	ND	N/A	N/A
	467	57.9	N/A	N/A	(187)	(16.3)	(ND)	N/A	N/A	0.463	82.1	N/A	N/A
299-W19-101/50	277.5	5.8	N/A	N/A	32.5	1.7	ND	N/A	N/A	78.2	924	N/A	N/A
8/8/05-8/23/05	297.5	11.9	N/A	N/A	89	3.9	4	N/A	N/A	6.6	ND	N/A	N/A
	320	18.7	N/A	N/A	120	3.5	5.7	N/A	N/A	7.62	ND	N/A	N/A
	351	28.2	N/A	N/A	69	7	4.2	N/A	N/A	1.1	ND	N/A	N/A
	380	37	N/A	N/A	120	8.8	4.9	N/A	N/A	1.11	ND	N/A	N/A
299-W19-105	280	7.2	N/A	N/A	(88)	(2.2)	(ND)	N/A	N/A	9.02	205	N/A	N/A
1/11/06-1/16/06	308	15.8	N/A	N/A	(24)	(ND)	(ND)	N/A	N/A	2.66	85.5	N/A	N/A
	339	25.2	N/A	N/A	(19)	(ND)	(ND)	N/A	N/A	1.88	196.5	N/A	N/A
	379	37.4	N/A	N/A	(ND)	(5.4)	(ND)	N/A	N/A	1.04	34.2	N/A	N/A
299-W19-107	287	5	N/A	4,500	(118)	(5.5)	(2.2)	N/A	(21)	4.6	ND	N/A	N/A
3/28/06-4/10/06	300	8.9	N/A	8,900	(156)	(3.5)	(2.3)	N/A	(41)	0.994	ND	N/A	N/A
	320	15	N/A	7,600	(132)	(4.1)	(3.5)	N/A	(44)	1.35	ND	N/A	N/A
	360	27.2	N/A	9,500	(201.5)	(5.85)	(4.8)	N/A	(31)	0.952	ND	N/A	N/A
	400	39.4	N/A	10,300	(115)	(9.7)	(7)	N/A	(16)	0.935	ND	N/A	N/A
	429	48.3	N/A	9,300	(20.6)	(8.4)	(5)	N/A	(13)	0.813	ND	N/A	N/A
299-W19-46	269	4.1	N/A	N/A	N/A	N/A	N/A	N/A	55.8	23.4	153	N/A	ND
11/19/02-11/21/02	280	7.4	N/A	N/A	N/A	N/A	N/A	N/A	30.1	131	163	N/A	597

Table 4-3. Depth-discrete Sampling Results during Well Drilling within the 200-UP-1 OU

Well Name and Sample Date Range	Sample Depth		Sample Results										
			Field Parameters					Other Chemicals			Radionuclides		
	Below Land Surface (ft)	Below Water Table (m)	Specific Conductance (µS/cm)	Dissolved Oxygen (µg/L)	Carbon Tetrachloride (µg/L)	Chloroform (µg/L)	Trichloroethene (µg/L)	Chromium (µg/L)	Nitrate (mg/L)	Uranium (µg/L)	Technetium-99 (pCi/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)
	300	13.5	357	N/A	98	2	0.46	N/A	35.4	134	212	N/A	ND
	320	19.6	N/A	N/A	N/A	N/A	N/A	N/A	179	22.9	1,360	N/A	ND
	340	25.7	453	N/A	46	6.1	2.1	N/A	65.5	2.26	715	N/A	ND
	360	31.8	N/A	N/A	ND	ND	ND	N/A	15.1	0.88	55.7	N/A	ND
	379	37.6	395	N/A	75	8	4	N/A	21.2	1.57	215	N/A	ND
299-W19-48	290	11	N/A	N/A	37	4.25	ND	N/A	332	147	1,450	1.62	490
11/30/04-12/16/04	342.5	27	N/A	N/A	75	10.575	2.5	N/A	21.175	1.275	140	1.07	ND
	400	44.5	N/A	N/A	100	10.85	3.5	N/A	14.1	0.965	33	ND	ND
	414.1	48.8	N/A	N/A	40	8.6	1.2	N/A	15.35	1.63	37	ND	ND
299-W19-49	279	7.6	N/A	N/A	23	1.4	ND	N/A	N/A	111	ND	N/A	N/A
9/1/05-9/6/05	295	12.5	N/A	N/A	63	3.4	ND	N/A	N/A	48	ND	N/A	N/A
	315	18.6	N/A	N/A	130	5	ND	N/A	N/A	30.3	ND	N/A	N/A
	349	29	N/A	N/A	120	3.6	ND	N/A	N/A	2.72	1,320	N/A	N/A
	379	38.1	N/A	N/A	100	5.5	1.6	N/A	N/A	1.6	ND	N/A	N/A
299-W21-2	289	8.4	N/A	N/A	(16)	(ND)	(ND)	N/A	N/A	4.63	257	N/A	N/A
11/24/04-12/7/04	309	14.5	N/A	N/A	(6.5)	(ND)	(ND)	N/A	N/A	2.54	ND	N/A	N/A
	334	22.2	N/A	N/A	(6.4)	(3.5)	(ND)	N/A	N/A	0.92	ND	N/A	N/A
	349	26.7	N/A	N/A	(13)	2.9 (3.1)	1.1 (ND)	N/A	N/A	1.46	ND	N/A	N/A
	369	32.8	N/A	N/A	16 (11)	3.6 (3.2)	1.2 (ND)	N/A	N/A	1.12	34.2	N/A	N/A
	381	36.5	N/A	N/A	13 (8.15)	3.2 (ND)	ND (ND)	N/A	N/A	0.902	51.3	N/A	N/A
299-W22-47	231	0.5	N/A	N/A	N/A	N/A	N/A	1.15[a]	39.67	N/A	306	N/A	N/A
1/10/05-1/21/05	235	1.7	N/A	N/A	N/A	N/A	N/A	0.98[a]	103.13	N/A	10,455	N/A	N/A
	240	3.2	N/A	N/A	N/A	N/A	N/A	0.76[a]	106.24	N/A	16,575	N/A	N/A
	243	4.1	N/A	N/A	N/A	N/A	N/A	0.73[a]	121.18	N/A	11,135	N/A	N/A
	248	5.7	N/A	N/A	93 (36)	3.4	ND	196	107.92	N/A	19,550	N/A	N/A
	253	7.2	N/A	N/A	N/A	N/A	N/A	32.6[a]	110.52	N/A	20,060	N/A	N/A
	258	8.7	N/A	N/A	N/A	N/A	N/A	18.4[a]	110.01	N/A	20,230	N/A	N/A

Table 4-3. Depth-discrete Sampling Results during Well Drilling within the 200-UP-1 OU

Well Name and Sample Date Range	Sample Depth		Sample Results										
			Field Parameters					Other Chemicals			Radionuclides		
	Below Land Surface (ft)	Below Water Table (m)	Specific Conductance (µS/cm)	Dissolved Oxygen (µg/L)	Carbon Tetrachloride (µg/L)	Chloroform (µg/L)	Trichloroethene (µg/L)	Chromium (µg/L)	Nitrate (mg/L)	Uranium (µg/L)	Technetium-99 (pCi/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)
	263	10.2	N/A	N/A	N/A	N/A	N/A	4.44[a]	107.76	N/A	20,230	N/A	N/A
	269	12.1	N/A	N/A	96 (145)	3.6	ND	235	108.81	N/A	20,740	N/A	N/A
	273	13.3	N/A	N/A	N/A	N/A	N/A	50.1[a]	73.79	N/A	14,042	N/A	N/A
	278	14.8	N/A	N/A	N/A	N/A	N/A	74.3[a]	79.56	N/A	15,011	N/A	N/A
	283	16.3	N/A	N/A	N/A	N/A	N/A	49.1[a]	90.26	N/A	16,490	N/A	N/A
	288	17.9	N/A	N/A	81 (90)	3	ND	142	81.79	N/A	15,215	N/A	N/A
	293	19.4	N/A	N/A	N/A	N/A	N/A	1.05[a]	48.71	N/A	11,118	N/A	N/A
	298	20.9	N/A	N/A	N/A	N/A	N/A	2.65[a]	76.36	N/A	12,393	N/A	N/A
	303	22.4	N/A	N/A	N/A	N/A	N/A	1.32[a]	14.28	N/A	1,989	N/A	N/A
	308	23.9	N/A	N/A	3.4 (3.1)	ND	ND	0.87	4.03	N/A	272	N/A	N/A
	313	25.5	N/A	N/A	N/A	N/A	N/A	1.09[a]	6.67	N/A	629	N/A	N/A
	318	27	N/A	N/A	N/A	N/A	N/A	1.01[a]	4.42	N/A	323	N/A	N/A
	323	28.5	N/A	N/A	N/A	N/A	N/A	1.04[a]	2.24	N/A	85	N/A	N/A
	328	30	N/A	N/A	3.7 (5.2)	ND	ND	0.76	8.33	N/A	340	N/A	N/A
	333	31.6	N/A	N/A	N/A	N/A	N/A	1.17[a]	2.19	N/A	85	N/A	N/A
	338	33.1	N/A	N/A	N/A	N/A	N/A	0.95[a]	1.75	N/A	51	N/A	N/A
	343	34.6	N/A	N/A	N/A	N/A	N/A	0.99[a]	1.36	N/A	51	N/A	N/A
	348	36.1	N/A	N/A	2.6 (3.9)	ND	ND	0.80	1.47	N/A	51	N/A	N/A
299-W22-50	215	0.0	Rejected	N/A	13	2.3	ND	ND	58.0	0.78	4,240	N/A	31,400
11/23/99-1/12/00	241	6.6	235	N/A	5.6	0.91	ND	ND	12.8	3.34	812	N/A	19,900
	258	11.8	228	N/A	0.94	0.69	ND	ND	2.12	1.09	ND	N/A	969
	313	28.6	242	N/A	1.5	0.80	ND	ND	1.15	0.58	ND	N/A	304
	393	53.0	307	N/A	5.6	0.78	ND	ND	3.19	0.79	ND	N/A	ND
	441	67.6	323	N/A	0.89	0.76	ND	ND	12.8	0.43	ND	N/A	ND
	545	99.3	234	N/A	ND	ND	ND	ND	4.87	30.9	ND	N/A	ND
299-W22-69	259.75	7.2	N/A	N/A	(2.6)	(ND)	(ND)	N/A	N/A	2.01	1,080	N/A	N/A
1/30/06-2/8/06	288.5	16	N/A	N/A	(ND)	(ND)	(ND)	N/A	N/A	1.89	ND	N/A	N/A

Table 4-3. Depth-discrete Sampling Results during Well Drilling within the 200-UP-1 OU

Well Name and Sample Date Range	Sample Depth		Sample Results										
			Field Parameters					Other Chemicals			Radionuclides		
	Below Land Surface (ft)	Below Water Table (m)	Specific Conductance (µS/cm)	Dissolved Oxygen (µg/L)	Carbon Tetrachloride (µg/L)	Chloroform (µg/L)	Trichloroethene (µg/L)	Chromium (µg/L)	Nitrate (mg/L)	Uranium (µg/L)	Technetium-99 (pCi/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)
	316.5	24.5	N/A	N/A	(ND)	(ND)	(ND)	N/A	N/A	1.24	ND	N/A	N/A
	375	42.4	N/A	N/A	(11)	(ND)	(ND)	N/A	N/A	1.05	ND	N/A	N/A
299-W22-72	251	4.2	N/A	9,500	(3.5)	(ND)	(ND)	N/A	N/A	0.715	ND	N/A	N/A
2/23/06-2/28/06	270	10	N/A	10,700	(ND)	(ND)	(ND)	N/A	2.8	0.89	ND	N/A	N/A
	290	16.1	N/A	8,000	(ND)	(ND)	(ND)	N/A	2.5	1.1	ND	N/A	N/A
	310	22.2	N/A	3,600	(ND)	(ND)	(ND)	N/A	N/A	1.23	ND	N/A	N/A
	319.5	25.1	N/A	7,800	(3.8)	(ND)	(ND)	N/A	N/A	1.3575	ND	N/A	N/A
	357.8	36.8	N/A	8,000	(5.3)	(ND)	(ND)	N/A	N/A	1.12	ND	N/A	N/A
299-W22-86	250	4.8	N/A	9,300	(10)	(ND)	(ND)	N/A	(23)	3.29	2,000	N/A	N/A
3/13/06-3/16/06	267	10	N/A	9,000	(11.6)	(ND)	(ND)	N/A	(18.5)	1.601	1,300	N/A	N/A
	290	17	N/A	8,700	(ND)	(ND)	(ND)	N/A	(15)	4.124	645	N/A	N/A
	310	23.1	N/A	8,700	(ND)	(ND)	(ND)	N/A	N/A	0.997	161	N/A	N/A
	320	26.2	N/A	8,250	(ND)	(ND)	(ND)	N/A	(7)	1.277	134.25	N/A	N/A
	350	35.3	N/A	8,500	(2.25)	(ND)	(ND)	N/A	(5.5)	0.313	94.05	N/A	N/A
299-W22-87	269	5.6	N/A	N/A	(3.8)	(ND)	(ND)	N/A	N/A	1.08	ND	N/A	N/A
12/20/05-12/27/05	299.5	14.9	N/A	N/A	(6.4)	(ND)	(ND)	N/A	N/A	1.25	ND	N/A	N/A
	329	23.9	N/A	N/A	(ND)	(ND)	(ND)	N/A	N/A	0.82	ND	N/A	N/A
	379.5	39.3	N/A	N/A	(ND)	(ND)	(ND)	N/A	N/A	2.76	ND	N/A	N/A
299-W22-88	277.5	5	N/A	N/A	3.6	N/A	ND	N/A	N/A	N/A	ND	N/A	N/A
2/13/08-2/28/08	307	14	N/A	N/A	9.8	2	ND	N/A	N/A	N/A	ND	N/A	N/A
	347	26.2	N/A	N/A	14	2.2	ND	N/A	N/A	N/A	ND	N/A	N/A
	387	38.4	N/A	N/A	22	N/A	ND	N/A	N/A	N/A	ND	N/A	N/A
	438	53.9	N/A	N/A	8.8	1.6	ND	N/A	N/A	N/A	ND	N/A	N/A
699-30-66	275	6.3	N/A	N/A	ND (ND)	1.5	ND	49/ND[b]	15.7	0.196	ND	ND	18,000
9/8/04-10/12/04	312	17.6	N/A	N/A	ND (ND)	ND	ND	ND/1.36[b]	21.1	1.06	ND	ND	570
	342	26.7	N/A	N/A	ND (ND)	2.25	ND	9/26.5[b]	22.4	1.47	3.4	ND	ND
	387	40.4	N/A	N/A	ND (5.4)	4.3	ND	ND/4.73[b]	17.3	1.32	ND	ND	ND

Table 4-3. Depth-discrete Sampling Results during Well Drilling within the 200-UP-1 OU

Well Name and Sample Date Range	Sample Depth		Sample Results										
			Field Parameters					Other Chemicals			Radionuclides		
	Below Land Surface (ft)	Below Water Table (m)	Specific Conductance (µS/cm)	Dissolved Oxygen (µg/L)	Carbon Tetrachloride (µg/L)	Chloroform (µg/L)	Trichloroethene (µg/L)	Chromium (µg/L)	Nitrate (mg/L)	Uranium (µg/L)	Technetium-99 (pCi/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)
699-32-76	244	5.4	307	9,980	ND	N/A	ND	N/A	N/A	N/A	N/A	N/A	N/A
12/6/07-12/14/07	273	14.2	355	9,430	ND	N/A	ND	N/A	N/A	N/A	N/A	N/A	N/A
	299	22.1	371	7,580	ND	N/A	ND	N/A	N/A	N/A	N/A	N/A	N/A
	342	35.2	381	N/A	ND	N/A	ND	N/A	N/A	N/A	N/A	N/A	N/A
699-33-74	258	7.3	N/A	N/A	6.1	1	ND	N/A	N/A	N/A	701	N/A	N/A
3/18/08-3/24/08	288	16.4	N/A	N/A	2	N/A	ND	N/A	N/A	N/A	958	N/A	N/A
	318	25.6	283	13,400	ND	N/A	ND	N/A	N/A	0.58	902	N/A	N/A
	358	37.7	286	9,040	2.1	1.1	ND	N/A	N/A	0.5	481	N/A	N/A
699-33-75	242	2.2	542	10,400	13	1.1	ND	N/A	N/A	N/A	N/A	N/A	N/A
1/16/08-1/22/08	277	12.9	N/A	N/A	43	1.5	ND	N/A	N/A	N/A	N/A	N/A	N/A
	307	22	N/A	N/A	35	1.3	ND	N/A	N/A	N/A	N/A	N/A	N/A
	346	33.9	N/A	N/A	12	N/A	ND	N/A	N/A	N/A	N/A	N/A	N/A
699-33-76	243	6.2	N/A	N/A	3.3	N/A	ND	N/A	N/A	N/A	ND	N/A	N/A
3/3/08-3/6/08	273	15.3	N/A	N/A	3.6	N/A	ND	N/A	N/A	N/A	ND	N/A	N/A
	302	24.2	N/A	N/A	3.5	N/A	ND	N/A	N/A	N/A	ND	N/A	N/A
	342	36.3	N/A	N/A	6.8	N/A	ND	N/A	N/A	N/A	ND	N/A	N/A
699-34-72	261	7.9	N/A	N/A	ND	N/A	ND	N/A	N/A	1.62	85.5	N/A	N/A
2/28/08-3/10/08	287.4	15.9	N/A	N/A	ND	N/A	ND	N/A	N/A	1.33	ND	N/A	N/A
	328.4	28.4	N/A	N/A	1.4	N/A	ND	N/A	N/A	0.403	ND	N/A	N/A
	368.8	40.7	N/A	N/A	3.4	N/A	ND	N/A	N/A	0.251	ND	N/A	N/A
	417	55.4	N/A	N/A	ND	N/A	ND	N/A	N/A	N/A	ND	N/A	N/A
699-36-70A	286	9.8	309	N/A	ND	0.70	ND	ND	26	0.60	5.85	N/A	74,600
9/30/94-11/2/94	307	16.2	499	N/A	5.9	0.62	0.13	ND	63	1.98	29.9	N/A	56,900
	334	24.4	N/A	N/A	8.0	0.64	0.11	ND	72	1.99	33.6	N/A	56,900
	372	36.0	468	N/A	8.9	1.3	0.27	ND	62	2.84	12.1	N/A	77,300
	400	44.5	Rejected	N/A	N/A	ND	N/A	N/A	N/A	0.75	6.55	N/A	20,100
	430	53.6	370	N/A	ND	0.65	ND	ND	15	14.8	ND	N/A	1,010

Table 4-3. Depth-discrete Sampling Results during Well Drilling within the 200-UP-1 OU

Well Name and Sample Date Range	Sample Depth		Sample Results										
			Field Parameters					Other Chemicals			Radionuclides		
	Below Land Surface (ft)	Below Water Table (m)	Specific Conductance (µS/cm)	Dissolved Oxygen (µg/L)	Carbon Tetrachloride (µg/L)	Chloroform (µg/L)	Trichloroethene (µg/L)	Chromium (µg/L)	Nitrate (mg/L)	Uranium (µg/L)	Technetium-99 (pCi/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)
699-36-70B	270	1.5	N/A	N/A	ND (ND)	6.55	ND	N/A	103	1.17	250	ND	8,800
8/18/04-9/24/04	304	11.9	N/A	N/A	1.1 (ND)	1.7	ND	N/A	40	0.598	ND	N/A	1,200
	340	22.9	N/A	N/A	ND (ND)	3.1	ND	N/A	ND	ND	ND	ND	1,000
	375	33.5	N/A	N/A	8.5 (7.2)	3.5	ND	N/A	N/A	1.59	30	N/A	N/A
	417	46.3	N/A	N/A	ND (ND)	1.55	ND	N/A	5.5	0.11	ND	ND	325
699-38-70B	312	7.3	N/A	N/A	(55)	3.6	3	N/A	N/A	1.45	10	N/A	N/A
2/4/04-2/27/04	348	18.3	N/A	N/A	(309)	9.6	5.1	N/A	N/A	1.04	ND	N/A	N/A
	379	27.7	N/A	N/A	(311)	9.9	5.7	N/A	N/A	0.97	ND	N/A	N/A
	408	36.6	N/A	N/A	(470)	9.3	7.9	N/A	N/A	0.74	ND	N/A	N/A
	439	46	N/A	N/A	(428)	22	7.15	N/A	N/A	0.7	ND	N/A	N/A
	478	57.9	N/A	N/A	(14)	ND	ND	N/A	N/A	1.38	ND	N/A	N/A
699-38-70C	329	6.4	N/A	N/A	(25)	2.1	4.9	N/A	N/A	3.02	1,600	N/A	N/A
2/18/04-2/20/04	370	18.9	N/A	N/A	(28)	ND	9.1	N/A	N/A	2.76	970	N/A	N/A
	399	27.7	N/A	N/A	(32)	2.7	8.4	N/A	N/A	2.67	1,200	N/A	N/A
	415	32.6	N/A	N/A	(31)	2.7	6.9	N/A	N/A	2.79	1,200	N/A	N/A
699-40-65	358	6.4	N/A	N/A	ND	ND	ND	N/A	N/A	1.54	190	N/A	N/A
12/18/03-12/31/03	459	37.2	N/A	N/A	ND	ND	ND	N/A	N/A	2.92	ND	N/A	N/A

Notes: Values in parentheses are field analyzed results, which are generally not as accurate as laboratory analyzed results.

a. Chromium sample results for Well 299-W22-47 were collected by the air-lift method and are considered suspect. According to PNNL-15670, *Hanford Site Groundwater Monitoring for Fiscal Year 2005*, "air-lifted samples were deemed nonrepresentative because the water samples were in contact with sediment in a collection bottle for up to several days before a filtered sample was collected. During this time, the chromium in solution is believed to have been reduced by freshly exposed sediment surfaces (ground up basalt particles) and precipitated from solution, resulting in artificially low chromium concentrations. Chromium concentrations in all of the air-lifted samples were much lower than adjacent pumped samples."

b. Two values are provided: the first is hexavalent chromium and the second is total chromium. Chromium results for Well 699-30-66 are artificially low because of reducing conditions induced by the drilling process. Chromium results in the finished well are about 100 µg/L.

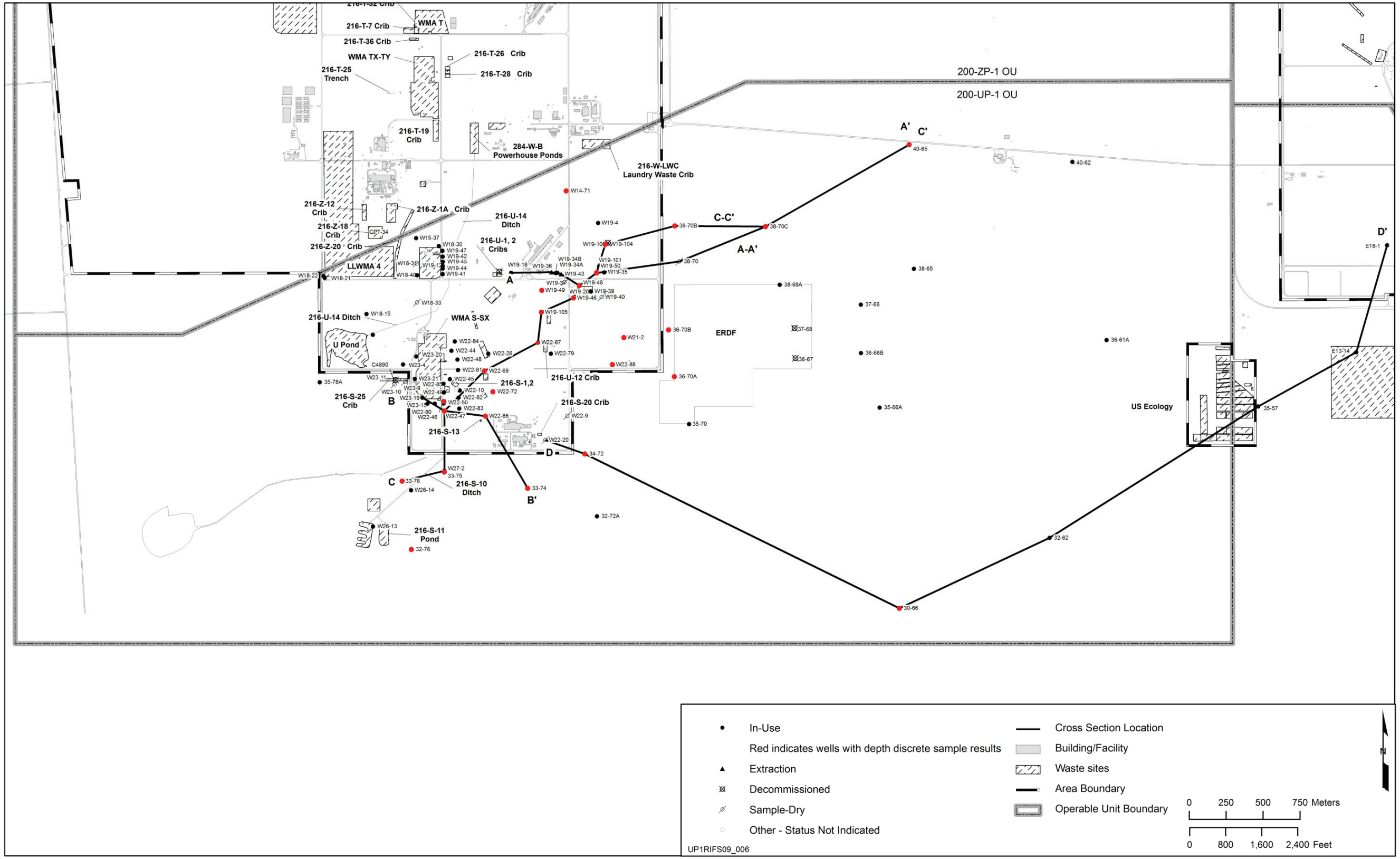

Figure 4-1. Wells and Cross Section Locations for the 200-UP-1 OU

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4.2.1 Technetium-99

During the RI, extensive groundwater sampling was performed for Tc-99 throughout the OU. Figure 4-2 shows all the wells sampled for Tc-99 (regardless of completion depth) and categorizes the maximum concentration observed between 2004 and 2009 as not detected (blue), detected but less than the federal DWS of 900 pCi/L (green), greater than the federal DWS but less than 10 times the federal DWS (yellow), or greater than 10 times the federal DWS (red). Tc-99 concentrations were found above the federal DWS at and downgradient (east) from the 216-U-1 and 216-U-2 Cribs, at RCRA WMA S-SX, and at WMA U, with concentrations exceeding 10 times the federal DWS downgradient from the 216-U-1 and 216-U-2 Cribs and WMA S-SX. To the east of the 200 West Area, Tc-99 was detected in groundwater but generally at concentrations below the federal DWS. Tc-99 was not detected in the monitoring wells at the 216-S-10 Pond and Ditch.

Figure 4-3 shows the Tc-99 plumes at the water table within the OU, based on average groundwater sample results for FY 2008. The Tc-99 plume downgradient from the 216-U-1 and 216-U-2 Cribs originates from the cribs, which received nearly 16 million L (4.2 million gal) of effluent between 1951 and 1961 (ARH-CD-745, *Input and Decayed Values of Radioactive Liquid Wastes Discharged to the Ground in the 200 Areas Through 1975*). Additional contaminant mass was added to the plume when effluent disposed of at the nearby 216-U-16 Crib in 1984 and 1985 migrated north along the CCU vadose perched water and mobilized the Tc-99 and uranium in the soil column beneath the 216-U-1 and 216-U-2 Cribs (DOE/RL-92-76, Rev. 1). The highest Tc-99 concentrations in groundwater occur between about 300 to 900 m (1,000 to 2,000 ft) downgradient (east) from the cribs, but another region of the plume above the federal DWS is interpreted to occur about 1.5 to 2 km (0.9 to 1.2 mi) east-northeast near Well 699-38-70C (Figure 4-1). Historically, the highest measured Tc-99 concentration in this plume was 41,000 pCi/L in Well 299-W19-24 (west of the 216-U-17 Crib) during October 1989.

To characterize the vertical extent of contamination within the 216-U-1 and 216-U-2 Cribs plume, depth-discrete groundwater sampling was performed during drilling of all new wells installed since FY 2003. In addition, Wells 299-W19-34A and 299-W19-34B, located between the P&T system extraction Wells 299-W19-36 and 299-W19-43, are screened below the water table and provide additional information on the vertical distribution of contamination. Figure 4-4 shows a cross section of the Tc-99 plume from the 216-U-1 and 216-U-2 Cribs (cross sections are shown on Figure 4-1), and Figure 4-5 shows depth discrete Tc-99 and uranium groundwater sample results from data collected when wells were installed.

At Well 699-38-70C, Tc-99 was found to exceed the federal DWS throughout the entire thickness of the unconfined aquifer (33 m [108 ft]), from near the water table to the top of the Ringold lower mud unit (Figure 4-1). The highest concentration was 1,600 pCi/L near the water table, but the concentration in the deepest sample above the Ringold lower mud unit was 1,200 pCi/L. Vertical dispersion is a mechanism by which this plume became fully mixed vertically throughout the aquifer at this distance from the source (about 2.0 km [1.2 mi]). At Wells 299-W19-46 and 299-W19-49, the highest Tc-99 concentrations (1,360 and 1,320 pCi/L, respectively) occurred between 20 and 30 m (65 and 100 ft) below the water table. At the remaining locations within the plume where depth-discrete sample results were available (Wells 299-W19-43, 299-W19-48, and 299-W19-101), the plume was limited to the upper 10 to 20 m (30 to 65 ft) of the aquifer.

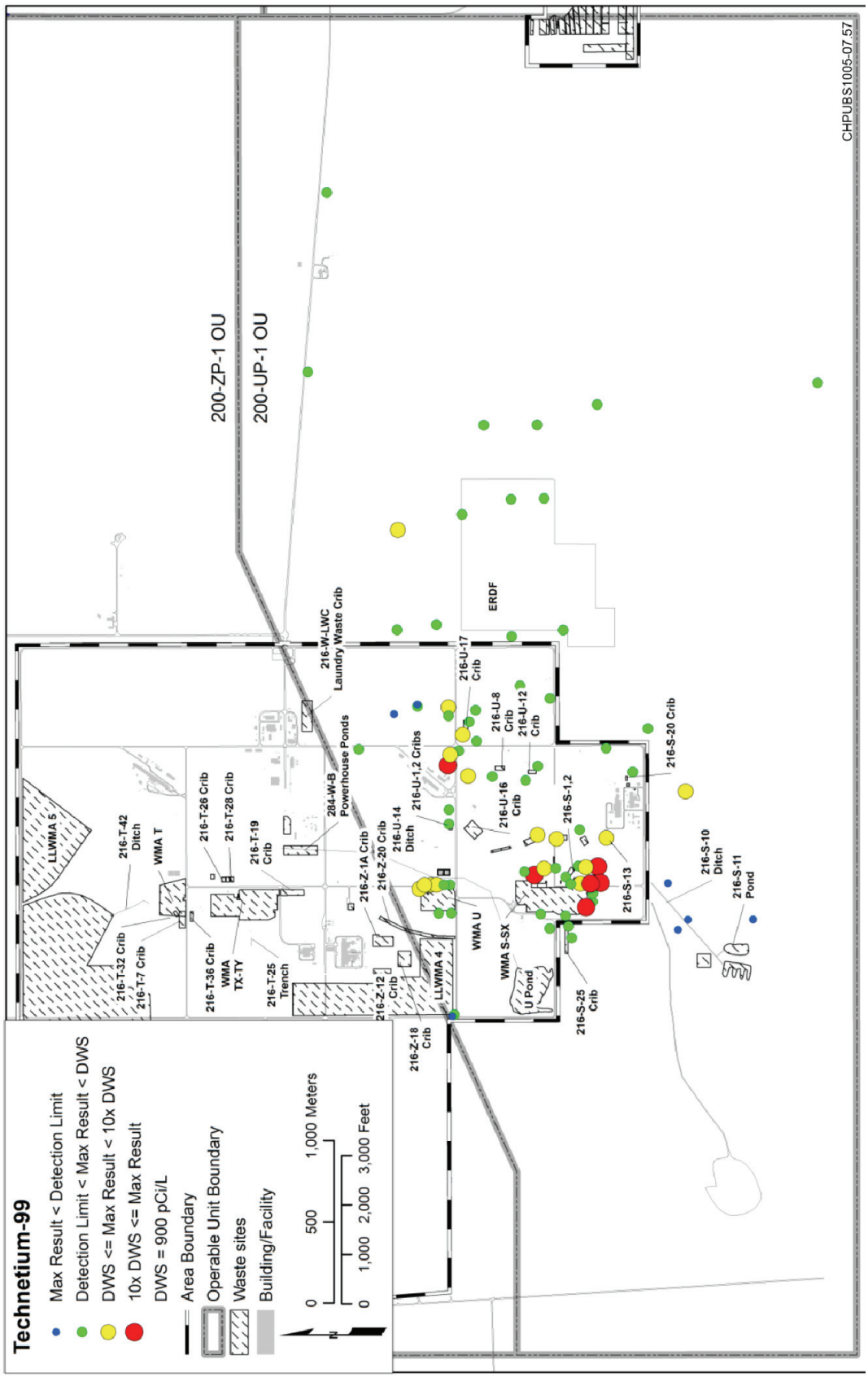
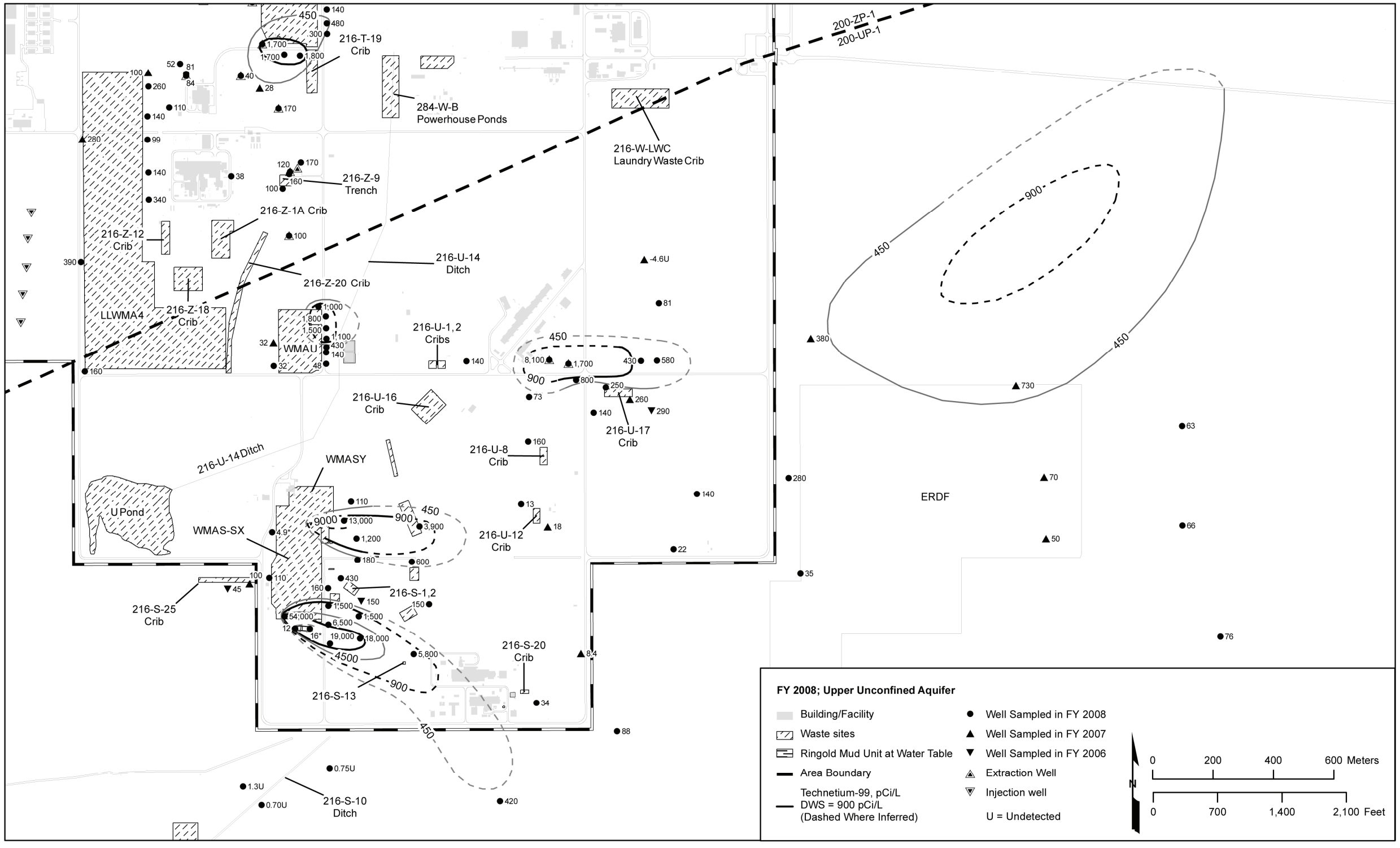


Figure 4-2. Maximum Sample Results for Technetium-99 during the Remedial Investigation



Source: DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*.

Figure 4-3. Average FY 2008 Technetium-99 Concentrations in the 200-UP-1 OU, Upper Part of Unconfined Aquifer

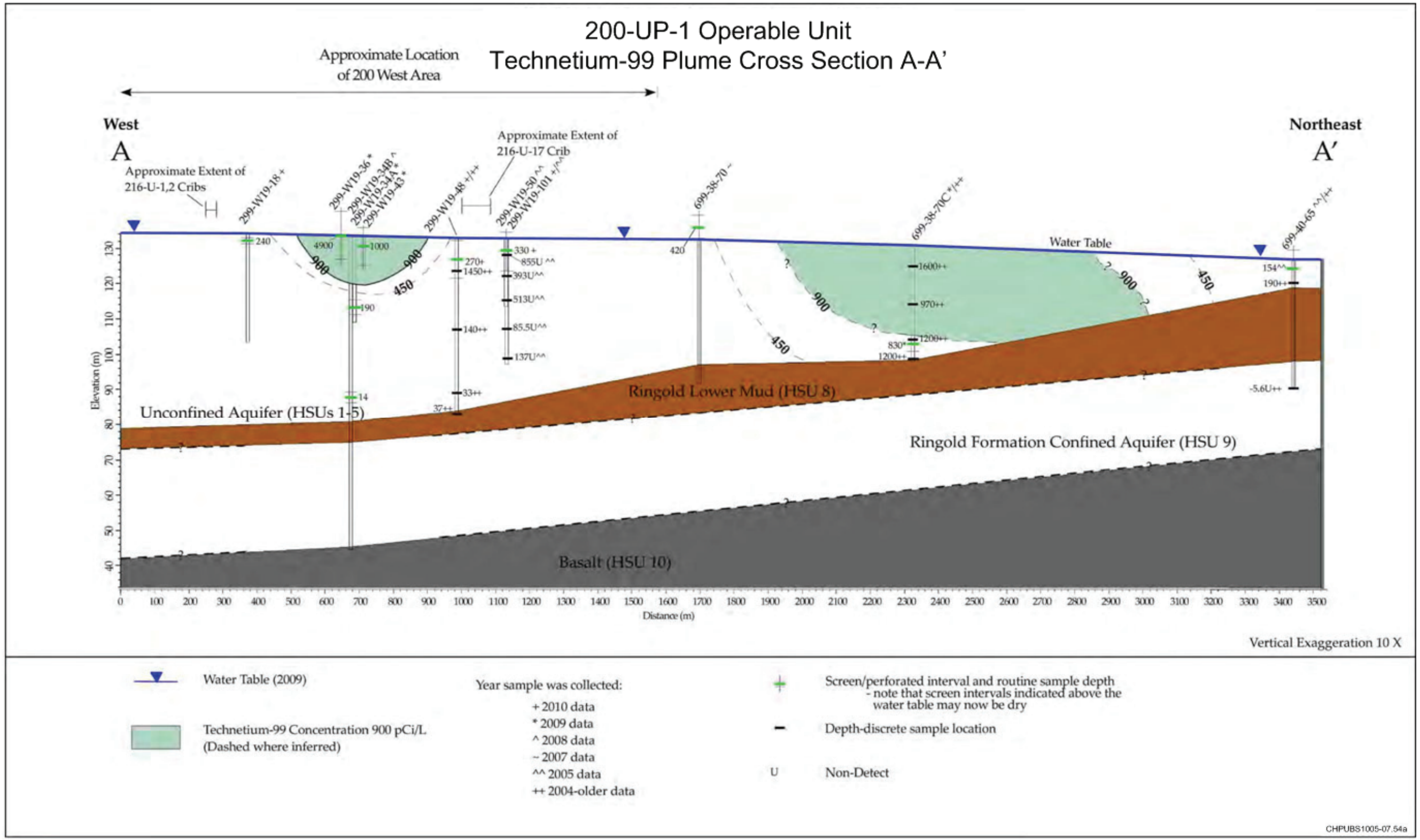
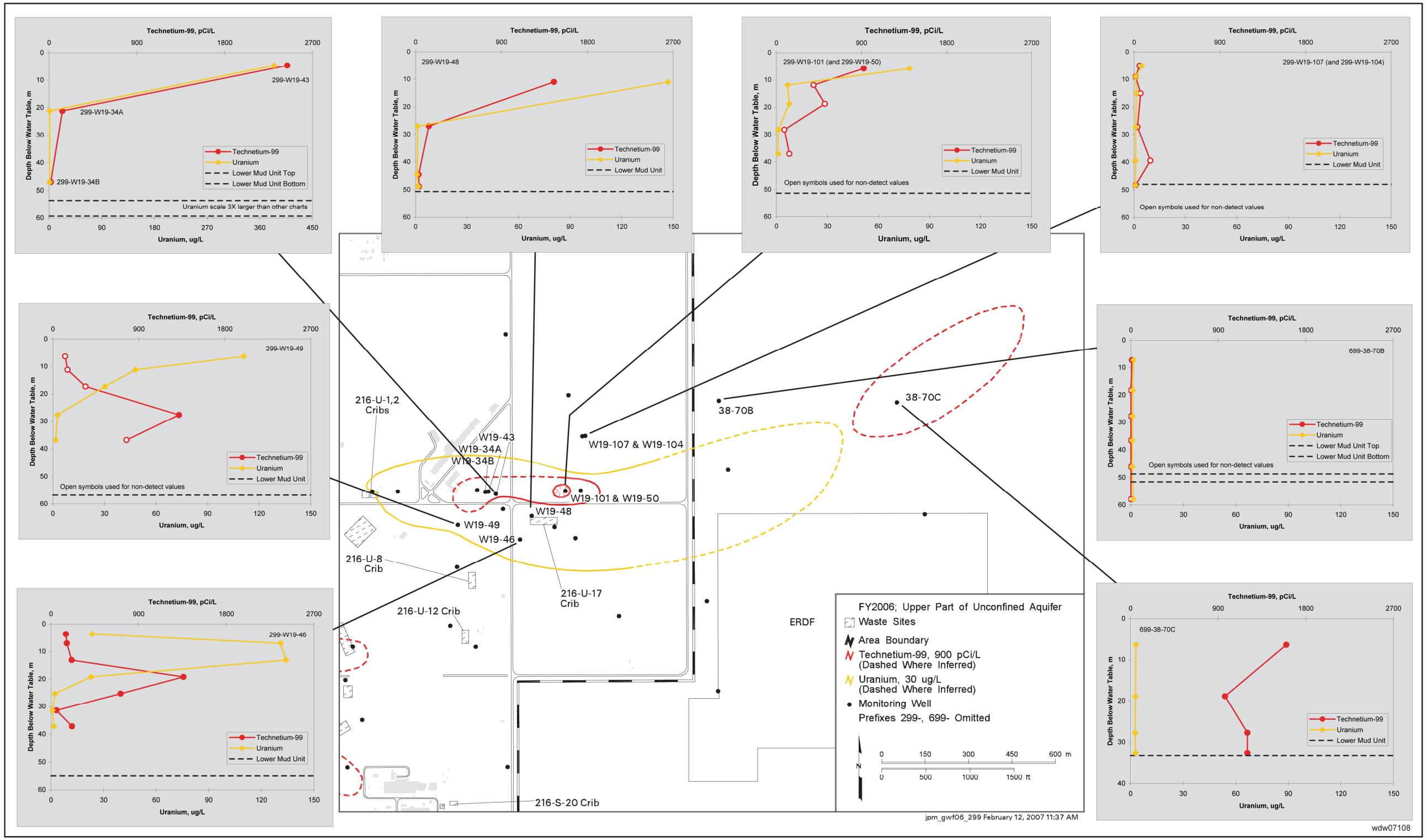


Figure 4-4. Cross Section of the Technetium-99 Plume from the 216-U-1 and 216-U-2 Crib



Source: PNNL-16346, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*.

Figure 4-5. Depth-discrete Sampling Results for Technetium-99 and Uranium in the Northern Part of the 200-UP-1 Operable Unit

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An IRA P&T system has been operating in the highest concentration part of the 216-U-1 and 216-U-2 Cribs plume since 1994, and the system has been successful in reducing Tc-99 concentrations in the aquifer. As of FY 2008, Tc-99 concentrations exceeded the 900 pCi/L federal DWS in extraction Wells 299-W19-36 and 299-W19-43, but concentrations were below the federal DWS at all of the nearby wells (Wells 299-W19-34A, 299-W19-34B, 299-W19-35, 299-W19-39, 299-W19-46, 299-W19-48, 299-W19-49, and 299-W19-101).

Concentrations in the extraction wells (Wells 299-W19-36 and 299-W19-43) have been below the IRA goal of 9,000 pCi/L since January 2008. Operation of this system has resulted in the separation of the Tc-99 plume into two parts, because the portion of the plume not captured by the system continued to migrate east. Section 4.3 provides additional discussion of the IRA.

At WMA S-SX, a Tc-99 plume originates from the SX Tank Farm in the southwestern corner of the WMA and another plume originates from the S Tank Farm in the northern part of the WMA (Figure 4-3). The highest Tc-99 concentrations within the OU occur in the southern plume at Well 299-W23-19 (inside the SX Tank Farm adjacent to Tank 241-SX-115). Well 299-W23-19 is within the source area, and the Tc-99 concentration in this well has varied (between 30,000 and 188,000 pCi/L) since sampling began in 1999, probably because of the episodic nature of contaminant migration from the vadose zone to the groundwater (Figure 4-6). Tank 241-SX-115 is the most likely source of this contamination (PNNL-13441, *RCRA Groundwater Quality Assessment Report for Waste Management Area S-SX [November 1997 through April 2000]*).

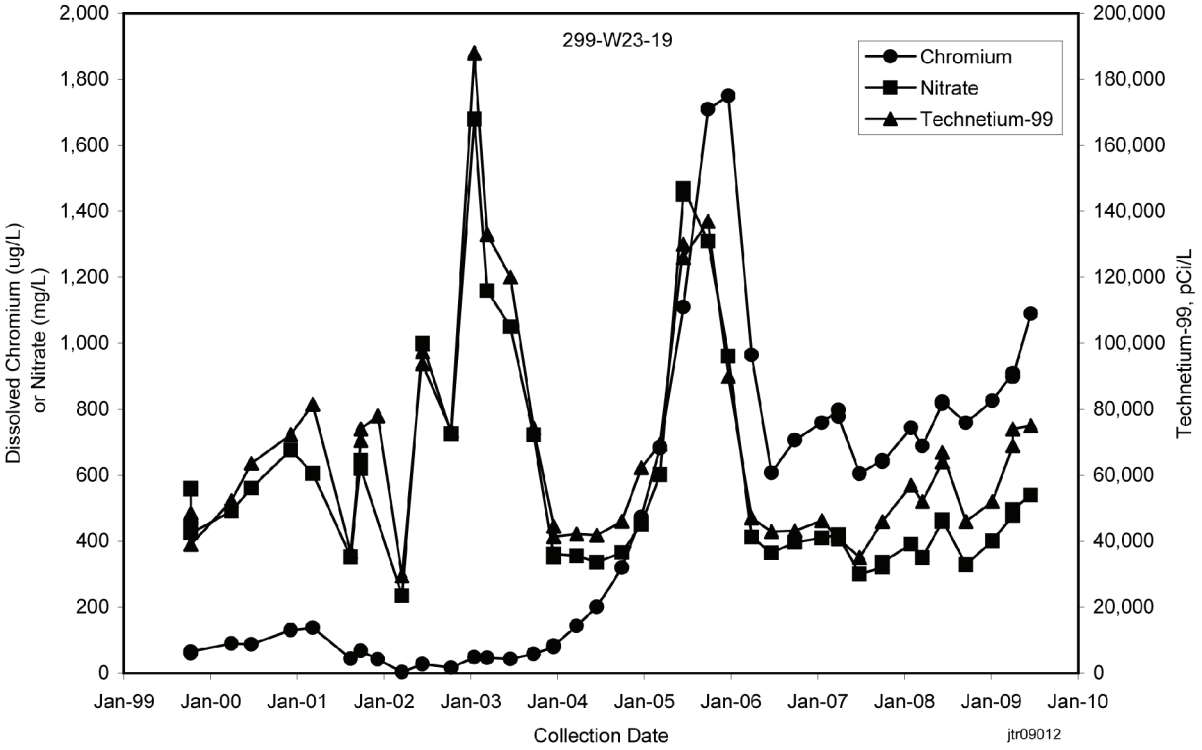

Figure 4-6. Chromium, Nitrate, and Technetium-99 Concentrations in Well 299-W23-19, Southern Portion of Waste Management Area S-SX

Concentrations near the water table occur above the federal DWS from the source area to between about 500 and 600 m (1,600 and 2,000 ft) downgradient. Beyond this, the plume orientation is southeastward toward Well 699-33-74, at concentrations generally below the DWS at the water table. This southeastward orientation results from the historical influence of the water table mound beneath the 216-U-10 Pond and later the 216-U-14 Ditch, which caused a more southerly groundwater flow direction before the mid-1990s. The southwestern boundary of the plume near and immediately downgradient from the source (WMA S-SX) is not well defined. Well 299-W22-47 was installed in 2005 with the goal of bounding the plume to the southwest. However, Tc-99 concentrations were higher at this location than in the wells to the north (Wells 299-W22-50 and 299-W22-49).

A low concentration area occurs in the southern Tc-99 plume from WMA S-SX around Wells 299-W22-80 and 299-W23-15. The FY 2008 average Tc-99 concentrations in these wells were 16 and 12 pCi/L, respectively. Higher concentrations are expected in these wells because they are near the source area, and high concentrations occur to the southeast at, and downgradient of, Well 299-W22-47 (FY 2008 average of 19,000 pCi/L). An in-well tracer test at Well 299-W22-80 and time-series sampling during extensive purging have indicated that relatively clean water may be migrating into the bottom of the well, moving up the wellbore, and diluting the Tc-99 concentration in the upper part of the plume (PNNL-14113, *Results of Detailed Hydrologic Characterization Tests—FY 2001*; PNNL-15070). A similar process is assumed to be occurring at Well 299-W23-15.

Figure 4-7 shows the vertical extent (Cross section B-B') of the southern Tc-99 plume from WMA S-SX. Data for three of the four wells used in this cross section, Well 299-W19-47 (installed during 2005), Well 299-W22-86 (2006), and Well 699-33-74 (2008), were obtained by depth-discrete sampling during drilling. The cross section shows that the Tc-99 plume occurs in the upper part of the unconfined aquifer; concentrations above the DWS occur no lower than 25 m (82 ft) below the water table.

The northern Tc-99 plume at WMA S-SX originates from the S Tank Farm where Tank 241-S-104 is the only tank known or assumed to have leaked (overfill event). Concentrations in groundwater above the DWS are interpreted to occur from the source area to about 400 m (1,300 ft) downgradient to the east near Well 299-W22-26. Tc-99 concentrations have remained low in upgradient Well 299-W23-20, confirming that the S Tank Farm is the source of this plume. Concentrations began increasing rapidly at two wells within this plume during FY 2007: Wells 299-W22-44 and 299-W22-26 (Figure 4-8). During June 2009, the concentration at Well 299-W22-44 was 17,000 pCi/L, and the concentration at Well 299-W22-26 was 4,800 pCi/L. Figure 4-9 shows the results of depth-discrete sampling for Tc-99 and uranium at the newly installed wells in the southern 200 West Area. Well 299-W22-69 is the only newly installed well near the northern plume from WMA S-SX. The depth-discrete samples collected at this location indicate that Tc-99 occurs near the water table.

Tc-99 concentrations in the downgradient wells at WMA U are elevated compared to concentrations in the upgradient wells. This downgradient increase in concentration beginning in 2003 indicates the U Tank Farm is a source of Tc-99 contamination (PNNL-13282, *Groundwater Quality Assessment for Waste Management Area U: First Determination*). However, concentrations are very low compared to WMA S-SX. The DWS (900 pCi/L) was exceeded in four downgradient monitoring wells during sampling in April 2009: Well 299-W18-30 at 1,100 pCi/L; Well 299-W19-42 at 1,700 pCi/L; Well 299-W19-45 at 1,500 pCi/L; and Well 299-W19-47 at 1,800 pCi/L. Concentrations are slowly increasing in these four wells (Figure 4-10). There is no information on the vertical distribution of contamination at WMA U.

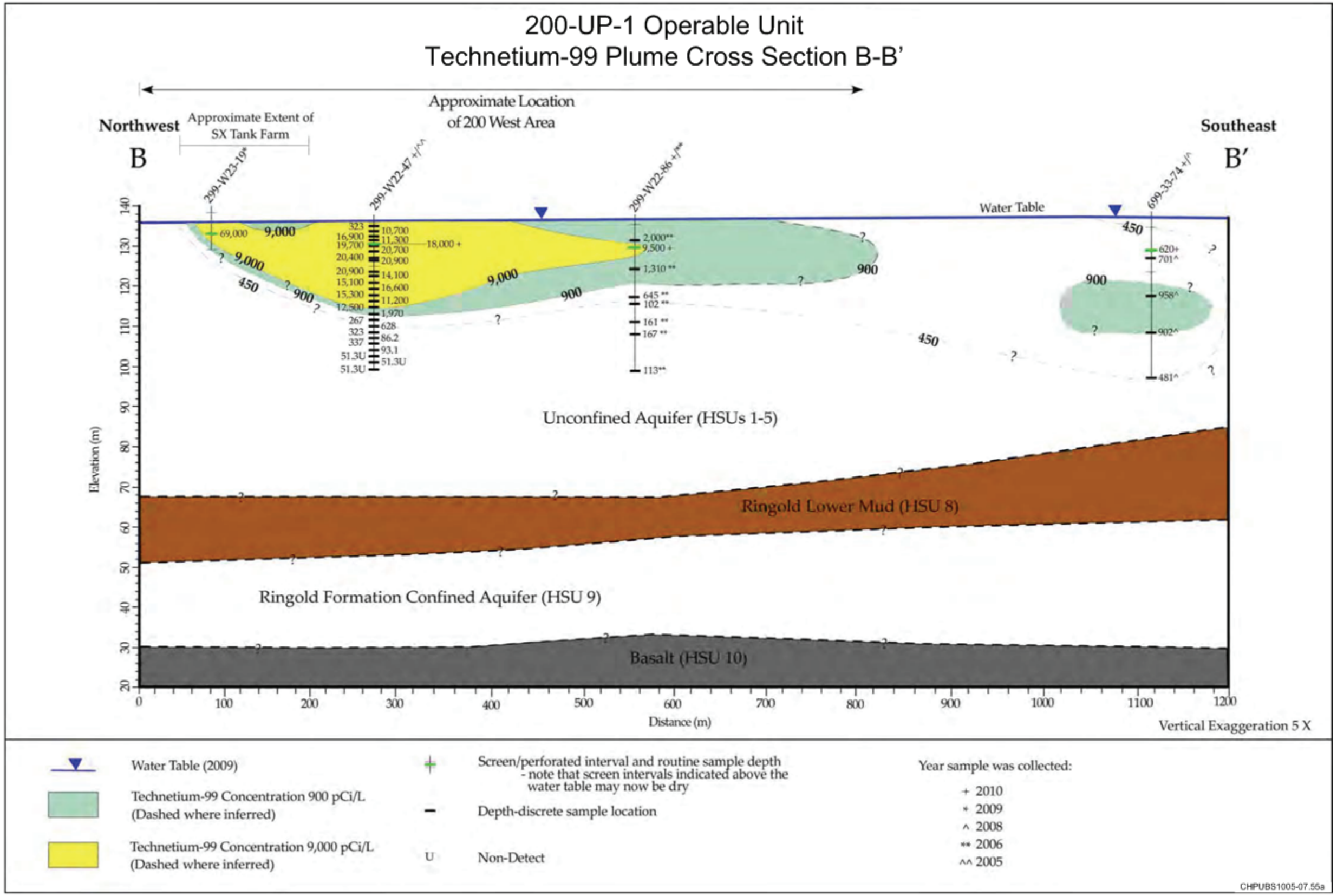

Figure 4-7. Cross Section of the Southern Technetium-99 Plume from Waste Management Area S-SX

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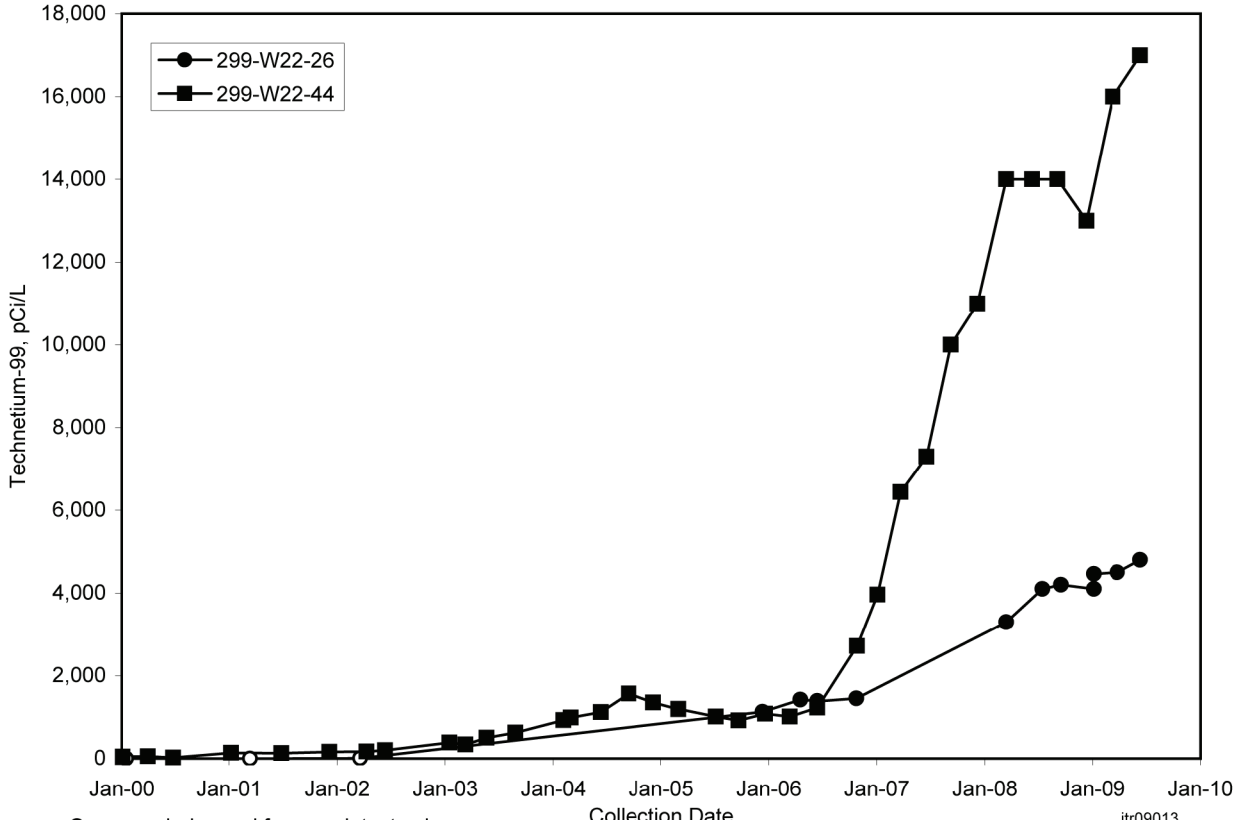

Figure 4-8. Technetium-99 Concentrations in Wells 299-W22-26 and 299-W22-44 Downgradient from the 241-S Tank Farm

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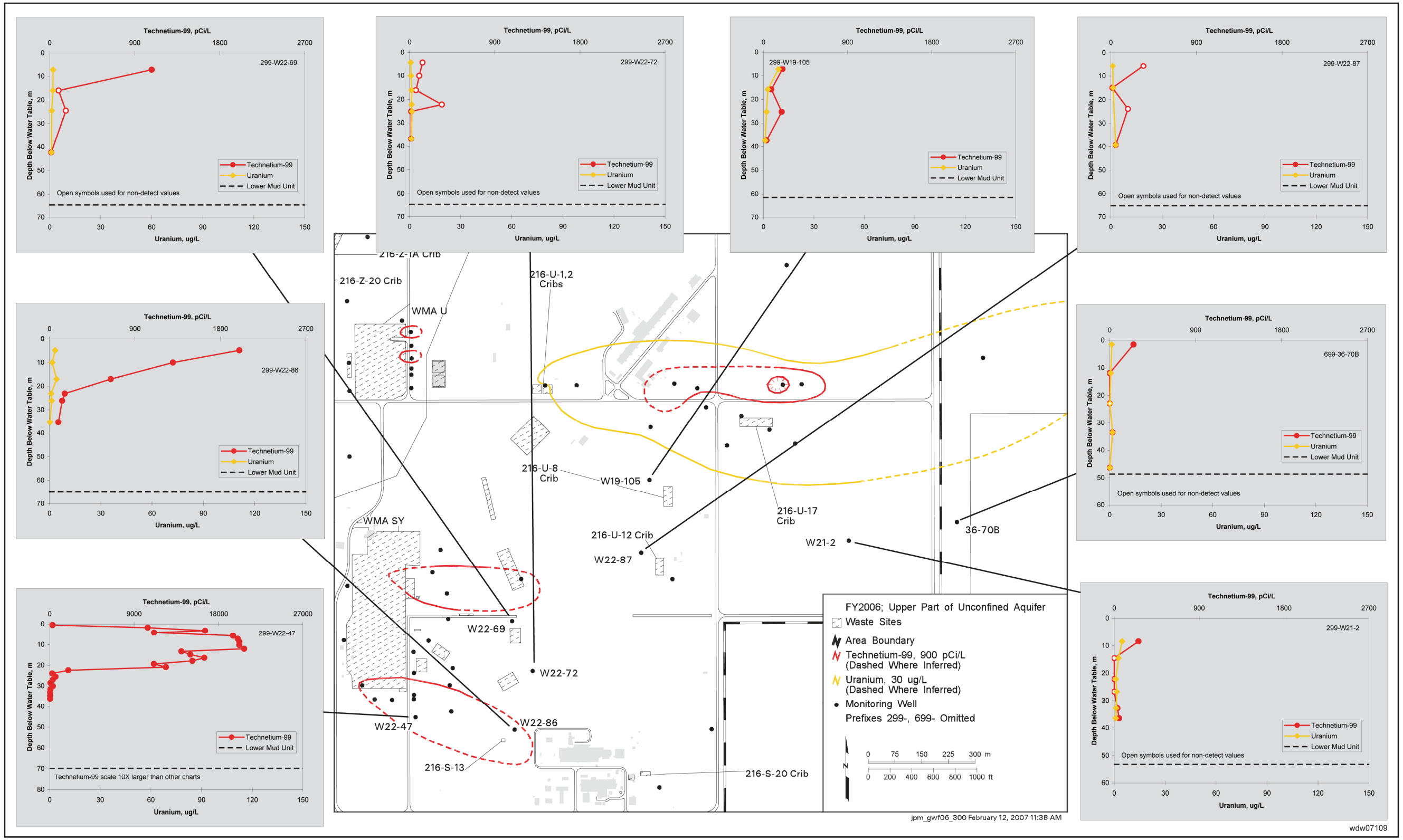

Source: PNNL-16346, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*.

Figure 4-9. Depth-discrete Sampling Results for Technetium-99 and Uranium in the Southern Part of the 200-UP-1 OU

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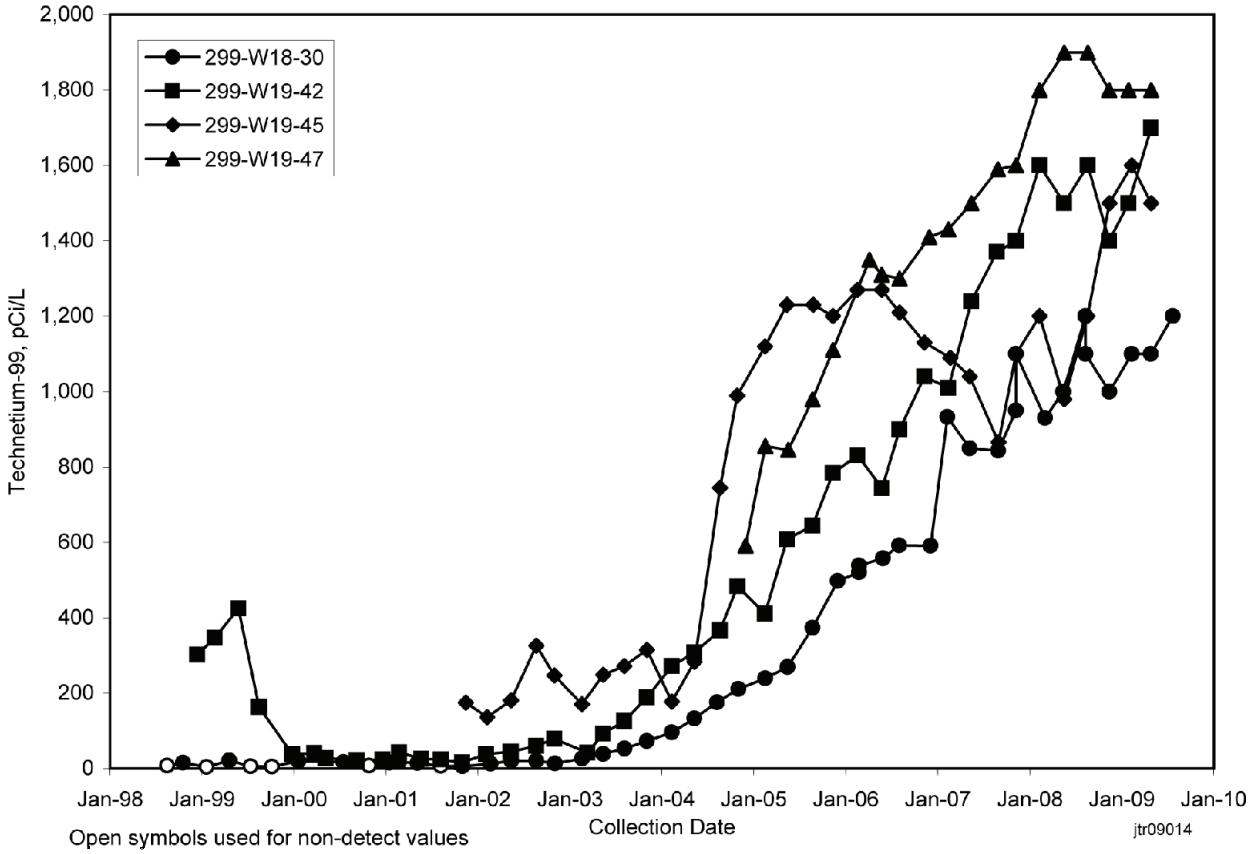


Figure 4-10. Technetium-99 Concentrations in Wells Downgradient from Waste Management Area U

4.2.2 Uranium

Extensive sampling for uranium was performed throughout 200-UP-1 OU during the RI. Figure 4-11 categorizes the maximum uranium concentration in each well sampled between 2004 and 2009. Uranium is naturally present in groundwater at levels above the laboratory detection limit, so uranium was detected in every sample. However, uranium concentrations exceeded the DWS (30 µg/L) in only two areas of the OU: downgradient from the 216-U-1 and 216-U-2 Cribs, and in the vicinity of the 216-U-10 Pond. Some of the uranium sample results exceeded 10 times the DWS in the 216-U-1 and 216-U-2 Cribs plume.

The uranium plume from the 216-U-1 and 216-U-2 Cribs extends about 1.5 km (0.9 mi) to the east at levels above the 30 µg/L DWS (Figure 4-12). Similar to the origin of Tc-99, the uranium originated from the cribs when they were active from 1951 to 1961. Additional mass was added to the groundwater plume when effluent that was disposed of at the nearby 216-U-16 Crib in 1984 and 1985 migrated north along a CCU perched groundwater in the vadose zone and mobilized the Tc-99 and uranium in the soil column beneath the 216-U-1 and 216-U-2 Cribs (DOE/RL-92-76, Rev. 1). One-dimensional simulations of uranium transport beneath these cribs suggest that the uranium bypassed the CCU by migrating to groundwater through an erosional window or along a wellbore (HNF-45099, *Development of a Geochemical Model for Uranium Transport in the Unsaturated and Saturated Sediments at the 200 West Area of the U.S. Department of Energy Hanford Site, Washington [MSE, ECCP-41]*).

An IRA P&T system has been operating in the highest concentration part of the 216-U-1 and 216-U-2 Cribs plume since 1995. While the system has been successful in reducing the uranium concentration to below the RAO of 300 µg/L, concentrations at all the water table monitoring wells in the baseline plume area continue to exceed the DWS of 30 µg/L. Uranium is less mobile in the aquifer compared to Tc-99, so uranium has not responded as well to the P&T system. Section 4.3 provides a more thorough discussion of the IRA.

Figure 4-5 and Figure 4-9 show the results of depth-discrete sampling for uranium during well installation. Figure 4-13 shows a cross section of the 216-U-1 and 216-U-2 Cribs plume. The data indicate that uranium in the 216-U-1 and 216-U-2 Cribs plume is limited to the upper 20 m (65 ft) of the aquifer and does not extend as far downgradient as the Tc-99. No exceedances of the DWS below 20 m (65 ft) deep occurred. Even in those wells in which Tc-99 was found relatively deep in the aquifer at concentrations above the DWS (Wells 299-W19-46, 299-W19-49, and 699-38-70C), uranium was not elevated at the same depths.

Near the source of the 216-U-1 and 216-U-2 Cribs plume, uranium continues to be elevated in Well 299-W19-18, although the concentration has decreased in recent years (Figure 4-14). The uranium concentration in this well during March 2009 was 407 µg/L, greater than 10 times the DWS. The persistence of uranium at this location may be because of an ongoing source of contaminant mass to the aquifer water, such as continued leaching from the vadose zone beneath the cribs or desorption of uranium from the aquifer sediment.

Uranium has been detected at concentrations slightly above the DWS in the vicinity of the 216-U-10 Pond in Wells 299-W23-4, 299-W18-21, and 299-W18-15. The maximum concentration in these wells between 2004 and 2009 was 35 µg/L in Well 299-W23-4 during March 2009. The source of this uranium is not known, but one possibility is slow leaching of uranium from the vadose zone soil beneath the 216-U-10 Pond. It has been estimated that the effluent disposed of in this pond may have contained about 2,100 kg (4,600 lbs) of uranium (RPP-26744, *Hanford Soil Inventory Model, Rev. 1*).

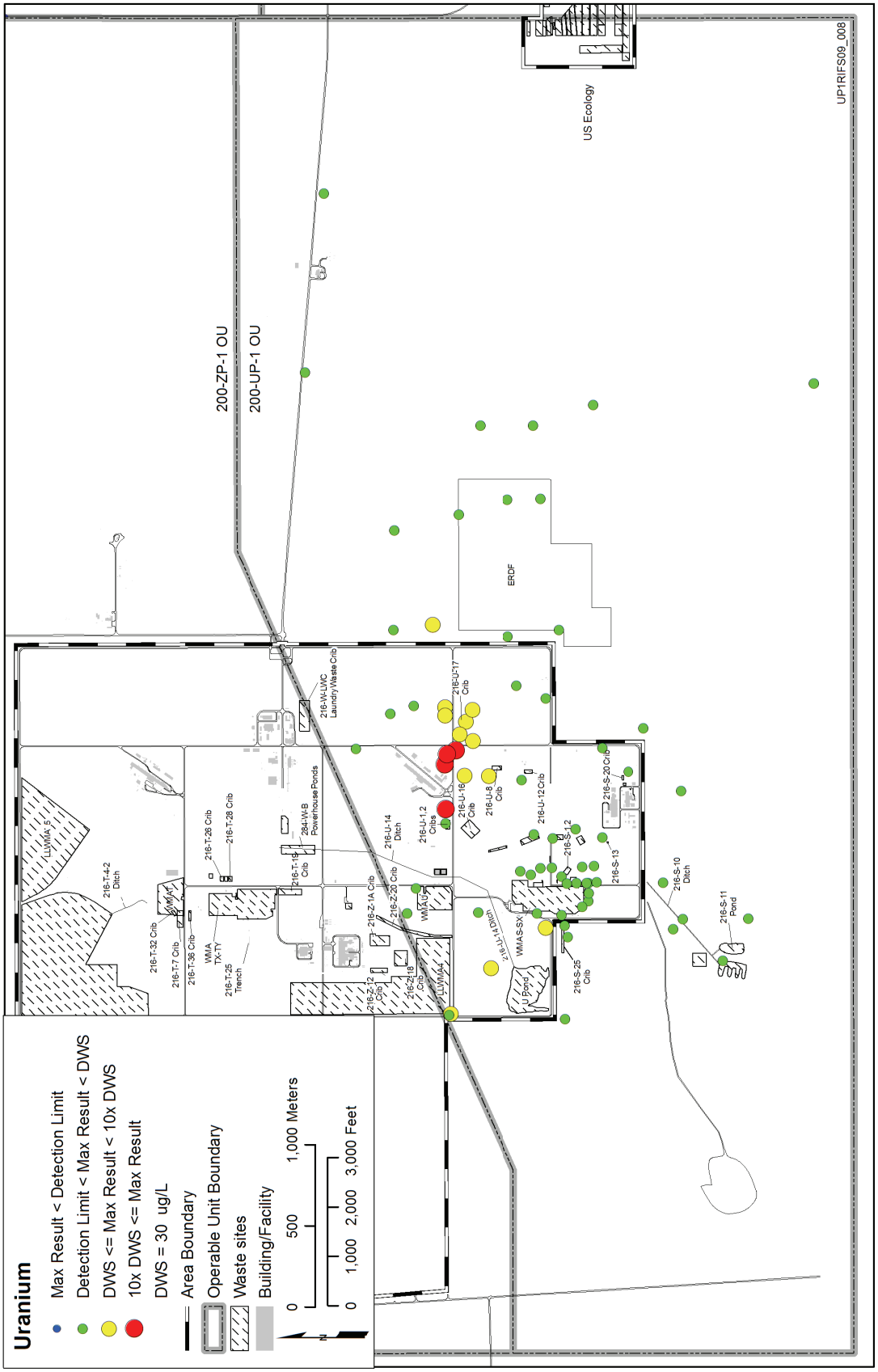
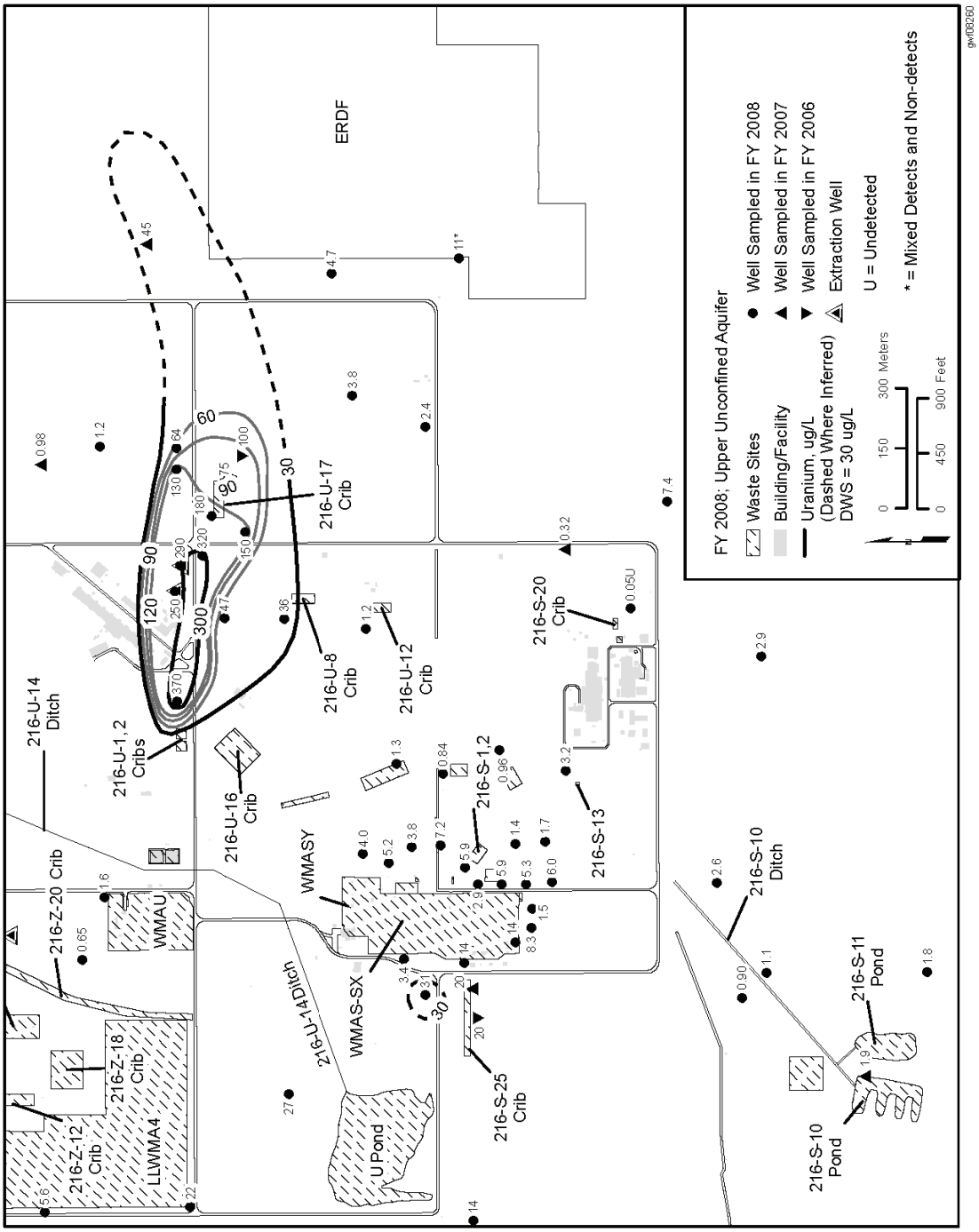


Figure 4-11. Maximum Sample Results for Uranium during the Remedial Investigation



Source: DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008.*

Figure 4-12. Average FY 2008 Uranium Concentrations in the 200-UP-1 OU, Upper Part of Unconfined Aquifer

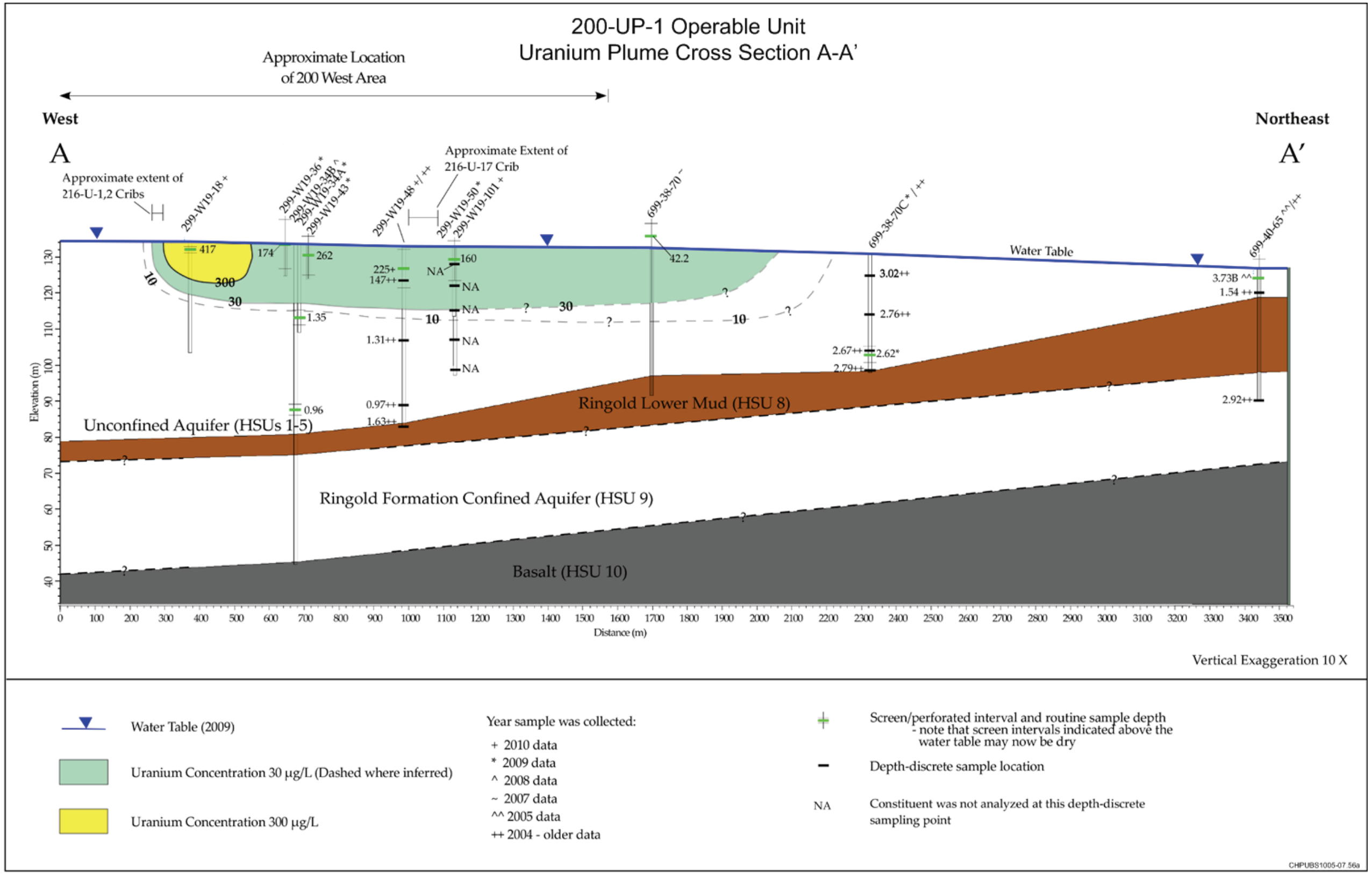


Figure 4-13. Cross Section of the Uranium Plume from the 216-U-1 and 216-U-2 Cribs

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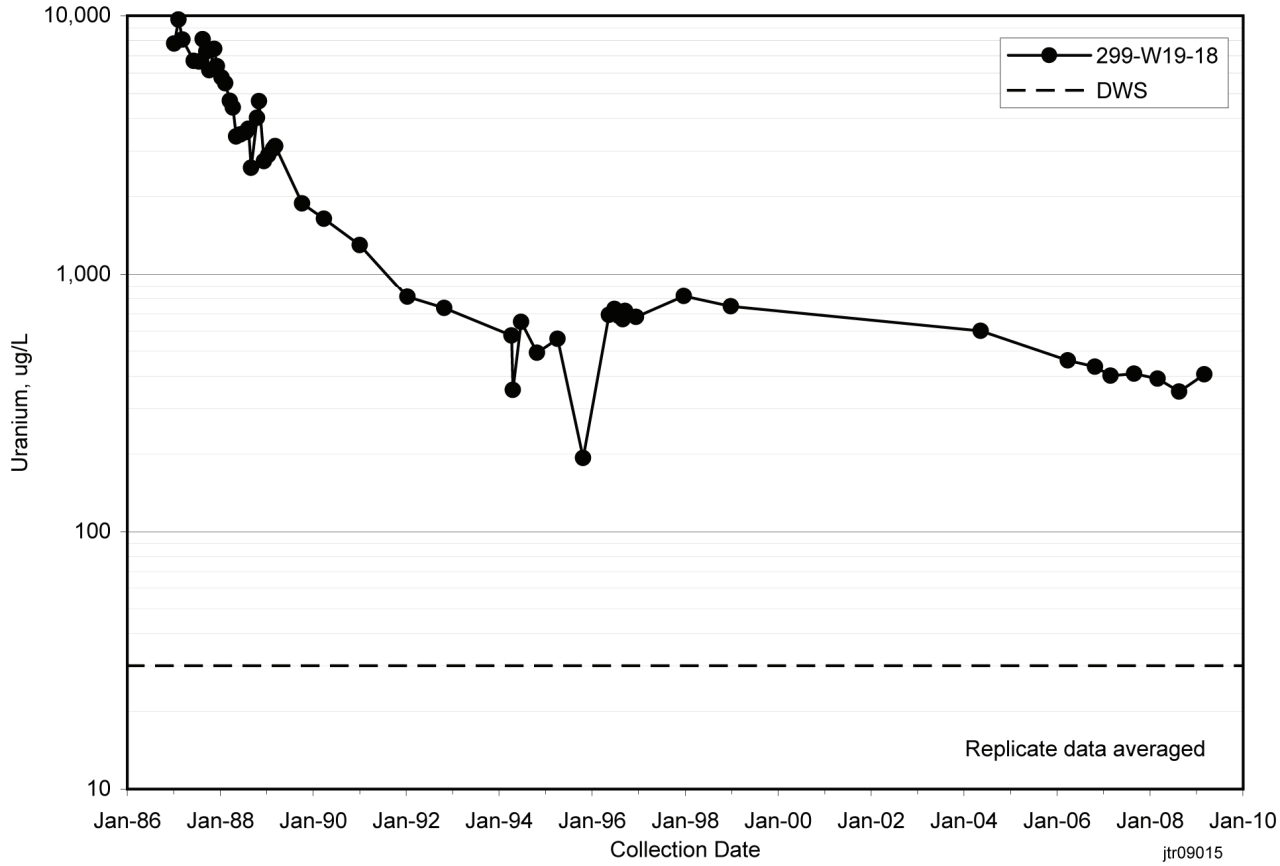

Figure 4-14. Uranium Concentrations in Well 299-W19-18, Downgradient from the 216-U-1 and 216-U-2 Cribs

4.2.3 Iodine-129

I-129 in the 200-UP-1 OU originates from the U Plant and REDOX Plant disposal facilities. Sample results from many wells exceeded the DWS (1 pCi/L) during the RI, and results from four wells east of the 200 West Area exceeded 10 times the DWS (Figure 4-15). I-129 was not detected upgradient from the U Plant and REDOX Plant cribs or south of the 200 West Area.

Figure 4-16 shows the I-129 plumes for FY 2008. One plume appears to originate from the 216-U-1 and 216-U-2 Cribs, while another originates from the southern part of the 200 West Area. At the current level of monitoring detail, these plumes merge downgradient and become indistinguishable. This combined plume (as defined by the 1 pCi/L contour) extends to the east about 3.5 km (2.2 mi). Groundwater sampling results near and downgradient from the 216-U-1 and 216-U-2 Cribs and the 216-S-9 Crib are flagged as not detected but are believed to represent valid approximations of the I-129 concentration in the aquifer. In the past, the analytical laboratory was conservative, by requiring confirmation through the presence of a secondary (less-sensitive) energy peak, before considering the I-129 detected (DOE/RL-2008-66). Oftentimes, this secondary peak was not observed at low I-129 concentrations. Beginning in 2009, the laboratory no longer required the secondary peak to be present, so I-129 detection limits are now frequently less than 1 pCi/L.

Figure 4-17 shows the vertical extent of the I-129 plume from the 216-U-1 and 216-U-2 Cribs. This plume occurs at shallow depths near the Interim U Plant P&T system and becomes fully mixed vertically about 1.5 to 2 km (0.9 to 1.2 mi) from the source. Vertical dispersion appears to be the likely mechanism by which the plume becomes fully mixed vertically.

The 216-S-1, 216-S-2, 216-S-7, and 216-S-9 Cribs were the most substantial sources of I-129 within the OU (RPP-26744). It is likely that these sources account for the highest concentrations within the I-129 plume east of the 200 West Area. The area of this plume, which has I-129 concentrations that are 10 times the DWS (inside the 10 pCi/L contour), is about 1.1 km^2 (0.4 mi^2). No information is available on the thickness of this plume. The maximum measured I-129 concentration during the RI was 39 pCi/L in Well 699-35-70 during September 2007 (Figures 4-1 and 4-18). This well is now dry and can no longer be sampled.

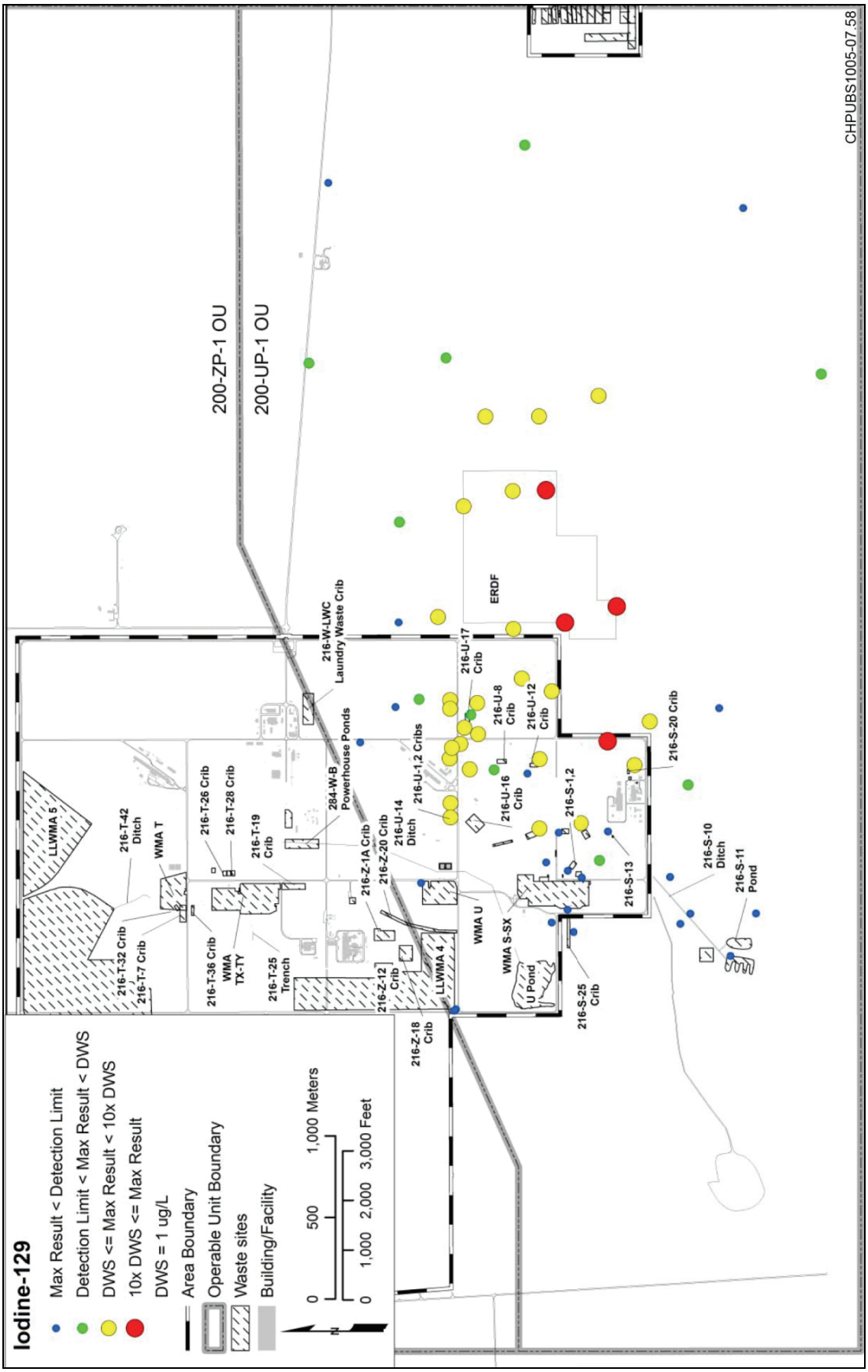

Figure 4-15. Maximum Sample Results for Iodine-129 during the Remedial Investigation

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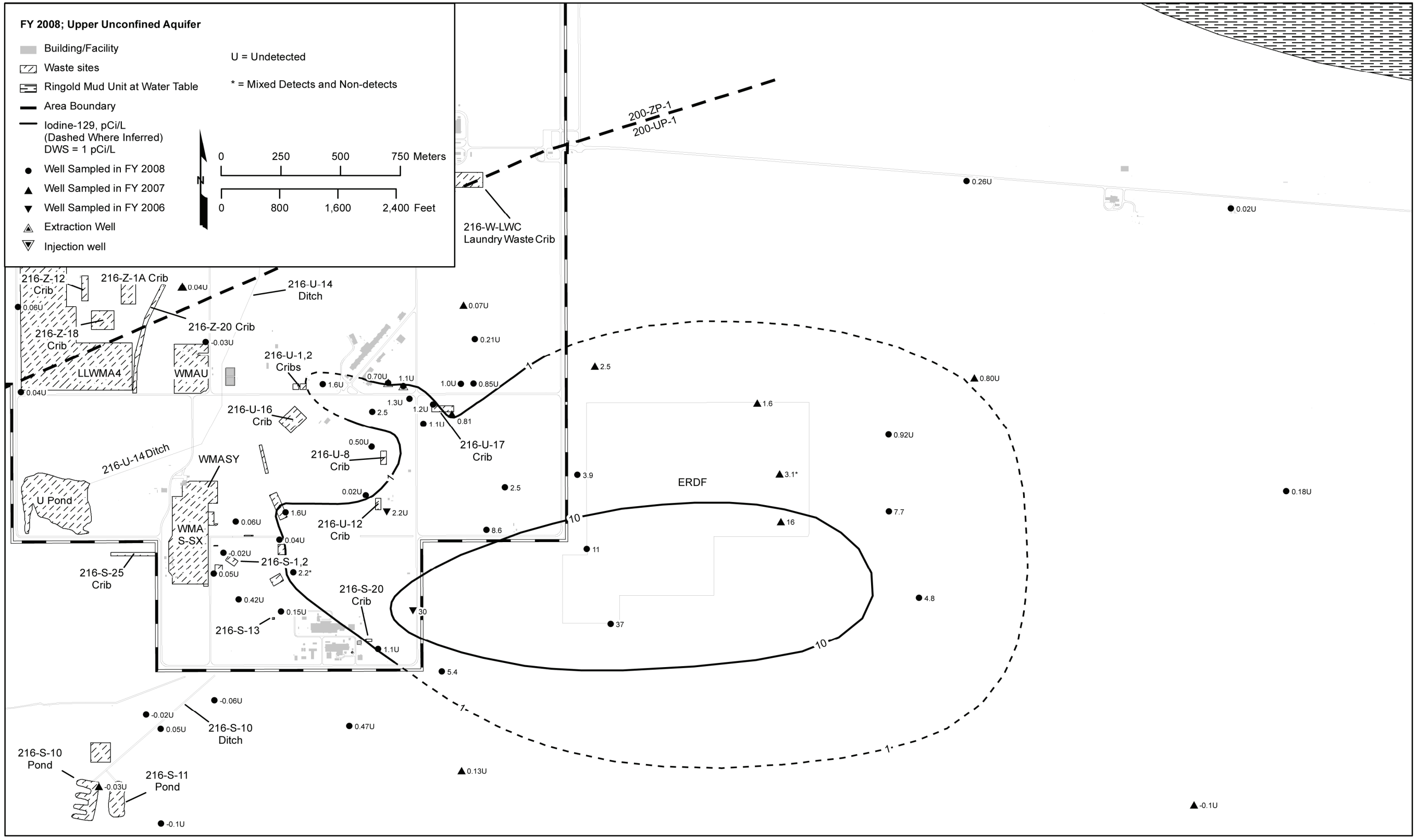

Source: DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*.

Figure 4-16. Average FY 2008 Iodine-129 Concentrations in the 200-UP-1 OU, Upper Part of Unconfined Aquifer

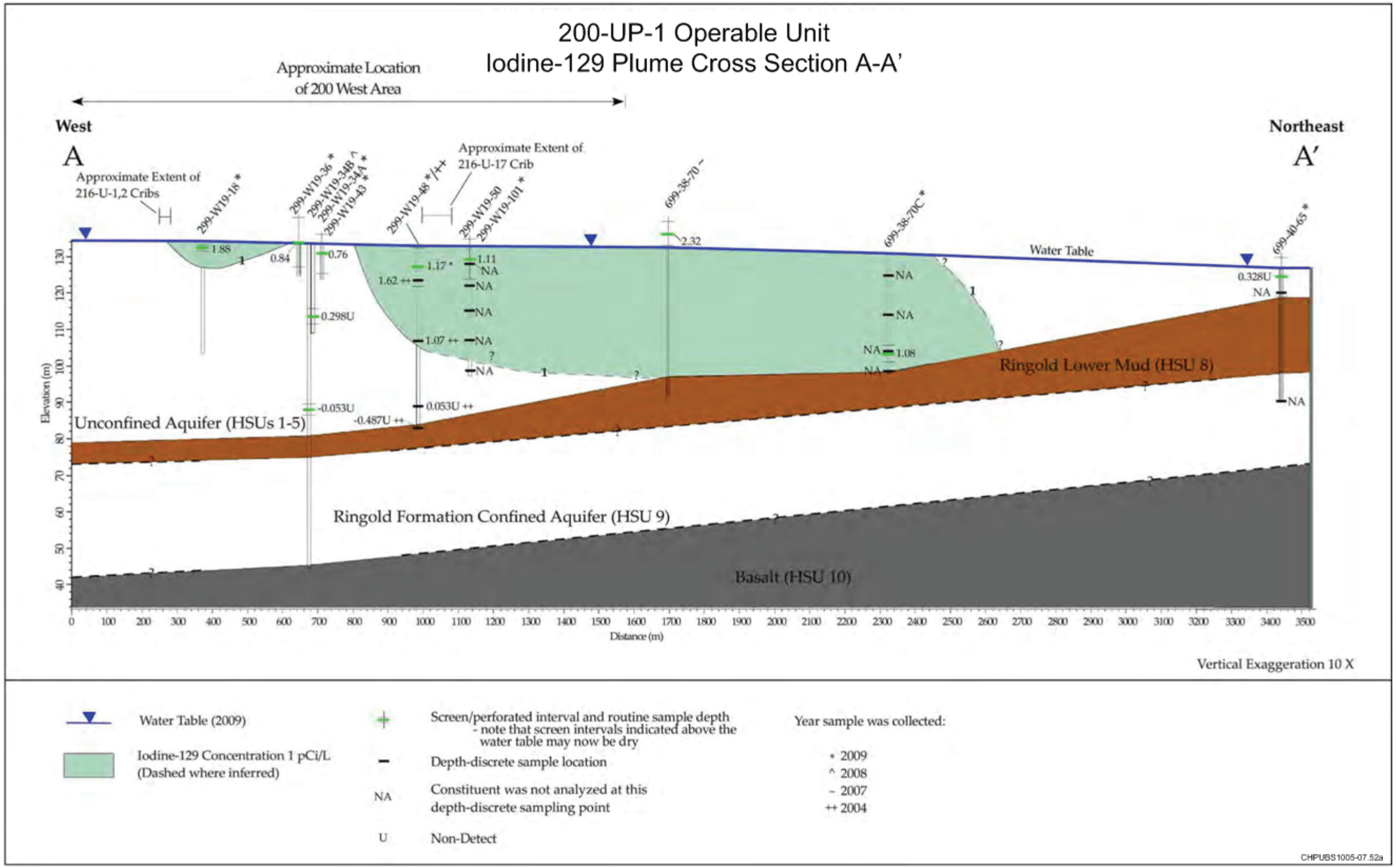

Figure 4-17. Cross Section of the Iodine-129 Plume from the 216-U-1 and 216-U-2 Cribs

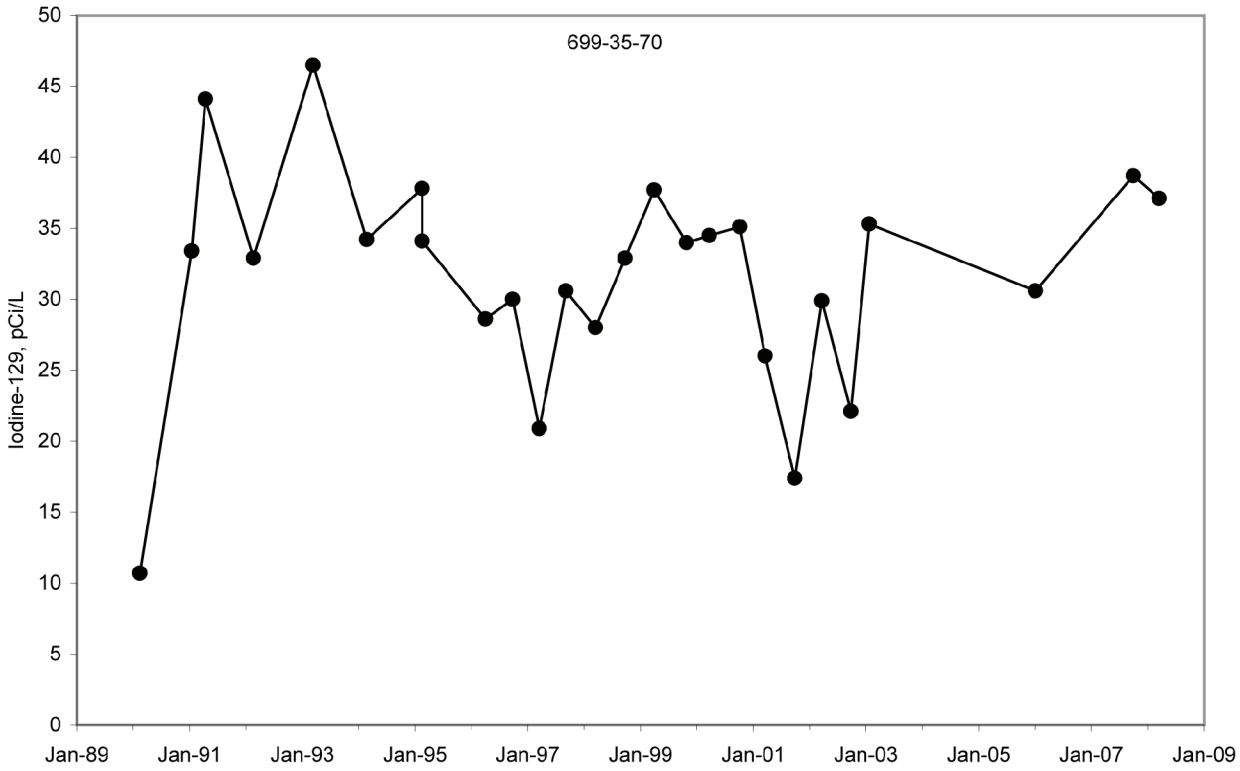

Figure 4-18. Iodine-129 Concentrations in Well 699-35-70, East of the 200 West Area

4.2.4 Chromium

Figure 4-19 summarizes the maximum sample results for total chromium collected during the RI. Chromium was found to exceed the federal DWS (100 µg/L) and the State MTCA B Cleanup Level of 48 ug/L in three regions of the OU: WMA S-SX Tank Farms, 216-S-20 Crib, and the area east and southeast of the S Plant, near the OU boundary. Figure 4-20 shows the interpreted total chromium plumes for FY 2008 (the contours are based on dissolved chromium—analyses for total chromium in filtered samples). The most substantial sources of chromium in the OU are the WMA S-SX Tank Farms, 216-S-20 Crib, and 216-S-10 Pond and Ditch (RPP-26744).[2] During the RI, samples from four wells at WMA S-SX exceeded the 100 µg/L DWS. The highest concentration occurred at Well 299-W23-19 (1,750 µg/L during December 2005). Figure 4-21 presents this information. The portion of this plume above both standards is estimated to extend about 375 m (1,200 ft) from the source area to the east. Depth-discrete sampling during drilling of Well 299-W22-47 indicated that the vertical distribution of chromium is similar to Tc-99; concentrations above both standards occur within the upper 20 m (65 ft) of the aquifer (Figure 4-22). A second plume occurs in the northern part of WMA S-SX, downgradient from the S Tank Farm. At Well 299-W22-44, the filtered total chromium concentration began increasing during 2007 (Figure 4-23), and the concentration reached 690 µg/L during March 2009. The other mobile tank waste constituents (Tc-99 and nitrate) also have increased substantially during this time. In general, chromium concentrations are increasing at WMA S-SX, and the areal extents of the northern and southern plumes are growing.

[2] A substantial amount of chromium was estimated to have been released to the 216-U-10 Pond, but the volume of effluent was so large that the average source concentration was quite low (about15 µg/L). A large amount of chromium was also estimated to have been released to the 216-S-8 Crib (adjacent to the SX Tank Farm), but groundwater sampling results do not indicate that this chromium has reached groundwater.

A chromium plume occurs southeast of the S Plant. During the RI, the maximum measured chromium concentration in this plume was 160 µg/L in an unfiltered sample from Well 699-32-62 during March 2009. Chromium also was elevated in Well 699-30-66 (102 µg/L in February 2006), which is completed deep in the aquifer just above the Ringold lower mud unit. This elevation suggests that chromium occurs throughout the aquifer thickness in this region. Figure 4-24 shows a cross section of this plume. Figure 4-25 shows the results of a chromium particle tracking analysis using a transient groundwater flow model. Particle tracks originating from the 216-S-10 Pond and Ditch and the 216-S-20 Crib in 1951 end in 2009 near the present position of the chromium plume. Further, it has been estimated that about 5,900 kg (13,007 lb) of chromium was released to the 216-S-20 Crib; about 3,000 kg (6,613 lb) was released to the 216-S-10 Pond and Ditch; and about 650 kg (1,433 lb) was released to the 216-S-19 Pond (RPP-26744). The estimated average source concentrations were much higher at the 216-S-20 Crib (about 43,000 µg/L) compared to the 216-S-10 Pond and Ditch (about 400 µg/L) and 216-S-19 Pond (about 500 µg/L), because of the volume of effluent released at each site. Thus, the 216-S-20 Crib is the most probable source for the chromium plume, although effluent from the 216-S-10 Pond and Ditch and 216-S-19 Pond may also have contributed.

Elevated total and hexavalent chromium concentrations, above the natural background, (see Table 4-1) continue near these sites today. For example, maximum chromium concentrations during the RI were 560 µg/L in a filtered sample from Well 299-W22-20 at the 216-S-20 Crib (September 2004) and 61 µg/L in an unfiltered sample from Well 299-W26-13 at the 216-S-10 Pond and Ditch (January 2008). No recent sampling has been conducted near the 216-S-19 Pond. Concentrations at Well 699-32-62 have been declining since chromium was first analyzed at this well in 1992 (Figures 4-1 and 4-26). The long-term rate of decline (for the filtered samples) is about 70 µg/L per decade. This may result from advection of the plume beyond this well, along with hydrodynamic dispersion.

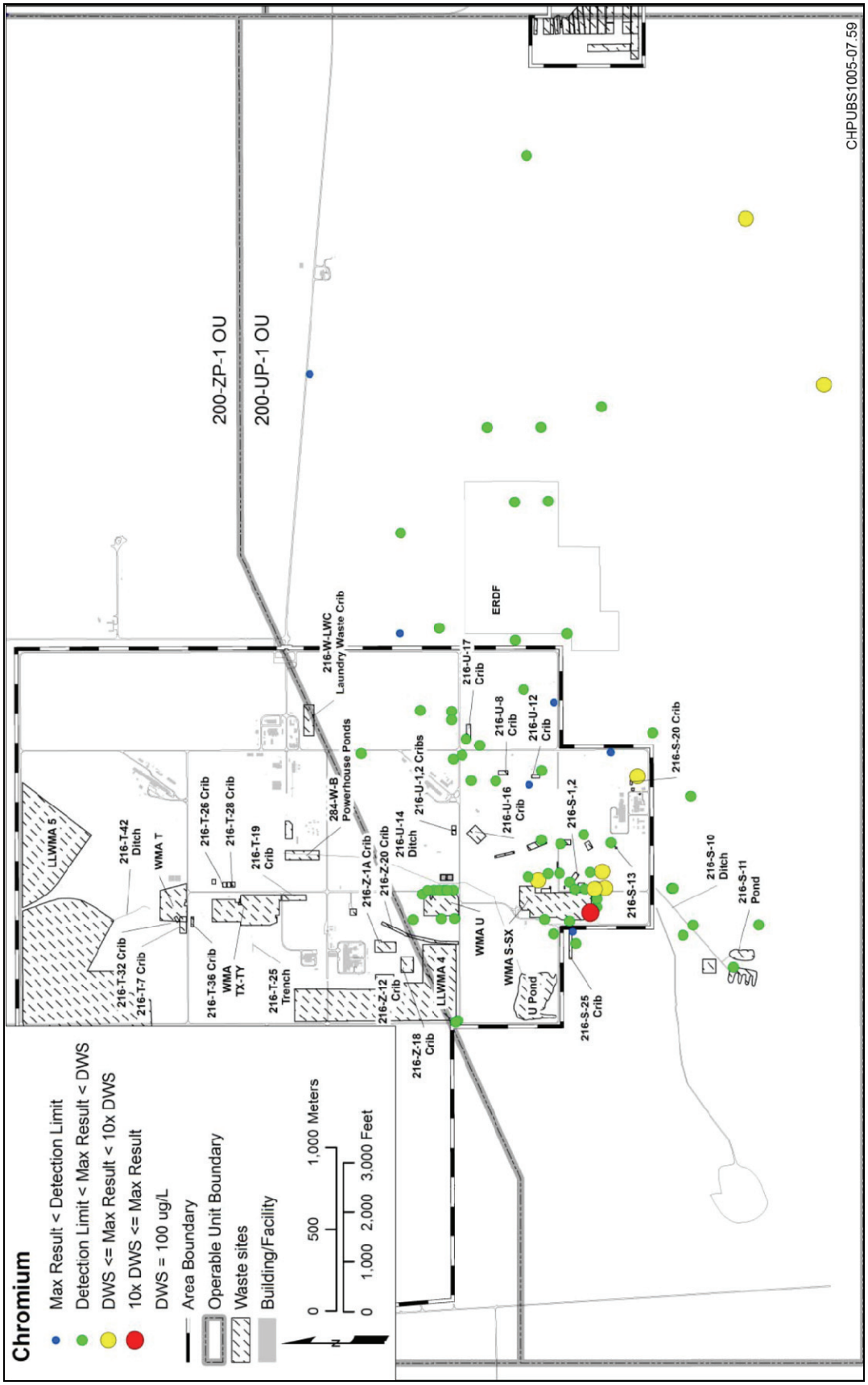

Figure 4-19. Maximum Sample Results for Chromium during the Remedial Investigation

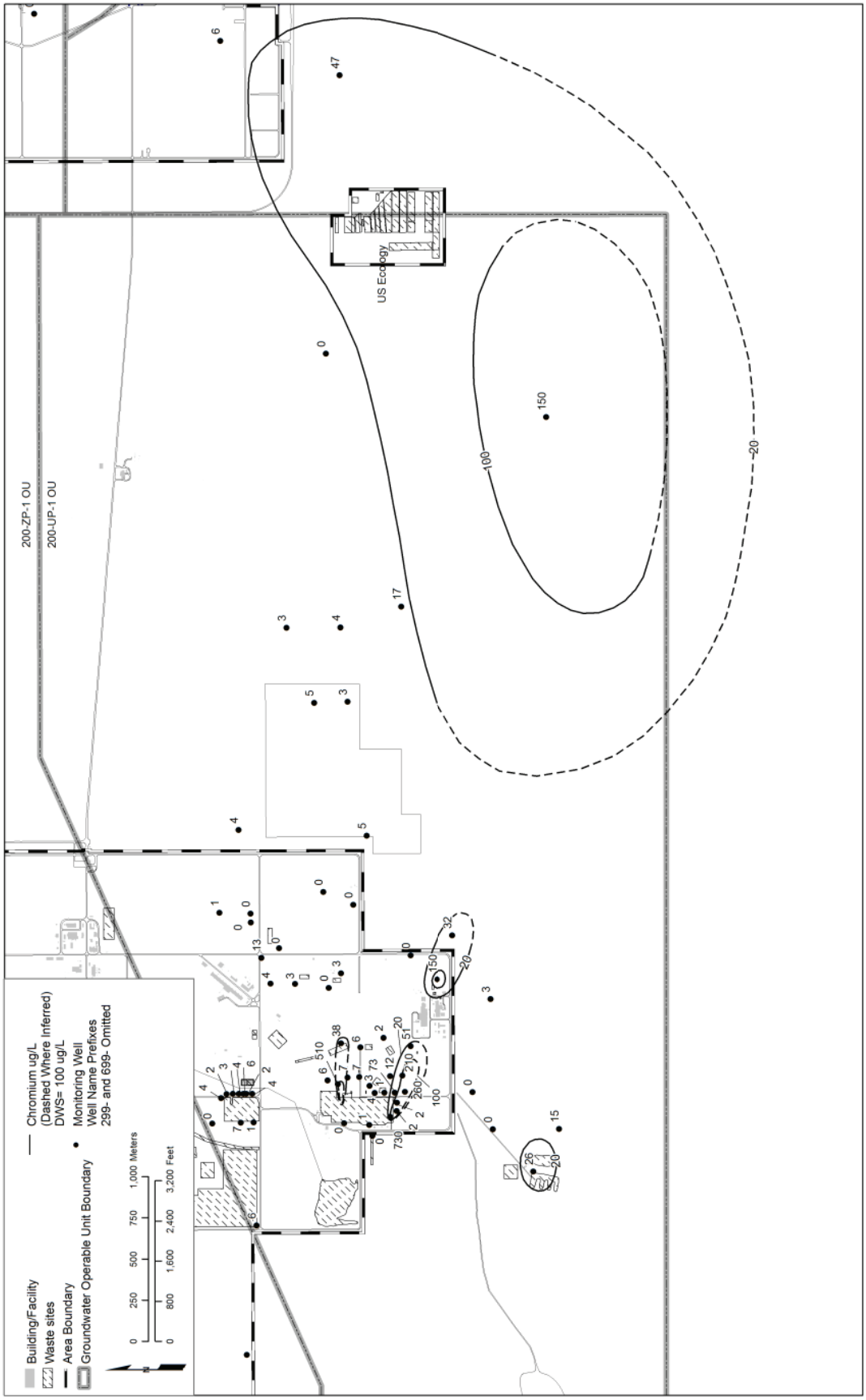

Figure 4-20. Average FY 2008 Chromium Concentrations in the 200-UP-1 OU, Upper Part of Unconfined Aquifer

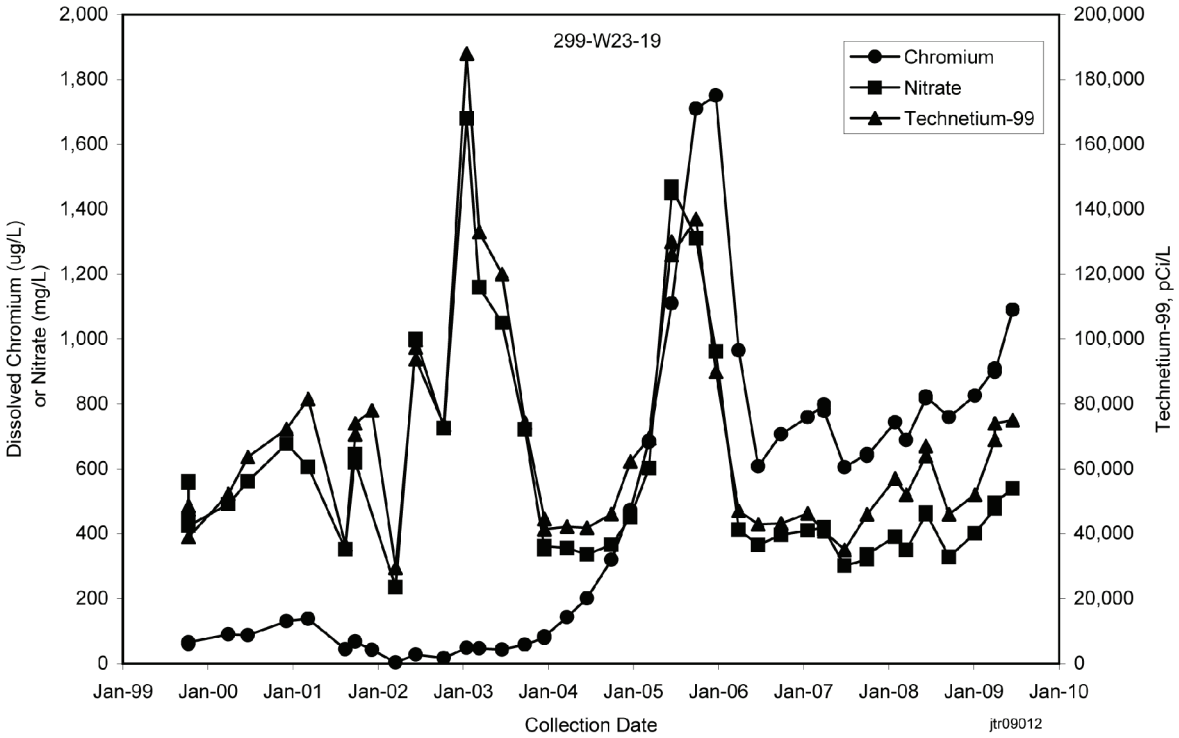

Figure 4-21. Chromium, Nitrate, and Technetium-99 Concentrations in Well 299-W23-19, Southern Portion of Waste Management Area S-SX

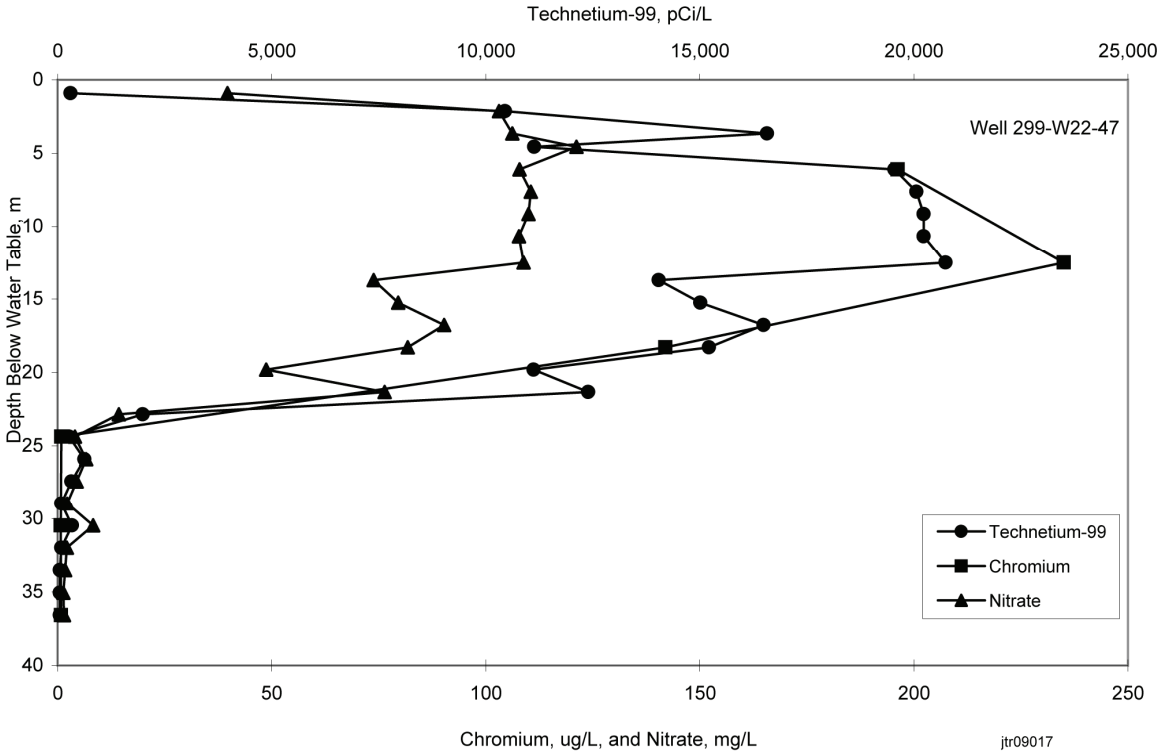

Figure 4-22. Depth-discrete Sample Results for Chromium and Nitrate in Well 299-W22-47 at Waste Management Area S-SX; Samples Collected during Drilling in January 2005

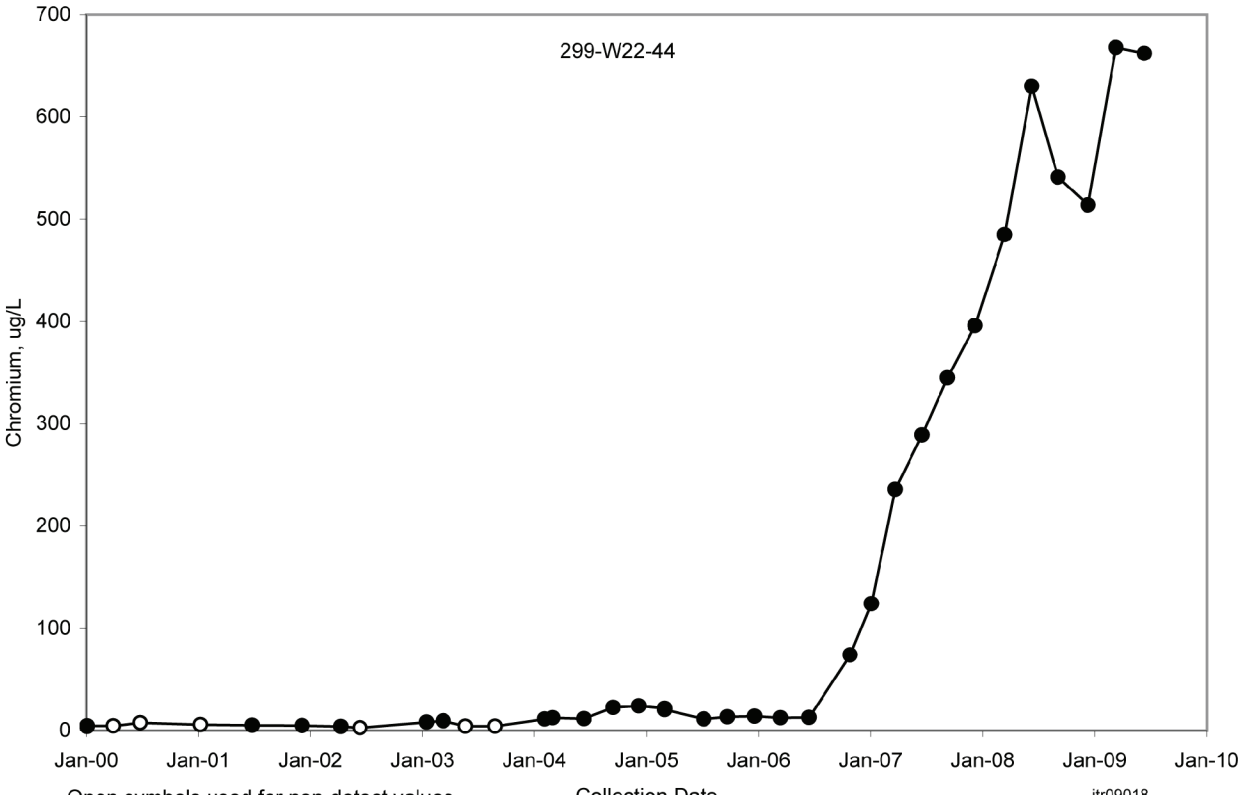

Figure 4-23. Chromium Concentrations in Well 299-W22-44, Downgradient from the 241-S Tank Farm

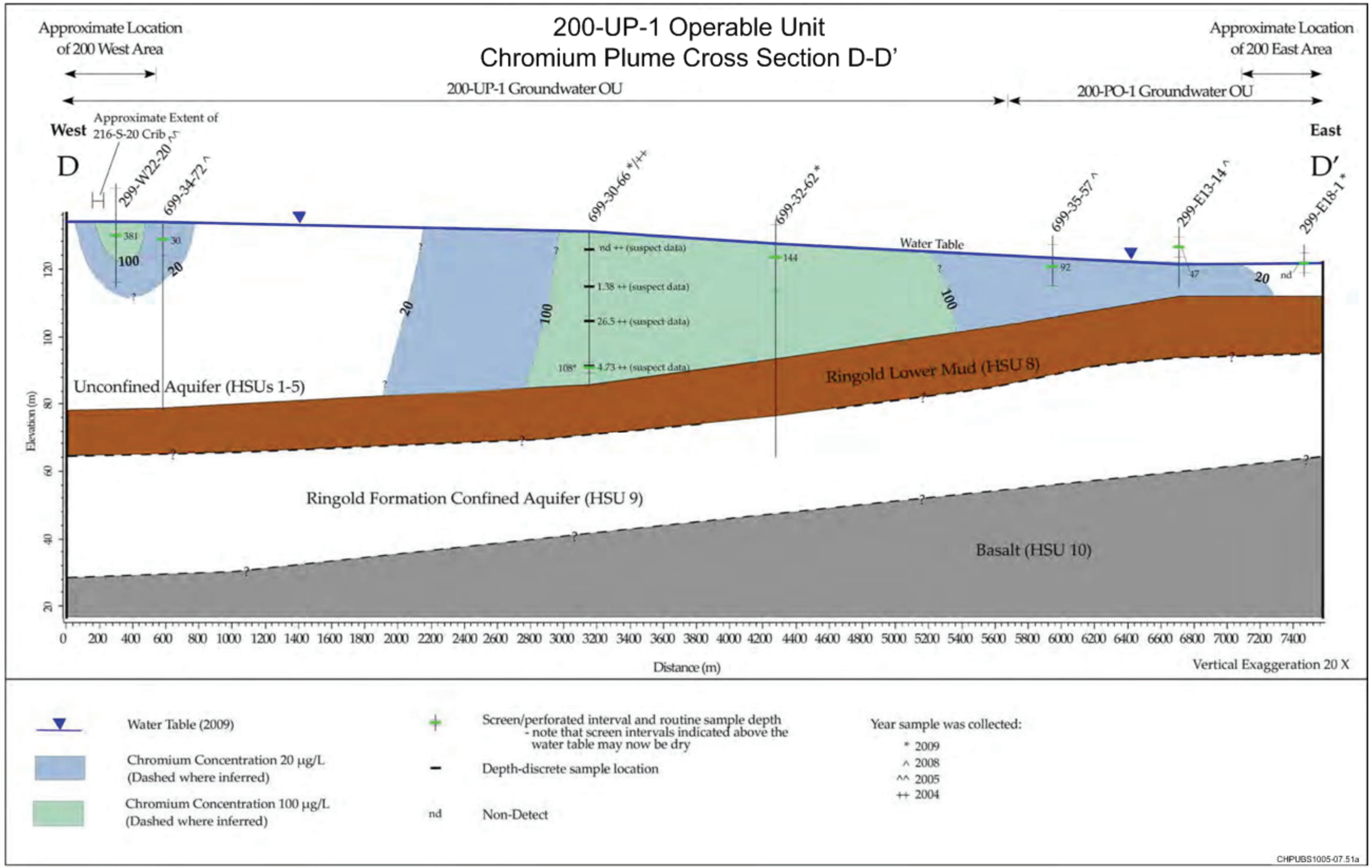

Figure 4-24. Cross Section of the Chromium Plume East-Southeast of the 200 West Area

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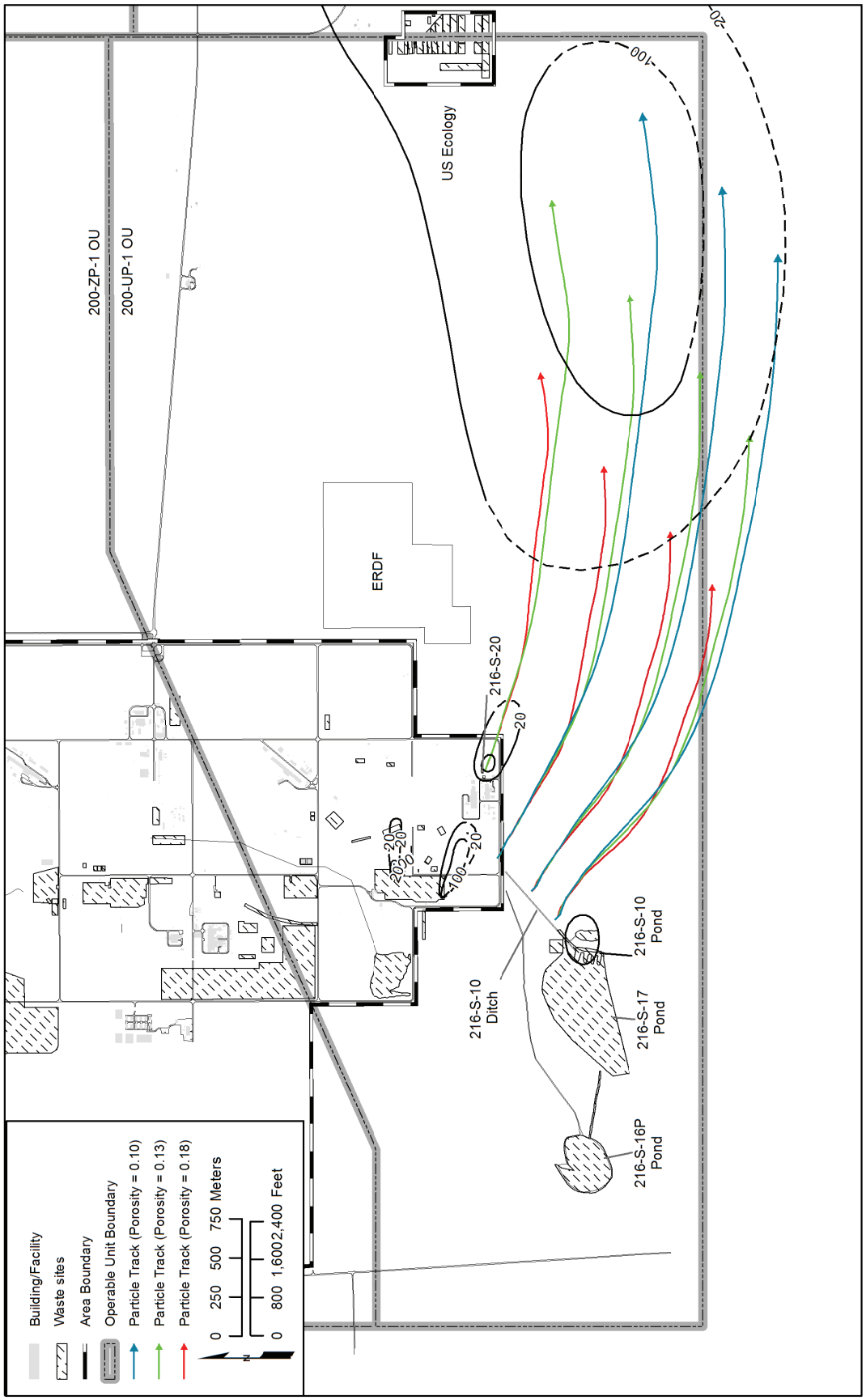


Figure 4-25. Simulated Total and Hexavalent Chromium Particle Movement between 1951 and 2009 from the 216-S-20 Crib and 216-S-10 Ditch

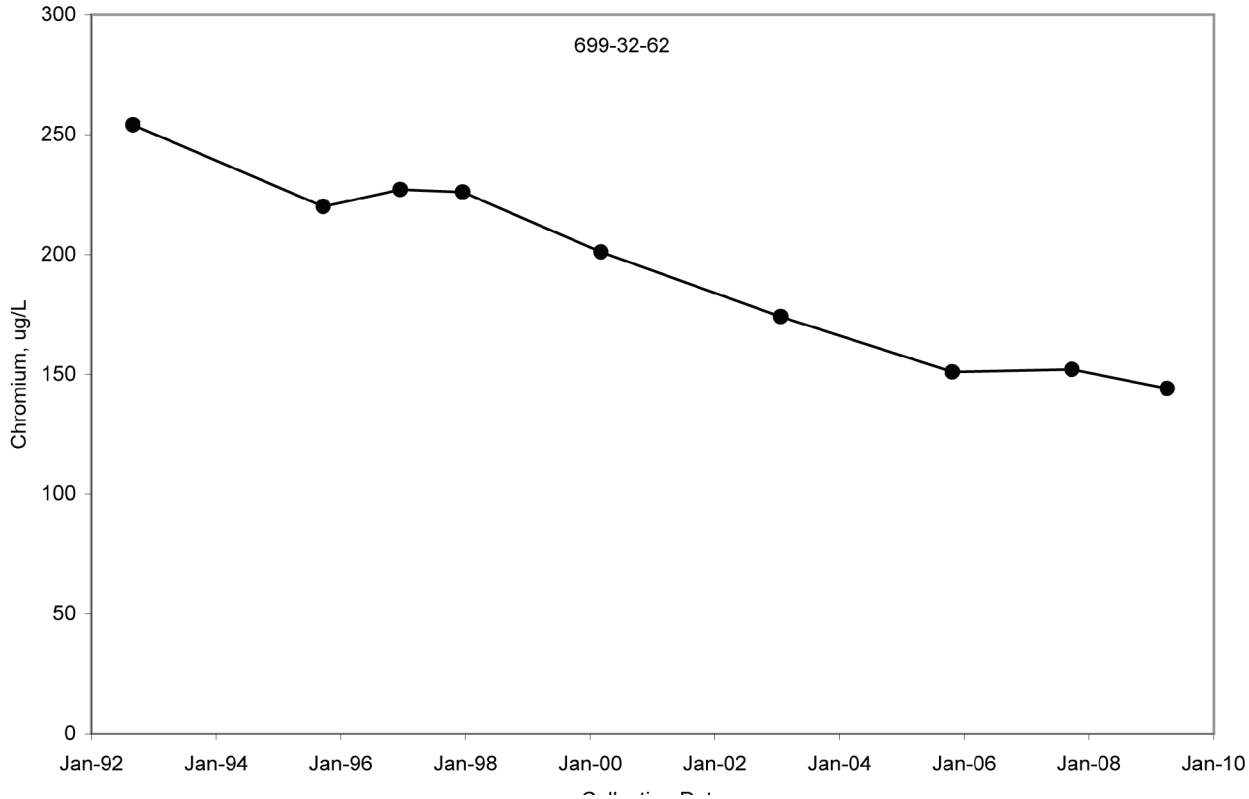


Figure 4-26. Chromium Concentrations in Well 699-32-62, East-Southeast of the 200 West Area

4.2.5 Tritium

Disposal facilities associated with the REDOX Plant are the primary sources of tritium in the 200-UP-1 groundwater interest area. The REDOX Plant operated from 1952 until 1967, although effluent releases continued to occur after that time. The most substantial sources were the 216-S-1, 216-S-2, 216-S-7, 216-S-21, and 216-S-25 Cribs (RPP-26744). In addition, substantial tritium inventories are estimated for the 216-U-8 and 216-U-12 Cribs. Figure 4-27 shows the maximum sampling results for tritium observed during the RI. Concentrations above the federal DWS (20,000 pCi/L) occur in the vicinity of the REDOX Plant cribs and downgradient to the east-northeast. Concentrations exceeded 10 times the federal DWS in four wells during the RI: Well 299-W22-9 (1,020,000 pCi/L during December 2005); Well 299-W22-20 (480,000 pCi/L during December 2005); Well 699-35-70 (277,000 pCi/L during January 2006); and Well 299-W23-9 (218,000 during October 2005).

Figure 4-28 shows the interpreted tritium plume. A large tritium plume originates from the REDOX Plant cribs in the southern part of the 200 West Area and extends about 5 km (3 mi) toward the east and northeast at levels above the 20,000 pCi/L federal DWS. Two high-concentration areas occur within this region: a large plume extends to the east and northeast from the 200 West Area and a smaller plume extends about 550 m (1,800 ft) to the east-southeast from the 216-S-25 Crib.

In the eastern high-concentration area, tritium concentrations are generally declining at six wells and increasing at three wells, indicating that the plume has localized areas of high concentrations. When these areas pass by wells, increasing concentrations may temporarily occur. Figure 4-29 shows tritium concentration trends for three wells within this plume: Wells 699-35-66A, 699-35-70, and 699-36-61A (Figure 4-1). Declining trends occur at Wells 699-35-70 and 699-35-66A, while a slight increasing trend occurs at Well 699-36-61A. Thus, concentrations are increasing slightly at the plume front, but not nearly

as rapidly as they are declining in the central part of the plume. The plume exhibits declining concentrations overall although the areal extent, as defined by the 2,000-pCi/L contour, has changed little over many years.

Tritium occurs above the federal DWS in eight wells downgradient from the 216-S-25 Crib. Historical concentrations fluctuated in a single well (Well 299-W23-9) on the downgradient side of the crib, but this well has gone dry and can no longer be sampled. Farther downgradient, trends are declining or stable in all but one well (Well 299-W23-21), which shows an increasing trend. Radioactive liquid effluent was disposed of in this crib from 1973 through 1980, and effluent from a P&T system at the 216-U-1 and 216-U-2 Cribs was disposed of in this crib in 1985. In the vadose zone beneath this crib, tritium in the residual soil moisture may be migrating slowly to the water table, which would account for the fluctuating tritium concentration trend in Well 299-W23-9.

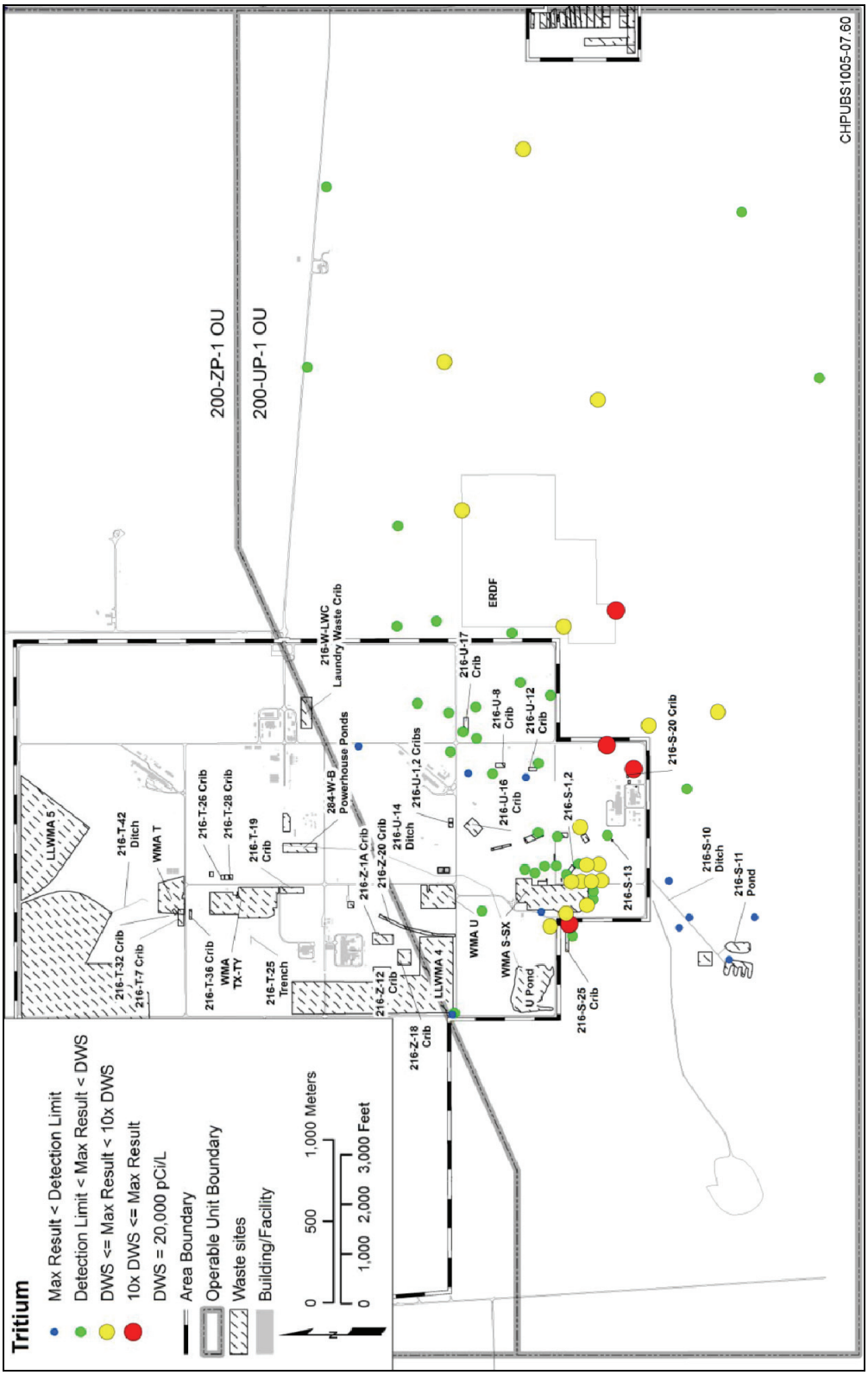
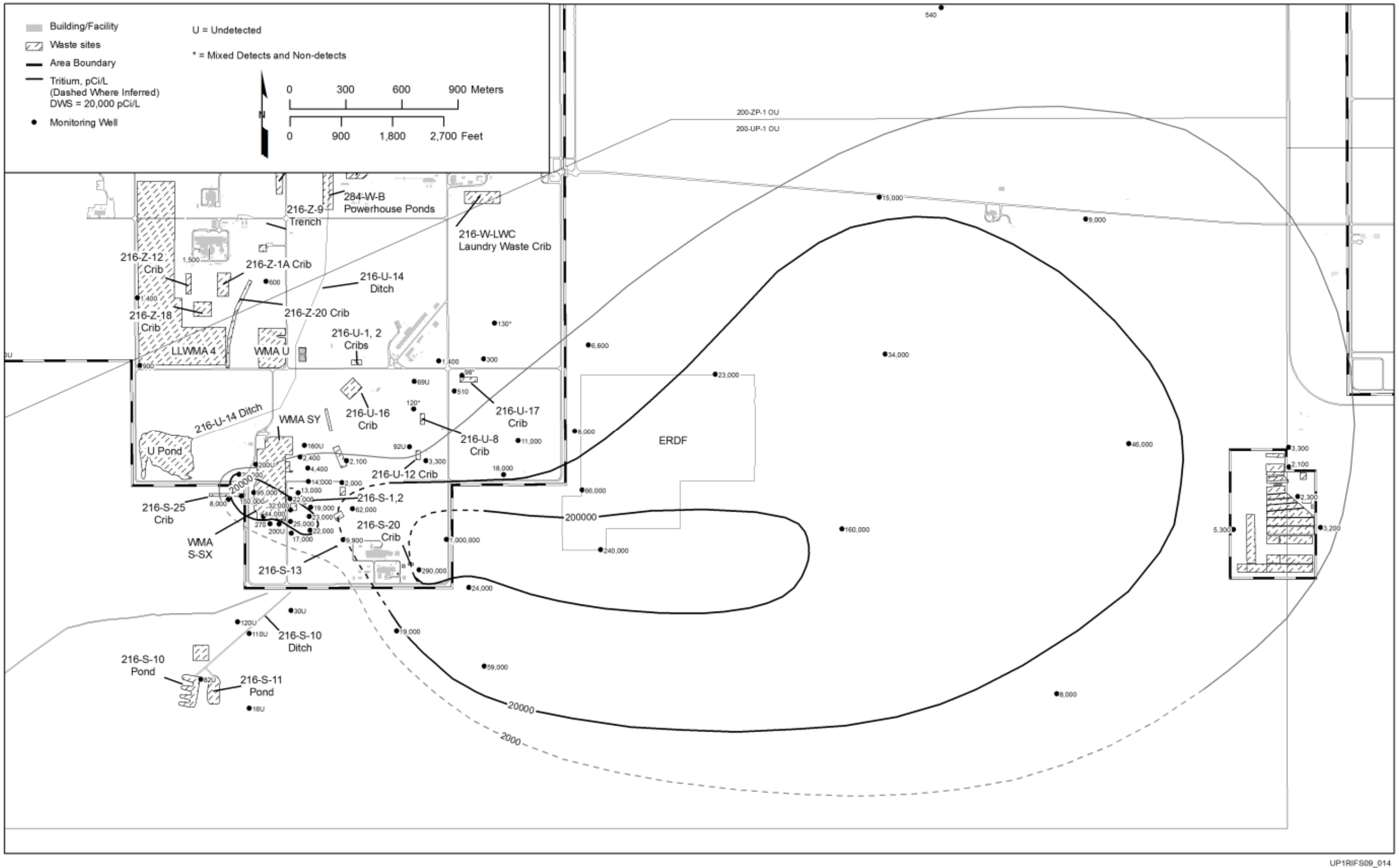


Figure 4-27. Maximum Sample Results for Tritium during the Remedial Investigation



Source: DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*.

Figure 4-28. Average FY 2008 Tritium Concentrations in the 200-UP-1 OU, Upper Part of Unconfined Aquifer

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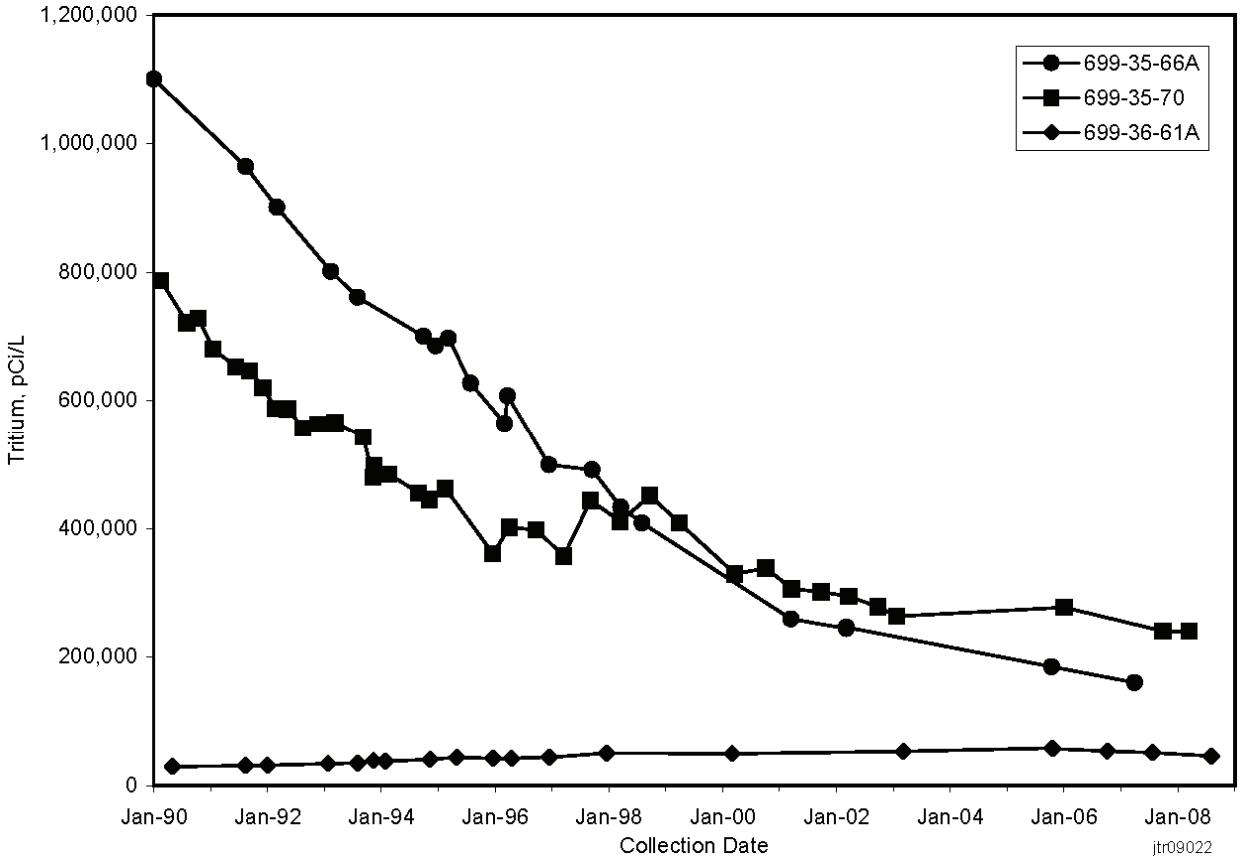

Figure 4-29. Tritium Concentrations in Wells 699-35-66A, 699-35-70, and 699-36-61A, East of the 200 West Area

4.2.6 Nitrate

The occurrence of nitrate above the federal DWS of 10 mg/L, as NO3-N (45 mg/L as NO3) is widespread within the OU. During the RI, nitrate concentrations were found above the federal DWS at the WMA S-SX Tank Farms, WMA U Tank Farm, near to or downgradient from the 216-S-20, 216-S-25, 216-U-1, and 216-U-2 Cribs, and in a large region extending from the 200 West Area (Figure 4-30). Concentrations greater than 10 times the federal DWS occurred in two wells at WMA S-SX (Wells 299-W23-19 and 299-W22-47) and in two wells at the IRA P&T area downgradient from the 216-U-1 and 216-U-2 Cribs (Wells 299-W19-43 and 299-W19-37).

Nitrate plumes in the 200-UP-1 OU originate from the U Plant and REDOX Plant disposal facilities, the most substantial of which were probably the 216-U-8 and 216-U-12 Cribs (RPP-26744). The nitrate plumes from these sources merge downgradient into a single large plume, which extends to the east and northeast about 4 km (2.5 mi) (Figure 4-31). The large nitrate plume occurs more to the north than the tritium, I-129, and chromium plumes. This observation is consistent with the U Plant cribs being the primary source of the nitrate plume, whereas REDOX Plant disposal facilities to the south are largely the sources of the other plumes. Figure 4-32 shows trends for nitrate in the northeast portion of the OU. Figure 4-33 (cross-section A-A') shows the vertical extent of the nitrate plume from the 216-U-1 and 216-U-2 Cribs through the P&T area. Similar to the Tc-99 and I-129 plumes in this area, nitrate occurs at shallow depths near the source and becomes fully mixed vertically between about 1.5 to 2 km (0.9 to 1.2 mi) downgradient from the source, most likely because of vertical dispersion.

WMA U is a source of nitrate to groundwater. Nitrate concentrations in several downgradient wells exceed the concentration in the upgradient well (Well 299-W18-40). The maximum nitrate concentration measured at the U Tank Farm during the RI was 109 mg/L in Well 299-W19-44 (August 2006). Nitrate occurs in two small plumes associated with REDOX Plant disposal facilities: one near the 216-S-20 Crib and another near the 216-S-25 Crib and WMA S-SX. From 1952 through 1972, the 216-S-20 Crib received waste from laboratory hoods and decontamination sinks in the 222-S Building, along with laboratory waste from the 300 Area. At Well 299-W22-20 (downgradient from the 216-S-20 Crib), the maximum nitrate concentration measured during the RI was 144 mg/L in December 2005. At a new well, Well 699-34-72, which is about 320 m (1,000 ft) downgradient from the 216-S-20 Crib, the average nitrate concentration was 32 mg/L during FY 2008. Thus, nitrate from this crib at concentrations exceeding the federal DWS appears to be localized to the crib vicinity.

The nitrate plume originating from the 216-S-25 Crib merges with the nitrate plume from WMA S-SX, and the portion of this combined plume above the federal DWS is interpreted to extend about 500 m (1,600 ft) to the east-southeast. The maximum concentration measured in this plume during the RI was 1,460 mg/L in Well 299-W23-19 during June 2005 (Figure 4-34). Concentrations in this well have since declined, ranging from about 300 to 540 mg/L between 2007 and 2009. Depth-discrete sampling during drilling at Well 299-W22-47 indicated the nitrate occurs within the upper 20 m (65 ft) of the aquifer, similar to Tc-99 and chromium (Figure 4-35).

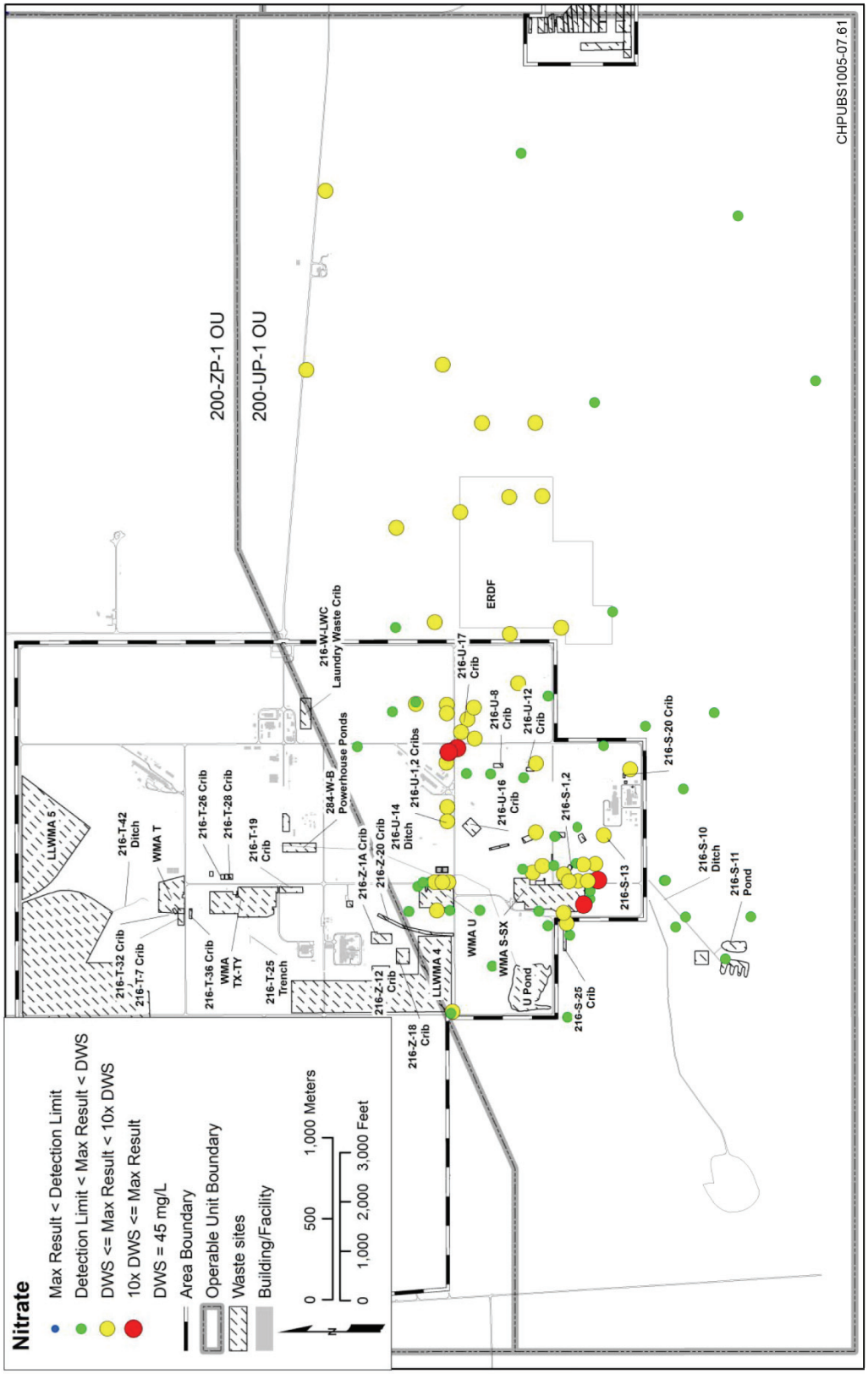

Figure 4-30. Maximum Sample Results for Nitrate during the Remedial Investigation

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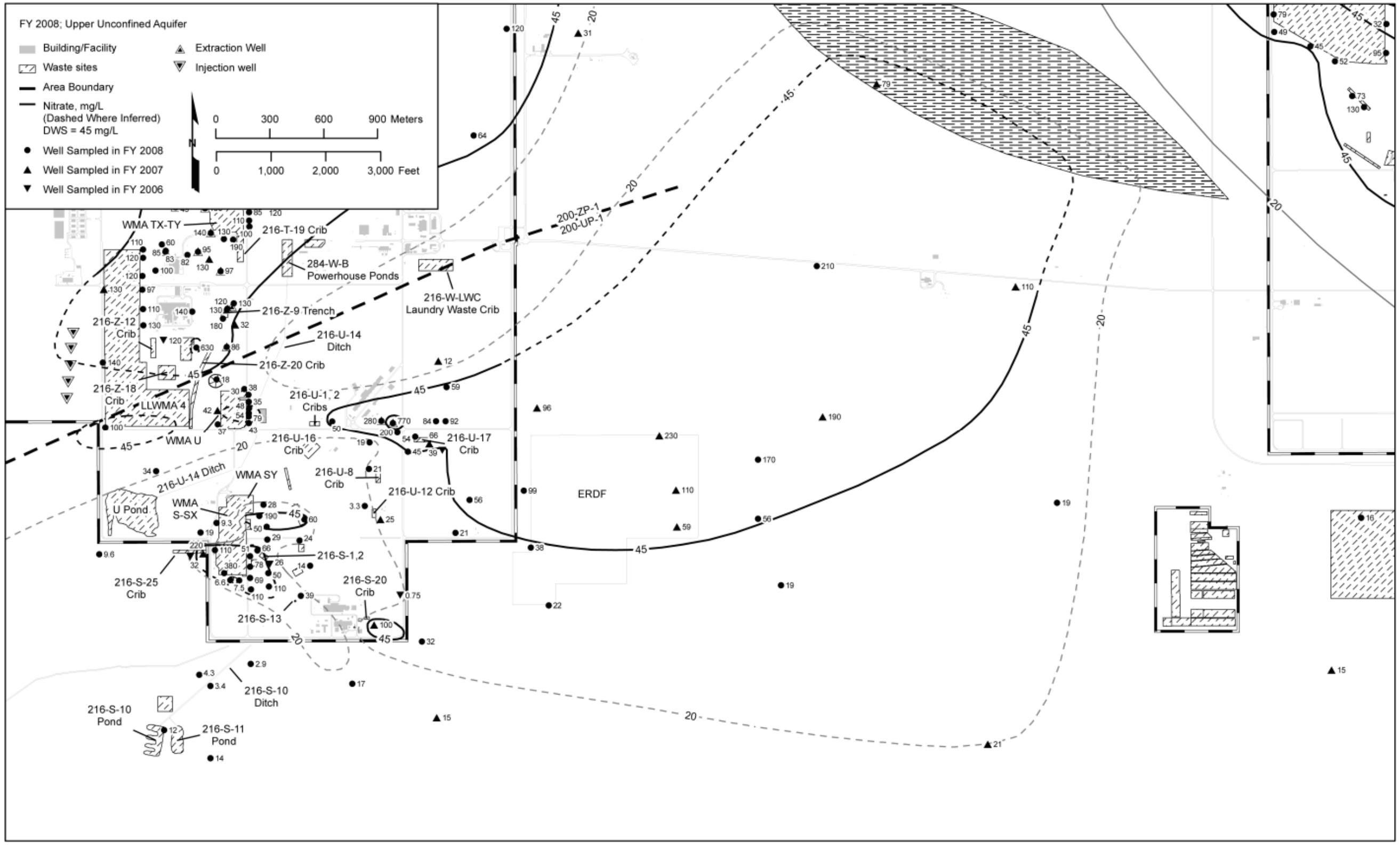

Source: DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*.

Figure 4-31. Average FY 2008 Nitrate Concentrations in the 200-UP-1 OU, Upper Part of Unconfined Aquifer

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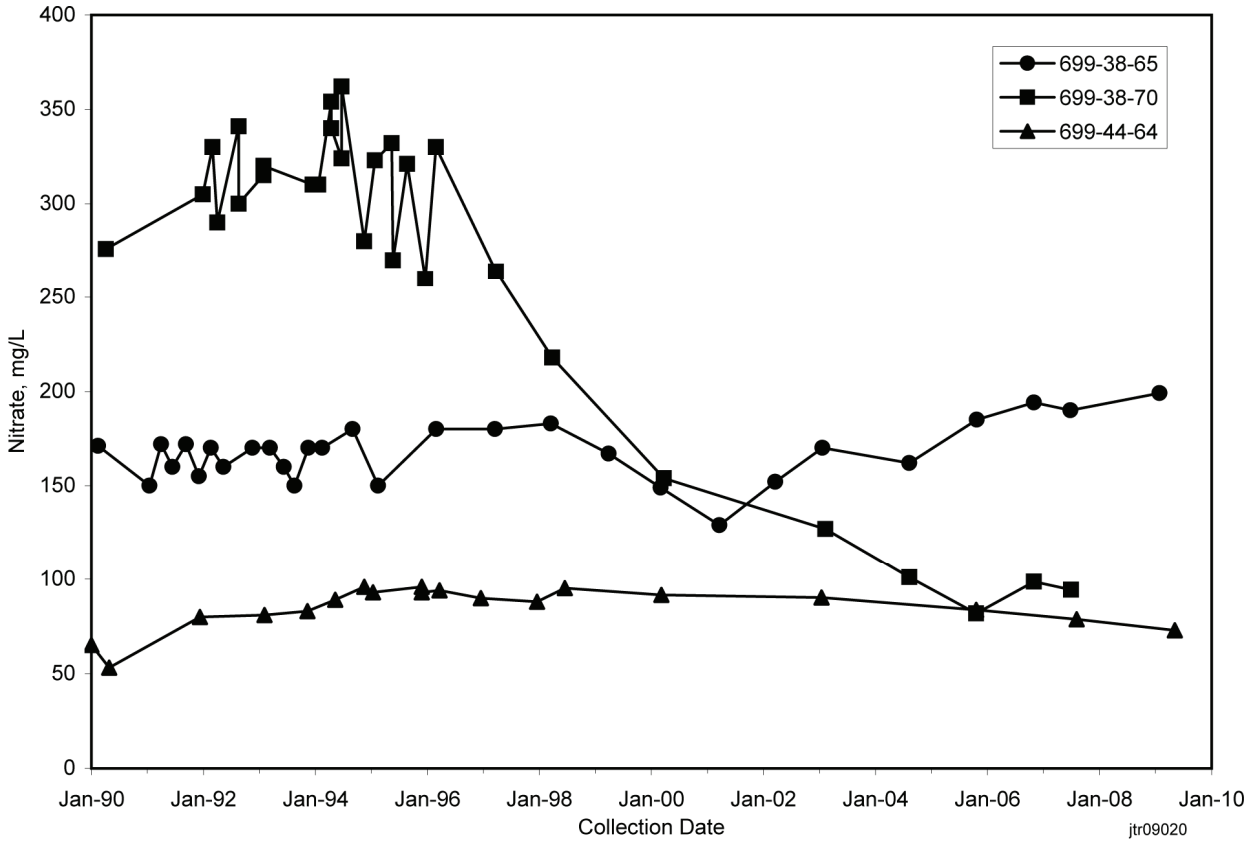

Figure 4-32. Nitrate Concentrations in Wells 699-38-65, 699-38-70, and 699-44-64, East of the 200 West Area

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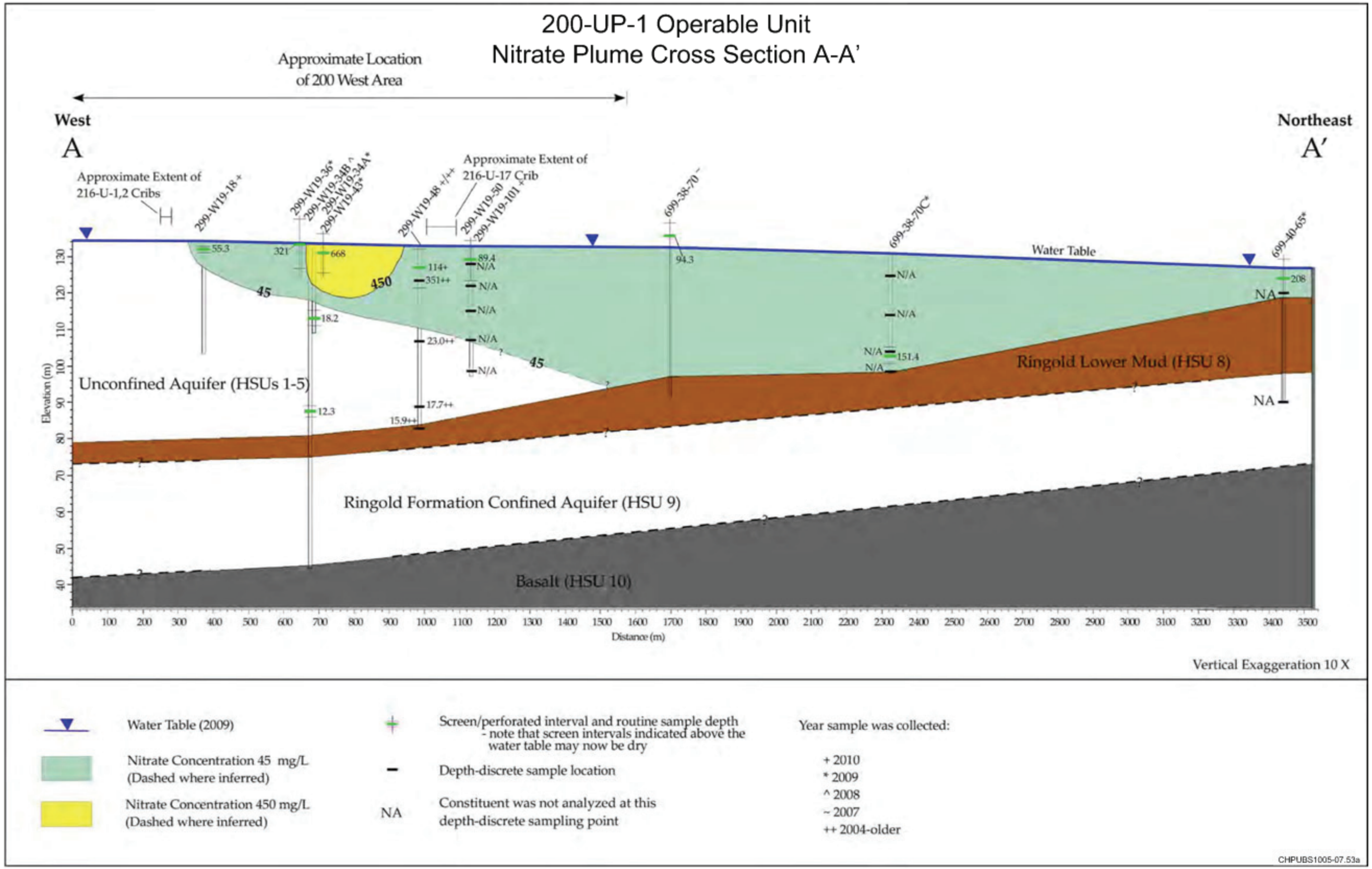

Figure 4-33. Cross Section of the Nitrate Plume from the 216-U-1 and 216-U-2 Cribs

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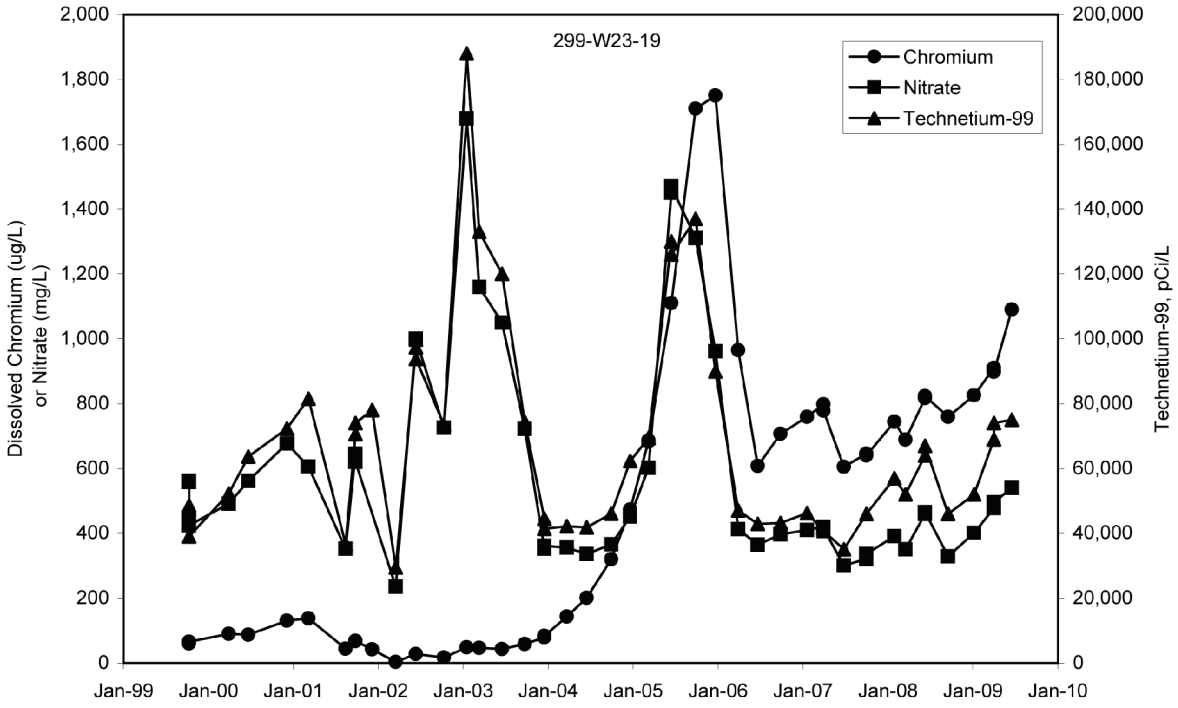


Figure 4-34. Chromium, Nitrate, and Technetium-99 Concentrations in Well 299-W23-19, Southern Portion of Waste Management Area S-SX

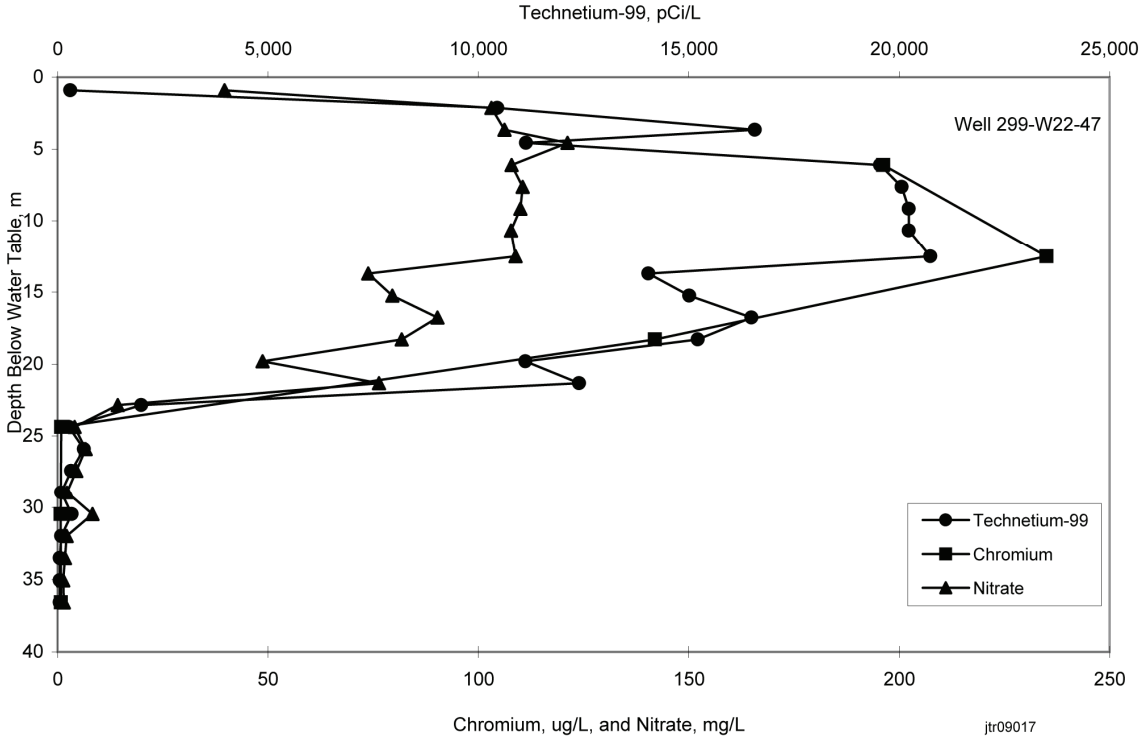


Figure 4-35. Depth-discrete Sample Results for Chromium, Nitrate, and Technetium-99 in Well 299-W22-47 at Waste Management Area S-SX; Samples Collected during Drilling in January 2005

4.2.7 Carbon Tetrachloride, Chloroform, and Trichloroethene

Carbon tetrachloride occurs above the federal DWS (5 µg/L) and the State MTCA Cleanup Level (3.4 ug/L) in numerous wells within the 200-UP-1 OU. The maximum concentration in 34 wells exceeded 10 times the federal DWS (Figure 4-36). The highest concentrations in the OU occur adjacent to the 200-ZP-1 OU and decrease toward the south and east. At the water table, the plume is widespread in the southern 200 West Area and extends about 1 km (0.6 mi) east (Figure 4-37). The ROD for the adjacent OU (200-ZP-1) identified the State MTCA B Cleanup Level of 3.4 ug/L as the remediation goal.

Examination of operational process records and DOE/RL-91-32, *Expedited Response Action Proposal (EE/CA & EA) for 200 West Area Carbon Tetrachloride Plume*, indicate the carbon tetrachloride plume originated from waste disposal sites associated with the PFP in the 200-ZP-1 OU. Historically, carbon tetrachloride was used in mixtures with other organics to recover plutonium from aqueous streams containing plutonium nitrate. The degraded or contaminated organic solvents containing carbon tetrachloride were disposed of in the 216-Z-9 Trench during operations at the 234-5 (Recuplex) Plant (1955 through 1962). Carbon tetrachloride containing solvents that originated from the later Plutonium Recovery Facility operations at the 236-Z Building were disposed of in the 216-Z-1A tile field from 1964 to 1969, and in the 216-Z-18 Crib from 1969 through May 1973. After May 1973, these wastes were routed to tank farms (DOE/RL-91-32). Figure 4-38 and Figure 4-39 illustrate the carbon tetrachloride plume and the associated chloroform plume (in 1990) as depicted in PNL-8073, *Hanford Site Ground-Water Monitoring for 1990*. These contour maps, generated from the limited data available before the 200-ZP-1 IRA was initiated, show a correlation between the groundwater contaminant concentrations and the previously listed disposal sites.

Results of the early site characterization activities are presented in WHC-SD-EN-TI-248, *1994 Conceptual Model of the Carbon Tetrachloride Contamination in the 200 West Area at the Hanford Site*, along with a discussion of the mechanisms by which carbon tetrachloride and associated degradation products could migrate south and eastward from the original 216-Z-9, 216-Z-1A, and 216-Z-18 disposal sites into the area now defined as the 200-UP-1 OU. Later characterization work that refined the CSM was conducted as part of DOE/RL-96-33; in addition, local groundwater monitoring wells were installed. The refined CSM for carbon tetrachloride, chloroform, and TCE in the 200-UP-1 groundwater is presented in BHI-01576. A discussion of carbon tetrachloride flow and transport in the area of the 216-Z-9 Trench is presented in "Carbon Tetrachloride Flow and Transport in the Subsurface of the 216-Z-9 Trench at the Hanford Site" (Oostrom et al., 2007). The salient feature of this discussion is that carbon tetrachloride is a mobile DNAPL that was able to migrate horizontally as a liquid in conjunction with the regional groundwater flow or while diffusing laterally through the vadose zone in the vapor phase. This migration carried carbon tetrachloride contamination from the original disposal locations into the 200-UP-1 OU.

The maximum measured carbon tetrachloride concentration within the 200-UP-1 OU during the RI was 1,600 µg/L in Well 299-W14-71 (April 2007). This concentration is comparable to the concentrations in 200-ZP-1. Much of the depth-discrete carbon tetrachloride sampling performed within the OU is summarized in Figure 3-21, which shows a cross section (C-C') of the plume from southwest to northeast through the southern 200 West Area. Carbon tetrachloride concentrations exceed 10 times the federal DWS (greater than 50 µg/L) in two areas of the cross section: a small area near Well 299-W22-47 in the vicinity of WMA S-SX; and a large area between Well 299-W19-105, near the 216-U-8 Crib and Well 699-38-70B, just outside the 200 West Area boundary to the east. At Well 299-W22-47, the highest carbon tetrachloride concentrations occur in the upper part of the aquifer near the water table (maximum value of 145 µg/L at 11 m [36 ft] below the water table). At the middle depth of the aquifer, concentrations decline to below the federal DWS. The situation is different in the eastern part of the cross

section, where concentrations generally increase with depth to the Ringold lower mud unit. This increase is most apparent in the sample results for Wells 299-W19-48 and 699-38-70B. The maximum measured value in the eastern part of the cross section was 470 µg/L in Well 699-38-70B at 36.5 m (120 ft) below the water table. These results are consistent with previous interpretations of the depth distribution of carbon tetrachloride, in which the maximum concentrations occur deeper in the aquifer in the eastern part of the plume (DOE/RL-2006-24, *Remedial Investigation Report for the 200-ZP-1 Groundwater Operable Unit*).

Two wells on the carbon tetrachloride cross section, Wells 699-38-70B and 699-40-65, were drilled to below the Ringold lower mud unit, and one groundwater sample was collected from each well at this depth. Carbon tetrachloride was not detected in Well 699-40-65 but was reported at 14 µg/L in Well 699-38-70B. This concentration was substantially below the reported result of 428 µg/L for the sample collected just above the Ringold lower mud unit. It is not known whether carbon tetrachloride is actually present below the Ringold lower mud unit at this location. It is possible that some carbon tetrachloride may have been dragged down to the bottom of the borehole during drilling. There is an erosional window through the Ringold lower mud unit in 200-ZP-1 has allowed some carbon tetrachloride to migrate into the Ringold Formation confined aquifer (Figure 3-19). This situation is known to have occurred in the southern 200-ZP-1 OU at Well 299-W13-1, about 800 m (2,600 ft) north-northwest from Well 699-38-70B (DOE/RL-2006-24).

Chloroform is a degradation product of carbon tetrachloride and tends to occur in wells containing carbon tetrachloride. Thus, some degradation of carbon tetrachloride may be occurring, although chloroform may also have been introduced to the aquifer from source areas in the 200-ZP-1 OU. Chloroform is widespread within the 200-UP-1 OU, but there were no exceedances of the federal DWS (80 µg/L for total trihalomethanes) in samples collected during the RI (Figure 4-40). The maximum measured concentration was 35 µg/L in Well 299-W14-71 (August 2007). There is no evidence of a local source of chloroform within the 200-UP-1 OU (other than possible degradation of carbon tetrachloride). Similar to carbon tetrachloride concentrations, chloroform concentrations tend to increase with depth as shown by depth-discrete sampling.

TCE is found within the 200-UP-1 OU largely in association with the carbon tetrachloride plume. The maximum concentrations measured during the RI exceeded the federal DWS (5 µg/L) in eight wells in the northern part of the OU, and in one well (Well 299-W22-20) downgradient from the 216-S-20 Crib (Figure 4-41). No sample results exceeded 10 times the federal DWS. The maximum measured concentration was 13 µg/L in Well 299-W14-71 (April 2007), the same well with the highest carbon tetrachloride and chloroform concentrations near the 200-ZP-1 boundary. Depth-discrete sampling results show that TCE concentrations tend to increase with depth, similar to carbon tetrachloride and chloroform. Concentrations have generally declined over time. For example, in FY 2008, sample results exceeded the federal DWS in only three wells: Wells 299-W14-71, 699-38-70B, and 699-38-70C. These three wells are screened deep within the unconfined aquifer just above the Ringold lower mud unit. During FY 2008, there were no exceedances of the federal DWS in wells monitoring the upper part of the aquifer near the water table.

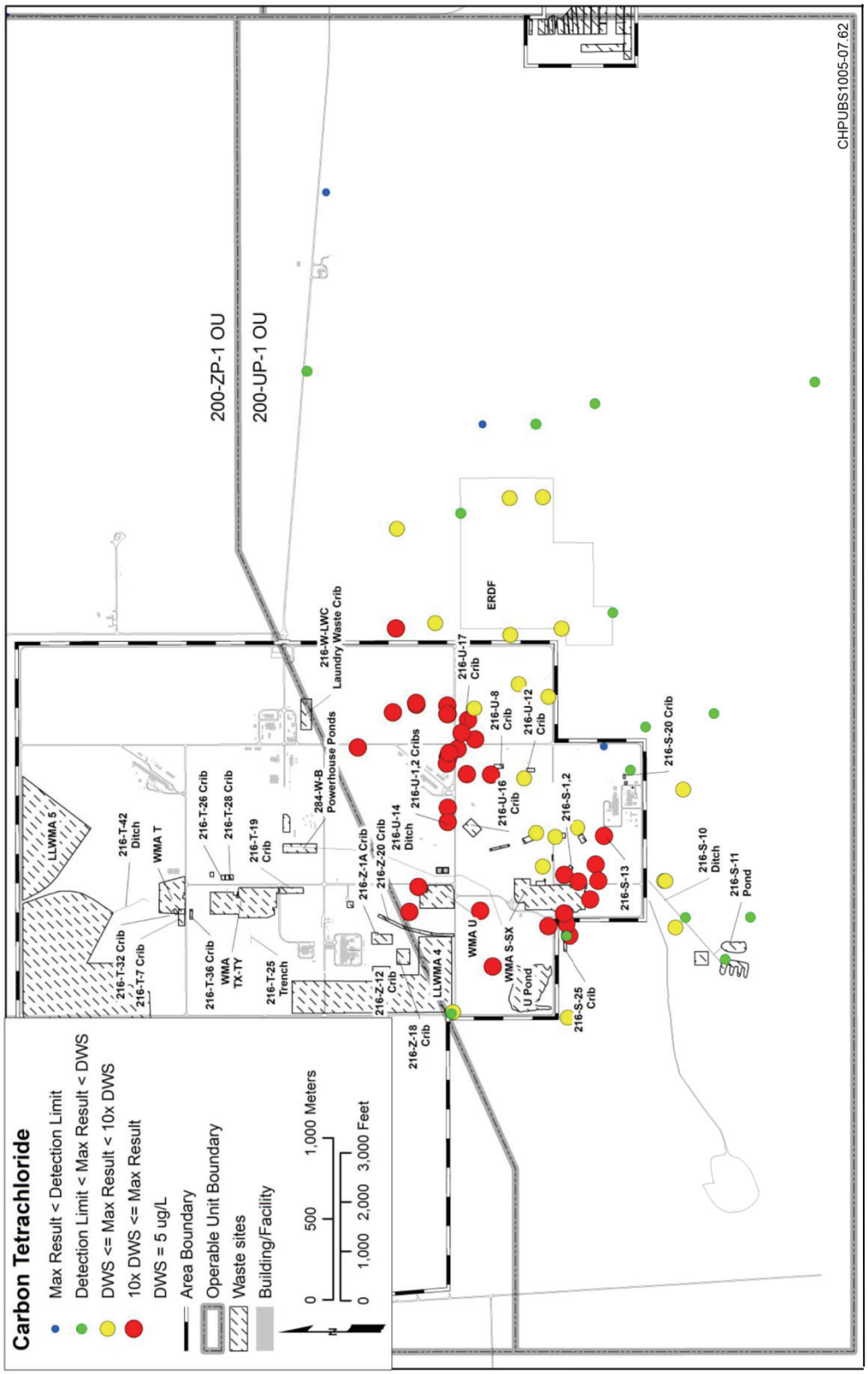
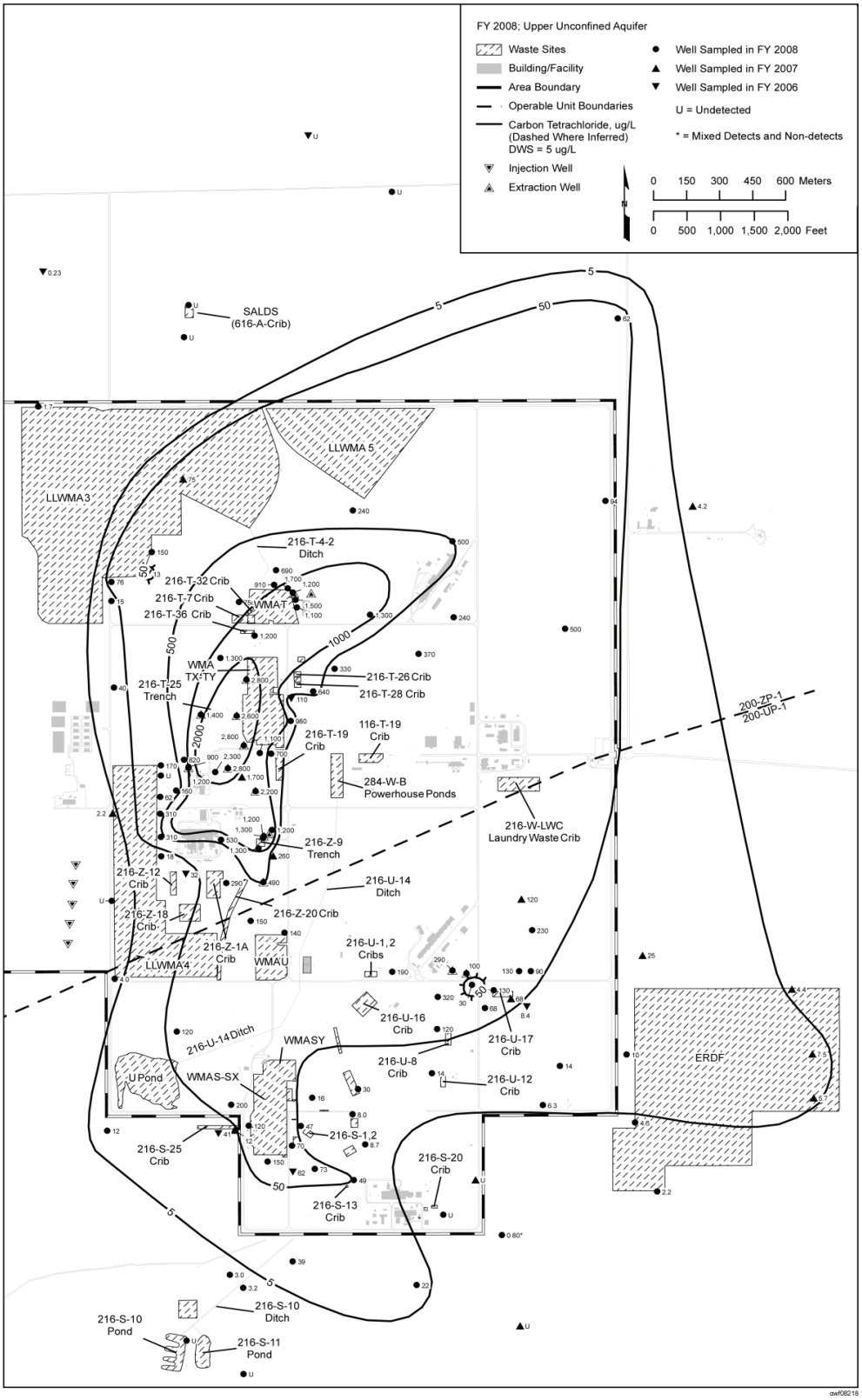
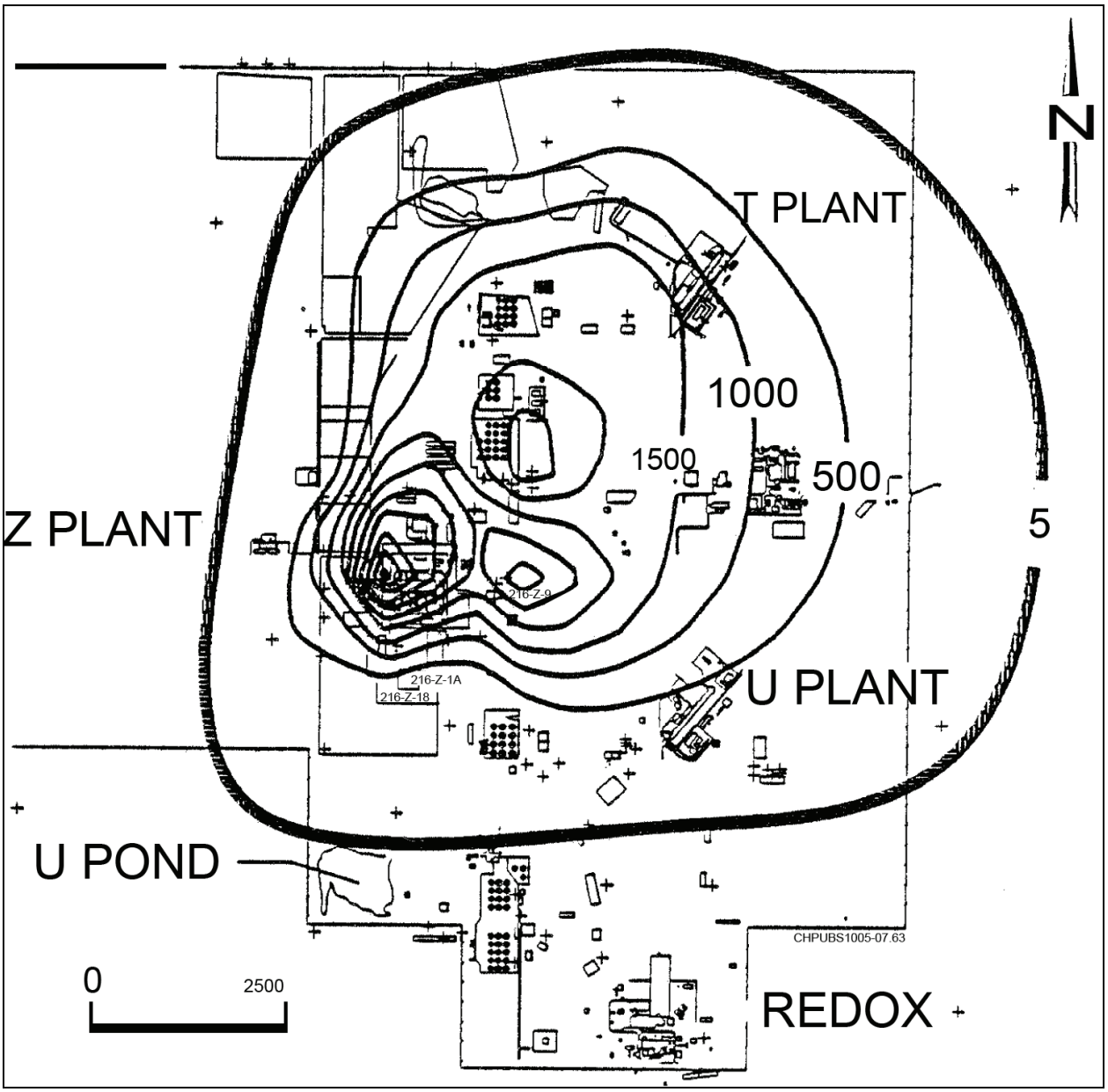


Figure 4-36. Maximum Sample Results for Carbon Tetrachloride during the Remedial Investigation



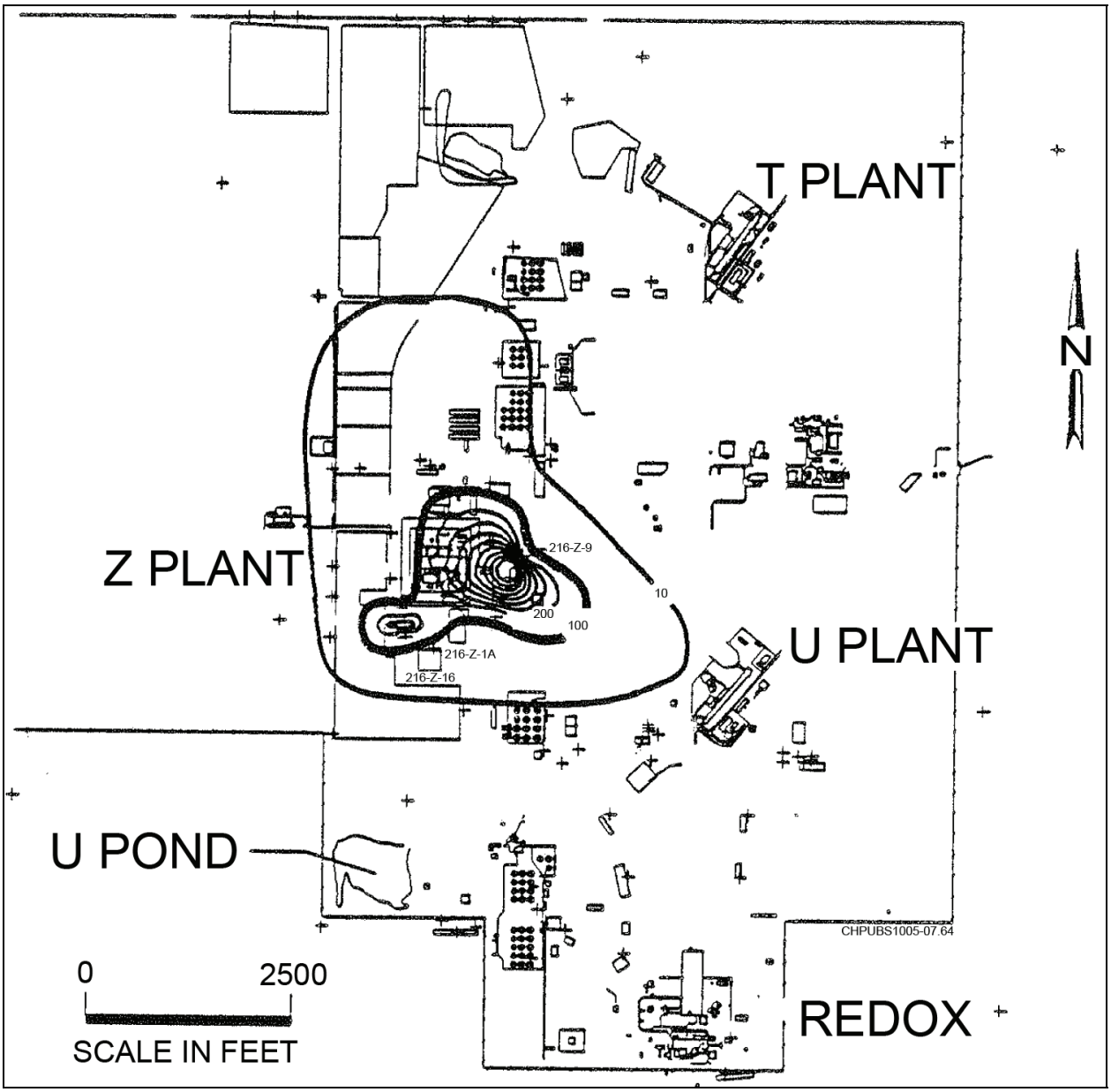
Source: DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*.

Figure 4-37. Average FY 2008 Carbon Tetrachloride Concentrations in the 200 West Area, Upper Part of Unconfined Aquifer



Source: PNL-8073, *Hanford Site Ground-Water Monitoring for 1990*.

Figure 4-38. 200 West Area Carbon Tetrachloride Plume Map for 1990 (µg/L)



Source: PNL-8073, *Hanford Site Ground-Water Monitoring for 1990*.

Figure 4-39. 200 West Area Chloroform Plume Map for 1990 (µg/L)

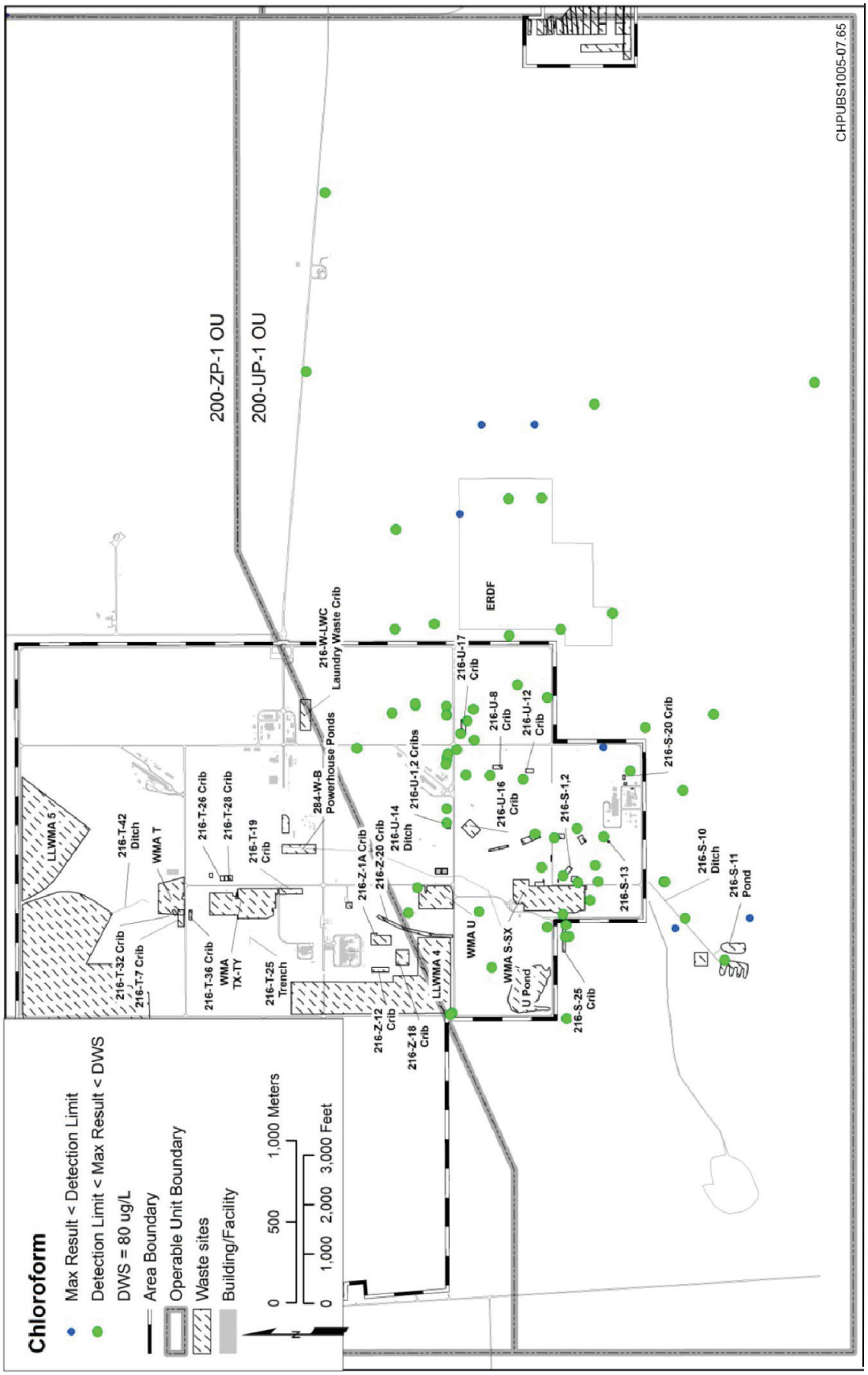


Figure 4-40. Maximum Sample Results for Chloroform during the Remedial Investigation

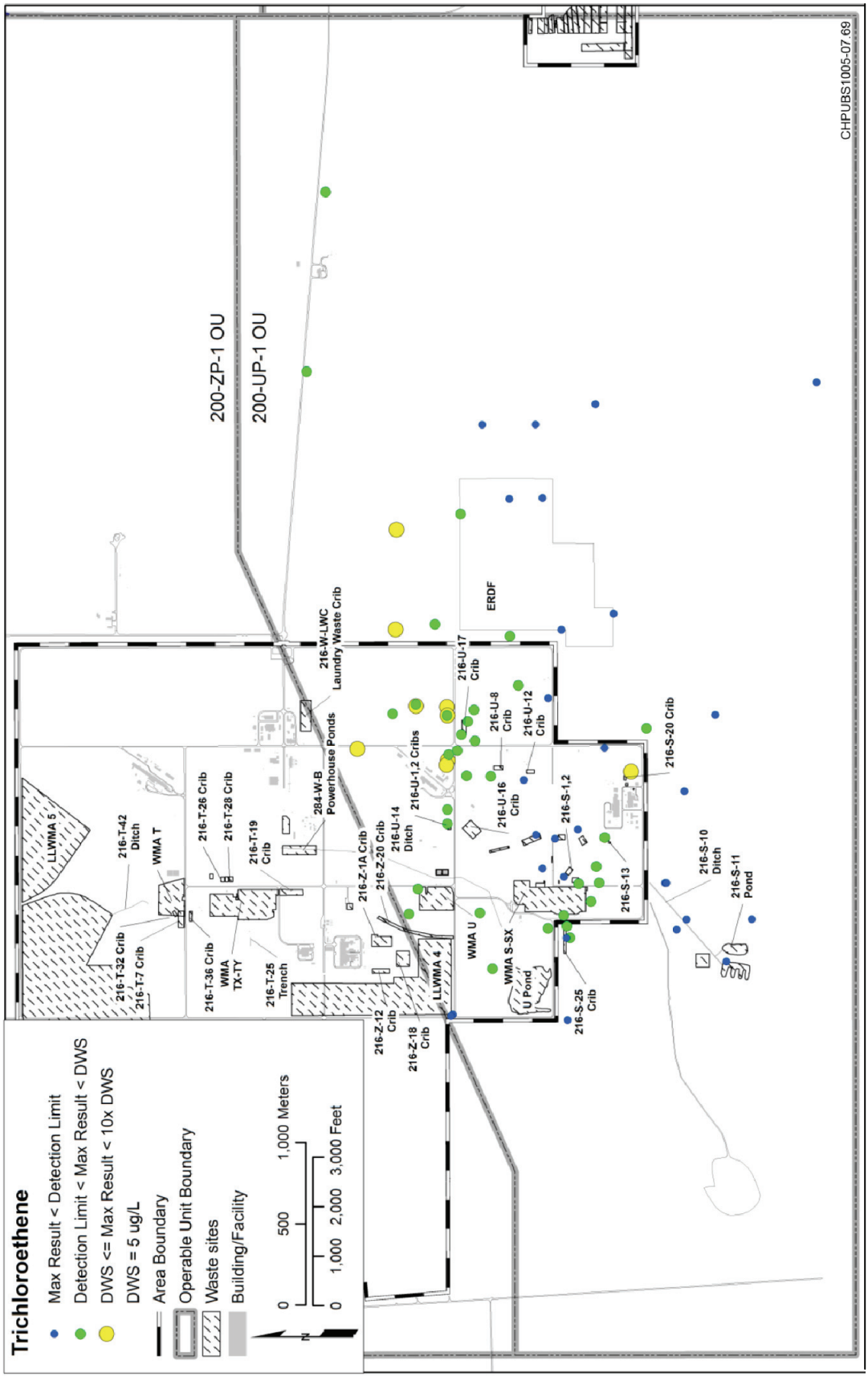


Figure 4-41. Maximum Sample Results for Trichloroethene during the Remedial Investigation

4.2.8 Arsenic, Cadmium, and Strontium-90

Other high priority COPCs not discussed in the previous sections are arsenic, cadmium, and Sr-90; only the latter occurs in 200-UP-1 OU groundwater as a contaminant. There were 13 analyses that detected Sr-90 however, it was found above the federal DWS (8 pCi/L) in a single well during the RI, Well 299-W22-10, downgradient from the 216-S-1 and 216-S-2 Cribs (Figure 4-42). The maximum measured concentration in this well during the RI was 32 pCi/L (December 2004). The 216-S-1 and 216-S-2 Cribs received highly acidic waste from the REDOX Plant between 1952 and 1956. In 1955, the waste is believed to have corroded the casing of an adjacent monitoring well (Well 299-W22-3, located 25 m [80 ft] west-northwest of Well 299-W22-10), which allowed the effluent to bypass the soil column and flow down the well directly into groundwater. This is the postulated pathway by which Sr-90 reached groundwater at this location.

Arsenic occurs naturally in the groundwater at concentrations above the laboratory method detection limit (0.4 µg/L) (DOE/RL-2008-66), so there were numerous detections of arsenic during the RI (Figure 4-43). Natural background arsenic concentrations have a geometric mean of 3.11 µg/L and a 95th percentile of 11.8 µg/L (Table 4-1). The maximum measured arsenic concentration (in unfiltered samples) during the RI was 6.9 µg/L in Well 699-35-66A (September 2006), which is within the natural background range and below the federal DWS (10 µg/L). Thus, there is no evidence of arsenic contamination in the groundwater within the 200-UP-1 OU.

Natural background concentrations for cadmium have a geometric mean of 0.274 µg/L and range up to 1.29 µg/L (95th percentile) (Table 4-1). These values are below the recent laboratory method detection limit of 4 µg/L (DOE/RL-2008-66), so cadmium was not detected in most wells within the OU. Single detections occurred in four wells ranging from 0.22 to 2.2 µg/L in 2004 and 2006 when detection limits were lower (Figure 4-44). The lack of consistent detections in these wells indicates that some of these results could be false positives. Further, all these results are below the 5 µg/L federal DWS. Thus, there is no evidence of cadmium contamination in the groundwater.

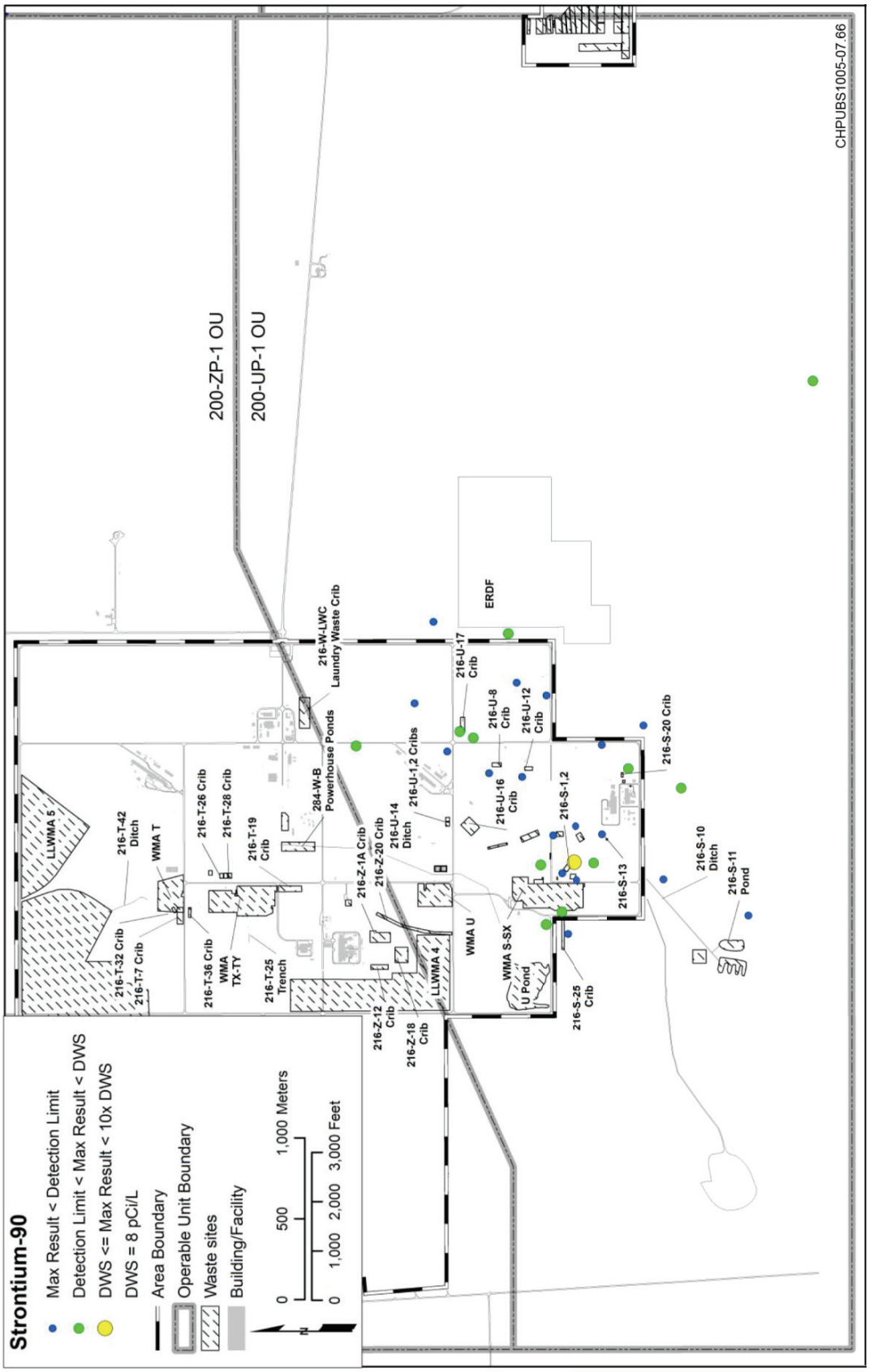


Figure 4-42. Maximum Sample Results for Strontium-90 during the Remedial Investigation

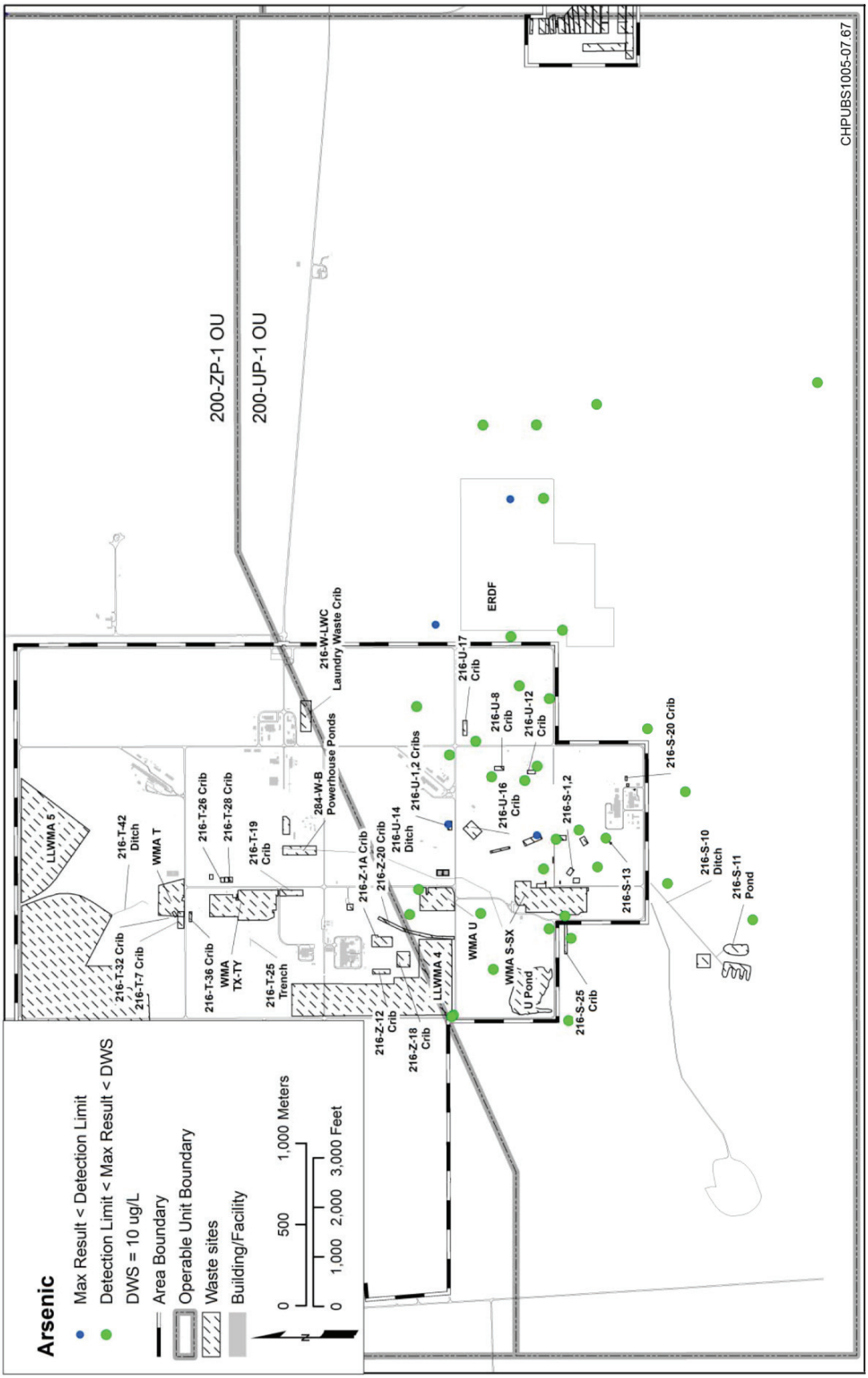


Figure 4-43. Maximum Sample Results for Arsenic during the Remedial Investigation

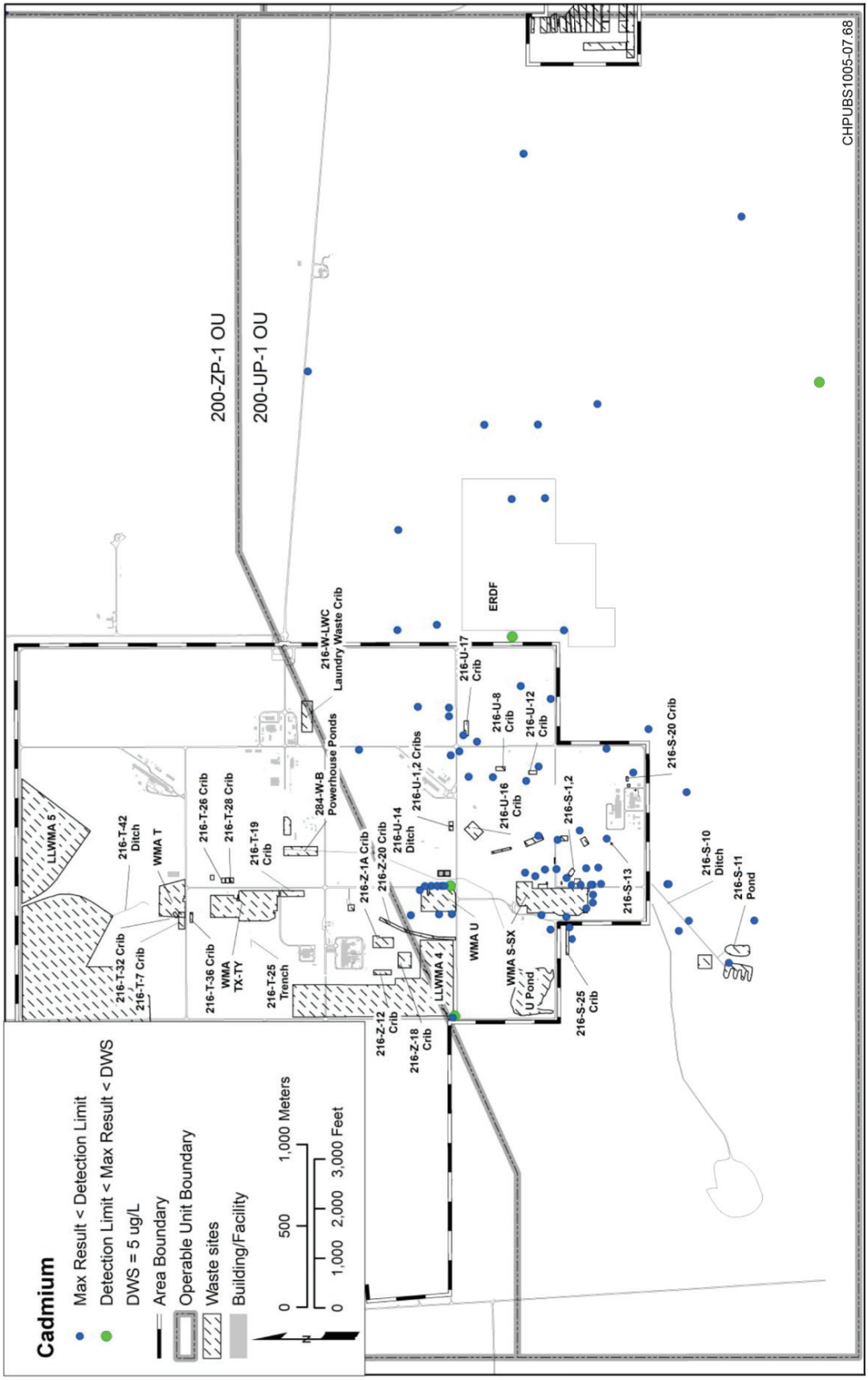


Figure 4-44. Maximum Sample Results for Cadmium during the Remedial Investigation

4.2.9 Additional Contaminants of Potential Concern

Table 4-2 lists the additional COPCs identified in DOE/RL-92-76, Rev. 1 and those identified specifically for this RI report. Note that 1,4-dioxane, bromodichloromethane, carbon-14, chloromethane, hexavalent chromium, magnesium, methylene chloride, selenium-79, PCE, and uranium-234, -235, and -238 are the only additional COPCs that occur in the groundwater at concentrations above the natural background. Chromium occurs in the groundwater in the soluble hexavalent (6+) form (this constituent was discussed in Section 4.2 as total chromium).

During the RI, 1,4-dioxane was detected once at 120 µg/L in Well 299-W22-20 (August 2006), near the 216-S-20 Crib. This constituent was also detected in two previous sampling events in this well at 110 µg/L (January 2002) and 160 µg/L (January 2003) (Figure 4-45). It also has been detected at a very low concentration in Well 699-34-72 (east of Well 299-W22-20 and the 216-S-20 Crib) at 5.8 µg/L (March 2010). Because of these multiple detections in different wells, it is concluded that this contaminant is present in the groundwater; the 216-S-20 Crib is the most likely source. From 1952 through 1972, this crib received waste from laboratory hoods and decontamination sinks in the 222-S Building, along with laboratory waste from the 300 Area. A federal DWS has not been established for 1,4-dioxane; however, a MTCA Method B groundwater cleanup level of 800 µg/L has been established based on a noncancer hazard quotient (HQ) of 1.0 and a cleanup level of 3.98µg/L based on an excess lifetime cancer risk of 1×10^{-6}.

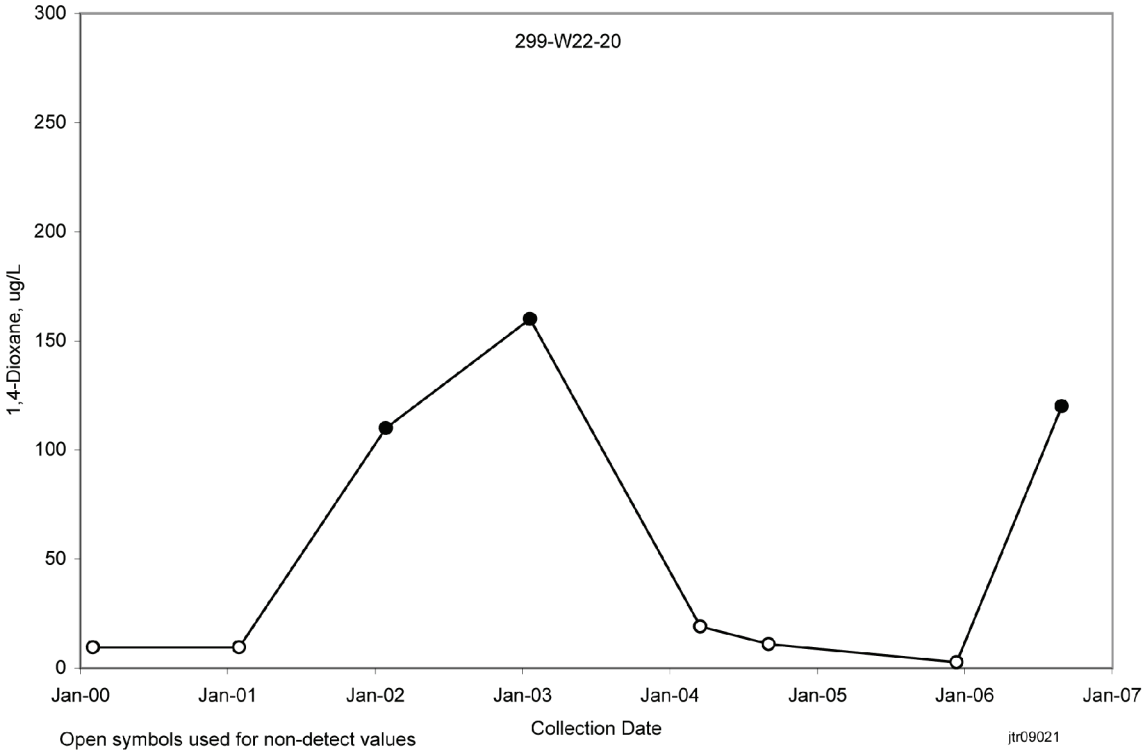


Figure 4-45. 1,4-Dioxane Concentrations in Well 299-W22-20, near the 216-S-20 Crib

There were 32 detections of bromodichloromethane and 25 detections of chloromethane from the nearly 200 analyses performed for each of these constituents during the RI. All of the chloromethane detections, and all but one of the bromodichloromethane detections, were flagged as estimated values near the method detection limit (detection limits ranged from 0.064 to 0.088 µg/L for bromodichloromethane and 0.036 to 0.1 µg/L for chloromethane) (DOE/RL-2008-66). The maximum reported values were 1.1 µg/L

for bromodichloromethane in Well 699-38-70B (August 2005) and 1.3 µg/L for chloromethane in Well 299-W19-48 (August 2005). The applicable federal DWS for bromodichloromethane is 80 µg/L for total trihalomethanes, and there is no federal DWS for chloromethane. These constituents are probably in the groundwater at very low levels and apparently migrated into the 200-UP-1 OU from the 200-ZP-1 OU. Chloromethane also may have originated within the 200-UP-1 OU as a degradation product of carbon tetrachloride.

Of the 17 detections of carbon-14 found during the RI, 9 were in Well 299-W22-72. The maximum concentration was 33 pCi/L (June 2008), which is well below the 2,000 pCi/L federal DWS. Two detections occurred in Well 299-W23-21, and single detections occurred in six other wells. This constituent is in the groundwater, especially at Well 299-W22-72, but concentrations are very low. The source is not known.

PCE was detected in 54 of the nearly 700 analyses for this constituent during the RI. The maximum detected value was 3.8 µg/L in Well 299-W19-107 (December 2008). The federal DWS is 5 µg/L. Of the 54 detections, only 6 are not flagged to indicate a laboratory QC problem or an estimated value near the method detection limit (1 µg/L) (DOE/RL-2008-66). Similar to bromodichloromethane and chloromethane, this constituent occurs at low levels in the groundwater and may have migrated into the 200-UP-1 OU from the 200-ZP-1 OU.

Magnesium occurs naturally in the groundwater, but 23 of the sample results during the RI were above the 95th percentile natural background concentration of 31,051 µg/L (Table 4-1). Magnesium typically occurs at concentrations above the natural background in association with contaminant plumes. The source of the magnesium is thought to be cation exchange reactions where sodium in waste liquids replaces calcium and magnesium in sediment during transport through the vadose zone, resulting in elevated concentrations of calcium and magnesium in the groundwater (PNNL-11810, *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas S-SX at the Hanford Site*).

The isotopes uranium-234, -235, and -238 were all found in groundwater during the RI. The highest concentrations occurred in Well 299-W19-18, within the uranium plume downgradient from the 216-U-1 and 216-U-2 Cribs. For the March 2006 sample event in this well, uranium-234 was reported at 166 pCi/L, uranium-235 at 7.14 pCi/L, and uranium-238 at 170 pCi/L. Uranium is regulated in groundwater as a metal using the federal DWS of 30 ug/L, expressed as total uramium and the individual radionuclides are set at a 4 mrem/yr dose basis for the sum of the doses from beta particle and photon emitters, 15 pCi/L for gross alpha emitter activity concentration (including Radium [Ra]-226 and excluding uranium and radon), and 5 pCi/L combined activity concentration for Ra-226 and Ra-228.

Examination of Table 4-2 shows that other constituents were found in groundwater samples at concentrations apparently above background levels, but many of these results are not representative of actual groundwater conditions. For example, laboratory analyses for aluminum have historically been problematic. Aluminum analyses by inductively coupled plasma-optical emission spectrometry (ICP-OES), Method 6010C (SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods*), "do not appear to be reliable at the low levels found in most of the groundwater samples" at the Hanford Site, and many results from this method are biased high (PNNL-15670). A comparison between ICP-OES and the more sensitive method, inductively coupled plasma-mass spectrometry (ICP-MS) Method 6020A (SW-846), was conducted during FY 2006 by analyzing 20 routine groundwater samples at the same laboratory by both methods. The results generally confirmed that the ICP-OES method produces a high percentage of false-positive results for aluminum (PNNL-16346). Thus, detections of aluminum by the ICP-OES method, especially above the secondary federal DWS of 50 to 200 µg/L,

should be viewed as probable false positives. PNNL-16346 stated that future analyses for aluminum would be performed using the ICP-MS method.

Aluminum was reported as detected in about one-half of the nearly 500 analyses for aluminum performed during the RI on samples from the 200-UP-1 OU. For all but five of these detections, the ICP-OES method was used, and the results are considered to be false positives. Many of these results are flagged in the HEIS by a laboratory or review qualifier to indicate a QC problem. The other five detections were from use of the ICP-MS method, and the reported aluminum concentrations ranged from 6.4 to 39.8 µg/L, which is below the secondary federal DWS of 50 µg/L. Further, only two of the detections were above the 95th percentile natural background concentration of 11.7 µg/L (Table 4-1). Thus, the weight of the evidence indicates that there is no aluminum contamination of groundwater within the 200-UP-1 OU.

Several results for iron were reported above the secondary federal DWS of 300 µg/L, but most of these results were in unfiltered samples. Iron concentrations can be quite variable in unfiltered samples because of the level of turbidity and the nature of the sediment, but high turbidity often results in high reported iron concentrations. Much of the turbidity in unfiltered groundwater samples results from fine sediment mobilized during the sampling process, and this sediment is not actually mobile in the aquifer. Thus, iron concentrations in unfiltered samples are not representative of aquifer conditions.

Several manganese results also were reported above the secondary federal DWS of 50 µg/L, but most of these exceedances occurred for only a short time in newly installed wells. Fresh sediment surfaces are created during the drilling process, and manganese is released from these surfaces in a chemical reaction until the sediments re-weather. This release sometimes causes elevated manganese concentrations in the groundwater adjacent to newly completed wells, which concentrations then decline over time (Figure 4-46). These concentrations are localized to the wells and do not represent ambient aquifer conditions.

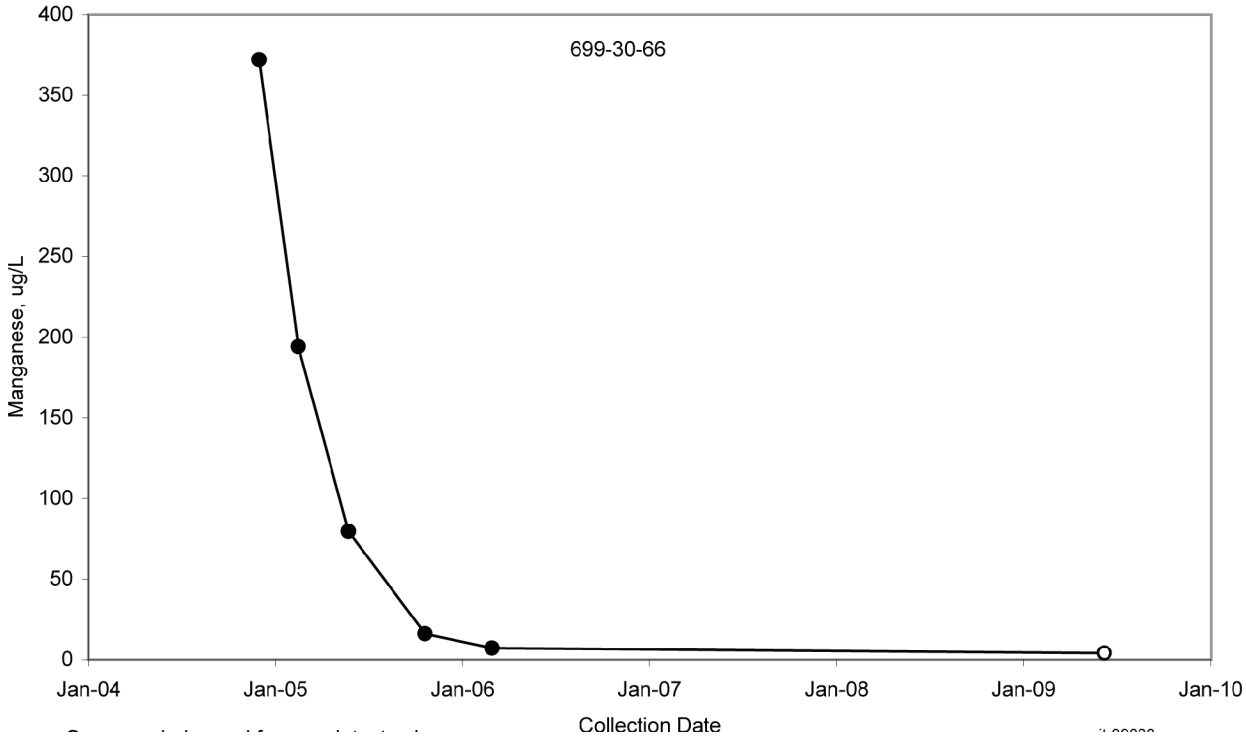


Figure 4-46. Manganese Concentrations in Well 699-30-66, Southeast of the 200 West Area

Methylene chloride was detected in 67 of 697 groundwater samples, of which 10 detections were at concentrations that exceeded the 5 µg/L federal DWS. Of these 10 detections above the federal DWS, 4 were flagged for further review and 2 were flagged as suspect and out of associated quality control limits. This constituent is a common analytical laboratory contaminant. There is no specific process history associated with this contaminant at the Hanford Site. Methylene chloride is a degradation product of carbon tetrachloride, so its presence in groundwater would not be unexpected where carbon tetrachloride contamination is present. Thus, it is uncertain whether these detections represent actual groundwater conditions or laboratory contamination. Note that methylene chloride is detected in a greater percentage of samples in the 200-UP-1 and 200-ZP-1 groundwater interest areas compared to other areas of the Hanford Site (Table 4-4).

Table 4-4. Methylene Chloride Detections in Groundwater at the Hanford Site from 2004 to 2009

Interest Area	Number of Analyses	Number of Detections	Percent Detected
100-FR-3	59	2	3.4
100-KR-4	36	1	2.8
100-NR-2	6	0	0.0
200-BP-5	77	2	2.6
200-PO-1	434	8	1.8
300-FF-5	941	30	3.2
1100-EM-1	183	11	6.0
100-HR-3-D	9	0	0.0
		Average	**2.5**
200-UP-1	697	67	9.6
200-ZP-1	1,174	120	10.2
		Average	**9.9**

The detection rate is about 10 percent in the 200-UP-1 and 200-ZP-1 areas, compared to an average rate of 2.5 percent in other areas. If the presence of methylene chloride in groundwater samples was solely caused by laboratory contamination, the detection rate should be similar across the Hanford Site. Thus, it appears that methylene chloride is likely present in the groundwater at the 200-UP-1 OU, but the reported concentrations may generally be higher than actual groundwater concentrations because of the laboratory contamination. The maximum measured concentration during the RI was 16 µg/L in Well 699-37-68 (during March 2006). In summary, methylene chloride appears to be a degradation product of carbon tetrachloride, with sample values that could be overstated as a result of laboratory contamination.

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5 Contaminant Fate and Transport and Conceptual Exposure Model

A three-dimensional numerical model was used to evaluate fate and transport within the 200-UP-1 OU and the adjacent downgradient areas. This technique uses a set of numerical models (CH2M HILL Plateau Remediation Company versions of MODFLOW-2000 and MT3DMS) to describe groundwater movement and contaminant fate and transport in three dimensions within the Hanford Central Plateau unconfined aquifer system. The model domain incorporates the entire Hanford Central Plateau area, which includes the 200 East and 200 West Areas and a large contiguous surrounding area. The relatively broad domain area allows for evaluation of the uncertainty posed by potential impacts from contaminant plumes that originate outside the 200-UP-1 OU.

The modeling activities and results of the simulations are summarized in the following subsections. Details of the groundwater fate and transport modeling for this OU are described in calculation briefs presented in Appendix D (ECF-HANFORD-10-0371, *Central Plateau Version 3 MODFLOW Model*; ECF-200UP1-10-0373, *200-UP-1 Remedial Investigation Report; Groundwater Contaminant Fate and Transport Model*).

5.1 Groundwater Modeling Process

The fate and transport model for the 200-UP-1 OU was developed following a systematic approach that implemented the following fundamental steps:

- Prepare an updated geologic description of the model domain, describing the distinct HSUs, their thickness, distribution within the domain, and the elevation of the contacts between units.
- Prepare and calibrate a groundwater flow model of the Central Plateau vicinity.
- Assemble plume maps that describe the distribution of selected contaminants within the Central Plateau aquifer system and identify contaminant transport characteristics.
- Estimate future groundwater contaminant concentrations and their geographic layers within the Central Plateau Groundwater Model domain using a calibrated three-dimensional fate and transport model.

5.1.1 Contaminants of Potential Concern Characteristics

The fate and transport of selected 200-UP-1 OU COPCs (namely, chromium [total and hexavalent], uranium, Tc-99, tritium, I-129, nitrate, PCE, TCE, chloroform, fluoride, and Sr-90) was simulated to evaluate future impacts to the unconfined aquifer. These contaminants were selected for transport evaluation because of their discernible presence in this OU, their broadly distributed groundwater plumes demonstrating that they have exhibited mobility in the past, and their presence in groundwater plumes with known elevated potential for future migration. Carbon Tetrachloride is also a COPC, but was not simulated in this modeling study because it was modeled in the 200-ZP-1 FS (DOE/RL-2007-28). Table 5-1 summarizes the characteristics of these contaminants. These contaminants include radioactive and nonradioactive contaminants, organic and inorganic contaminants, and metallic and nonmetallic contaminants. The contaminants evaluated in fate and transport simulations exhibit the common characteristic of being dissolved constituents in groundwater.

5.1.2 Contaminant Mobility

The COPCs in the 200-UP-1 OU exhibit varying levels of mobility in groundwater. All of the COPCs are sufficiently water soluble, so their solubility is not a limiting factor to their being transported in the 200-UP-1 OU aquifer system. The contaminants of interest for this 200-UP-1 OU fall into three general

categories of mobility in groundwater: highly mobile, moderately mobile, and slightly mobile.
The physical process that describes contaminant mobility in the 200-UP-1 OU is interaction of the contaminants with the solid phase portion of the aquifer system (sorption of contaminants to geologic aquifer materials). This characteristic determines the mass of dissolved contaminants in groundwater at any particular time or location. The sorption process is described by the contaminant-specific distribution coefficient (K_d). The K_d is defined as the ratio of the concentration of contaminant sorbed onto the solid phase portion of the aquifer to the concentration of contaminant in solution in the aquifer groundwater in a condition of equilibrium. Mathematically, the K_d is defined simply as the ratio of the sorbed phase concentration (c_{sorbed}) to the solution phase concentration $c_{solution}$ at equilibrium:

$$K_d = \frac{c_{sorbed}}{c_{solution}}$$

Dimensionally, the units for c_{sorbed} are expressed as µg of sorbed contaminant per g of solids (soil matrix), while the units for $c_{dissolved}$ are expressed as µg of dissolved contaminant per mL of water:

$$K_d \text{units} = \frac{\mu g/g}{\mu g/mL} = mL/g$$

The K_d value may be determined experimentally through laboratory batch or column leaching tests using samples of aquifer solids and actual or simulated groundwater. Alternatively, K_d may be determined through measurement of relative contaminant concentrations in groundwater and associated aquifer solids collected from a single representative location.

Contaminants classified in this study as highly mobile move freely with the water in which they are dissolved, exhibiting no direct interaction with the solid phase portion of the aquifer that would remove contaminant mass from the groundwater as it moves through the aquifer. The highly mobile contaminants exhibit a K_d of 0 (no retardation). Tritium is an example of a highly mobile contaminant.

Contaminants classified in this study as moderately mobile move readily with groundwater, but also exhibit a moderate degree of interaction with aquifer solids. Sorptive processes generally tend to slow the rate of migration of these contaminants through the aquifer; their observed concentration in groundwater decreases with migration downgradient through the aquifer system. The definition of moderately mobile is subjective. For the purposes of this study, moderately mobile contaminants are those exhibiting K_d values greater than zero but less than 1. I-129 is an example of a moderately mobile contaminant.

Those contaminants classified in this study as slightly mobile exhibit a high degree of interaction with aquifer solids; as a result, they migrate slowly through the aquifer. Their dissolved concentration in groundwater decreases dramatically with distance from a source or release point because of the relatively large fraction of the contaminant that becomes sorbed to the aquifer solids. For this study, slightly mobile contaminants are those exhibiting K_d values greater than 1. Sr-90 is an example of a slightly mobile contaminant.Sorption processes in any aquifer may include electrostatic ion exchange (cationic or anionic), precipitation reactions, physical adherence on particle surfaces, or combinations of multiple processes. The sorption processes may exhibit varying degrees of reversibility and variations in the rate of reversibility. The K_d of groundwater contaminants varies with differences in the content of fine-textured materials (silt and clay-sized particles) in the aquifer solids. As the content of fine materials in the aquifer solids increases, K_d tends to increase. As a result, contaminants tend to exhibit lower K_d in coarse-textured aquifer materials (sandy or gravelly materials) and higher K_d in fine-textured formations (silty and clayey materials).

Table 5-1 present the contaminant-specific K_d values for the 200-UP-1 COPCs. The contaminant K_d values used for this study were selected from published reports: PNNL-18564, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses: Fiscal Year 2008 Status Report*;

PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*; PNNL-17154, *Geochemical Characterization Data Package for the Vadose Zone in the Single-Shell Tank Waste Management Areas at the Hanford Site*; PNNL-16100, *Carbon Tetrachloride Partition Coefficients Measured by Aqueous Sorption to Hanford Sediments from Operable Units 200-UP-1 and 200-ZP-1*; PNNL-13560, *Assessment of Carbon Tetrachloride Groundwater Transport in Support of the Hanford Carbon Tetrachloride Innovative Technology Demonstration Program*; DOE/RL-2007-28, *Feasibility Study Report for the 200-ZP-1 Groundwater Operable Unit*. These reports describe experimental determination of K_d values for specific contaminants of interest in aquifer materials collected at the Hanford Site that represent aquifer conditions within the 200-UP-1 OU.

Table 5-1. Physical and Transport Characteristics of COPC

Chemical Name	CAS Number	Chemical Group	Molecular Weight (g/mole)	Radioactive Half-Life (yr)	Distribution Coefficient K_d (mL/g)
Carbon Tetrachloride [a]	56235	Volatile	153.82	N/A	0.011 [b]
Chloroform	67663	Volatile	119.38	N/A	0.0084 [c]
Tetrachloroethene	127184	Volatile	165.8	N/A	0.0749 [d]
Trichloroethene	79016	Volatile	131.39	N/A	0.0250 [e]
1,4-Dioxane	123911	Volatile	88.11	N/A	- [f]
Chromium	7440473	Metal	51.99	N/A	0 [g]
Hexavalent Chromium	18540299	Metal	51.99	N/A	0 [g]
Uranium, soluble salts	N/A	Metal	238.03	N/A	0.4 [h]
Nitrate	14797558	Nutrient	62.00	N/A	0 [h]
Fluoride	7782414	Inorganic	18.99	N/A	0 [i]
Iodine-129	15046841	Radionuclide	129.91	16,000,000	0.1 [h]
Technetium-99	14133767	Radionuclide	98.91	210,000	0 [h]
Tritium [j]	10028178	Radionuclide	6.03	12.33	0 [h]
Strontium-90	10098972	Radionuclide	87.62	28.9	12 [h]

a. Carbon tetrachloride was not simulated in this modeling study. It was modeled in the 200-ZP-1 FS (DOE/RL-2007-28, *Feasibility Study Report for the 200-ZP-1 Groundwater Operable Unit*).

b. Value is from DOE/RL-2007-28, Table D-58.

c. Value calculated from empirical relationship based on PNNL-13560 Table 16, Equation 2.

d. Value calculated from empirical relationship based on PNNL-13560 Equations 1 & 2, p. C.16 assuming foc=0.00027 and solubility of tetrachloroethene of 150 mg/L.

e. Value calculated from empirical relationship based on PNNL-13560 Equations 1 & 2, p. C.16 assuming foc=0.00027 and solubility of trichloroethene of 1100 mg/L.

f. Not simulated in groundwater flow and transport modeling as it was measured at only one well and therefore was below the threshold for simulation; see Chapter 6, Section 6.1.4.2, for further details.

g. K_d is conservatively (relative to groundwater protectiveness) assigned a value of zero for chromium and hexavalent chromium for groundwater simulation, resulting in greater contaminant mobility. The best estimated value is 0.8 (ECF-HANFORD-11-0165, *Evaluation of Hexavalent Chromium Leach Test Data Conducted in Vadose Zone Sediment*

Table 5-1. Physical and Transport Characteristics of COPC

Chemical Name	CAS Number	Chemical Group	Molecular Weight (g/mole)	Radioactive Half-Life (yr)	Distribution Coefficient K_d (mL/g)

Samples from the 100 Area).

h. Value is from PNNL-18564, Table 6.9 (sandy gravel).

i. Value is from PNNL-17154, Table 3.3 (sand-size sediments).

j. Tritium is generally present as tritiated water.

5.1.3 Fate and Transport Models and Approach to Simulations

This section explains the general process used for the simulation of contaminant migration in the 200-UP-1 OU. A detailed discussion of the contaminant fate and transport model development and the results of the fate and transport simulations, as applied to the 200-UP-1 OU, are presented in the following three environmental calculation files (Appendix D):

- ECF-HANFORD-10-0371
- ECF-200UP1-10-0373
- ECF-200UP1-10-0374, *Development and Evaluation of Remedial Alternatives for Iodine, Uranium, and Nitrate Plumes in the 200-UP-1 Operable Unit Using Central Plateau Groundwater Model, Version 3*

MODFLOW and MT3DMS software were used to simulate groundwater flow and contaminant transport, respectively for COPCs currently present in groundwater. MODFLOW solves the groundwater flow equation to calculate hydraulic heads and groundwater flow velocities. MT3DMS uses the resultant groundwater flow velocities and transport characteristics of the aquifer and contaminants to solve the groundwater advection-dispersion equation, yielding concentrations in time and space. The influence of the future movement of contaminants currently in the vadose zone down to the saturated aquifer is outside the scope of this analysis and, therefore, such sources are not included in the fate and transport modeling.

Two general categories of natural physical processes affect the concentration of contaminants in a groundwater plume over time: advection-diffusion processes related to the movement of water through the aquifer, and processes that are specific to the individual contaminants.

This modeling study assesses the fate and transport of contamination in the unconfined aquifer without further remedial action (the same model is subsequently used in the FS to assess potential pumping scenarios as part of potential remedial actions). Section 5.2 includes a discussion of the uncertainties related to modeling assumptions, including the potential for continuing releases from the vadose zone.

The following physical processes provide the primary effects on the estimated contaminant concentrations with time and distance from source locations in the 200-UP-1 OU:

- Dilution of the contaminants occurs as additional uncontaminated water enters the aquifer. This water can include uncontaminated groundwater entering the model domain from the lateral domain boundaries, meteoric water entering the aquifer from the top of the domain as a fraction of the annual precipitation falling on the ground surface, and clean water discharges to the aquifer from continuing operations at the Site.

- Dispersion of the dissolved contaminants occurs as groundwater moves through the aquifer system. Contaminants tend to become more dispersed as groundwater flows through a porous medium. Dispersion occurs because of small, localized variations in the water flow velocity at locations within the groundwater. This results in a more widespread distribution of the contaminant mass as the distance from the point of origin increases. This process is defined by the coefficient of hydrodynamic dispersion (D).

- Diffusion of dissolved contaminants occurs as a result of concentration gradients within the aquifer. The result of diffusion is similar to that of dispersion. The original contaminant mass becomes more widespread throughout the aquifer with time, and overall concentrations are reduced. This process is quantified by the coefficient of molecular diffusion (D_m).

In addition to advective-diffusive processes, selected contaminant-specific processes also affect groundwater contaminant concentrations over time and distance. These processes were included in the fate and transport simulations:

- Radioactive decay of radionuclides (I-129, Tc-99, and tritium) contaminants as quantified by the half-life of each isotope (Table 5-1).

- Interaction of the contaminants with the solid phase portion of the aquifer system (sorption of contaminants to geologic aquifer materials) reduces the mass of dissolved contaminants at any particular time or location. This process is quantified by the contaminant-specific K_d (Table 5-1).

Losses from the aquifer through volatilization of VOCs (PCE, TCE, and chloroform) were not considered in this simulation because of the groundwater depth.

The following steps were performed for contaminant fate and transport simulations for the 200-UP-1 OU:

1. A representative dataset describing the geological structure and hydraulic properties of the model domain was prepared through assembly of measurements and geologic observations from well and boring logs, as well as integration of surface geophysical survey data.

2. The geological structure data were used to prepare digital maps and define the representative HSU surfaces within the aquifer that were modeled. Figure 5-1 shows a plan view of the Central Plateau Groundwater Model domain. Figures 5-2 through Figure 5-4 show generalized hydrogeologic cross sections of the model domain. These cross sections illustrate the relationship of the assigned HSU model layers to the geology (lithologic units).

3. A historical dataset of groundwater elevations in groundwater monitoring wells across the model domain was assembled for use in model calibration. Figure 5-5 shows these wells (402 wells were used in calibrating this version of the Central Plateau Groundwater Model).

4. The COPC plumes in groundwater were described using digital plume maps that can be integrated with the hydraulic model of the aquifer. Plumes were established for the initial simulation conditions using observed contaminant concentrations from data collected during FY 2008, supplemented with 2005 through 2009 data where necessary. Chapter 3 provides additional information on development of initial conditions.

A model calibration was performed to compare the MODFLOW-calculated aquifer water levels to the observed historical measurements within the Central Plateau.

5.1.4 Central Plateau Conceptual Model Development

The aquifer occurs in a series of unconsolidated- to semi-consolidated fluvial deposits that accumulated over the past several million years, with the most recent deposits formed by cataclysmic flooding of the Columbia Basin within the last 20,000 years (the Missoula floods). Significant changes in the orientation of these geologic deposits and their geographic location relative to the unconfined aquifer occur between the western and eastern portion of the model domain.

In the western portion of the domain, the uppermost unconfined aquifer is composed of a sequence of deposits known as the Ringold Formation. For modeling purposes, the Ringold deposits have been grouped into three HSUs (Figures 3-8, 5-2, and 5-3). The oldest unit, Ringold unit A (HSU 9), is a coarse-grained silty, sandy, gravel that lies directly above the basalt bedrock. Next in the sequence is the Ringold lower mud unit (HSU 8), composed predominantly of fine-grained (silt/clay) deposits; the Ringold lower mud unit (HSU 8) forms a substantial restriction to the vertical movement of water (aquitard). The coarse-grained Ringold unit E (HSU 5) is deposited above the Ringold lower mud unit (HSU 8) and is the primary geologic unit containing the uppermost unconfined aquifer within the 200-UP-1 OU. Ringold unit 4 (HSU 4) is the youngest Ringold Formation unit and does not occur within the aquifer in 200 UP-1); HSU 4 is limited in extent primarily in the western portion of the model domain.

In the eastern portion of the model domain, the Ringold Formation deposits have been incised by recent erosional and depositional events that have formed highly conductive channels that are filled with relatively permeable, Hanford formation (HSU 1) and CCU (HSU 3) coarse-grained sediment (Figures 3-8, 5-2, 5-3, and 5-4). In the western portion of the model, the CCU (HSU 3) (which is composed of different lithologic material consisting of silt and calcic-rich sediment) and the Hanford formation (HSU 1) generally exist above the unconfined aquifer, whereas they extend below the water table of the unconfined aquifer in the eastern portion of the model domain and become dominant flow features of the model (Figures 5-2, 5-3, and 5-4). For this reason, the western CCU (HSU 3) and Hanford formation (HSU 1) are defined as separate HSUs in the model.

The distribution of each HSU within the model domain was determined by interpolating the contact elevations between HSUs onto the entire model grid. The elevations for these contacts were obtained from a database of interpreted geologic contacts created from Hanford well cores and geological and geophysical logs. These interpolated surfaces were then used to set the top and bottom elevations of the layers defined within the model. The seven model layers vary in elevation, so the varying elevations and thicknesses of each unit are explicitly represented. As a result, the HSU was represented by individual layer changes within the model domain (Figure 5-5). Model layers do not represent individual continuous HSUs nor do they represent a constant elevation slice through the aquifer.

Contaminant migration in the subsurface is driven by groundwater flow. Groundwater flow directions and velocities are, in turn, a function of fluid inputs to the aquifer and aquifer hydraulic properties. The model domain is underlain by basalt formations that are assumed to contribute a negligible amount of water to the flow system. Seven localized regions were identified that are significant inflow and outflow boundaries (Figure 5-1):

- Two gaps in the basalt sub-crops along the northern boundary of the model domain
- Two subsurface stream flows that enter the domain along the surface of the basalt
- One natural recharge to the aquifer from precipitation
- One artificial recharge arising from the disposal of water in ponds, cribs, and shallow wells
- One broad region of outflow along the southeastern and eastern edges of the model domain

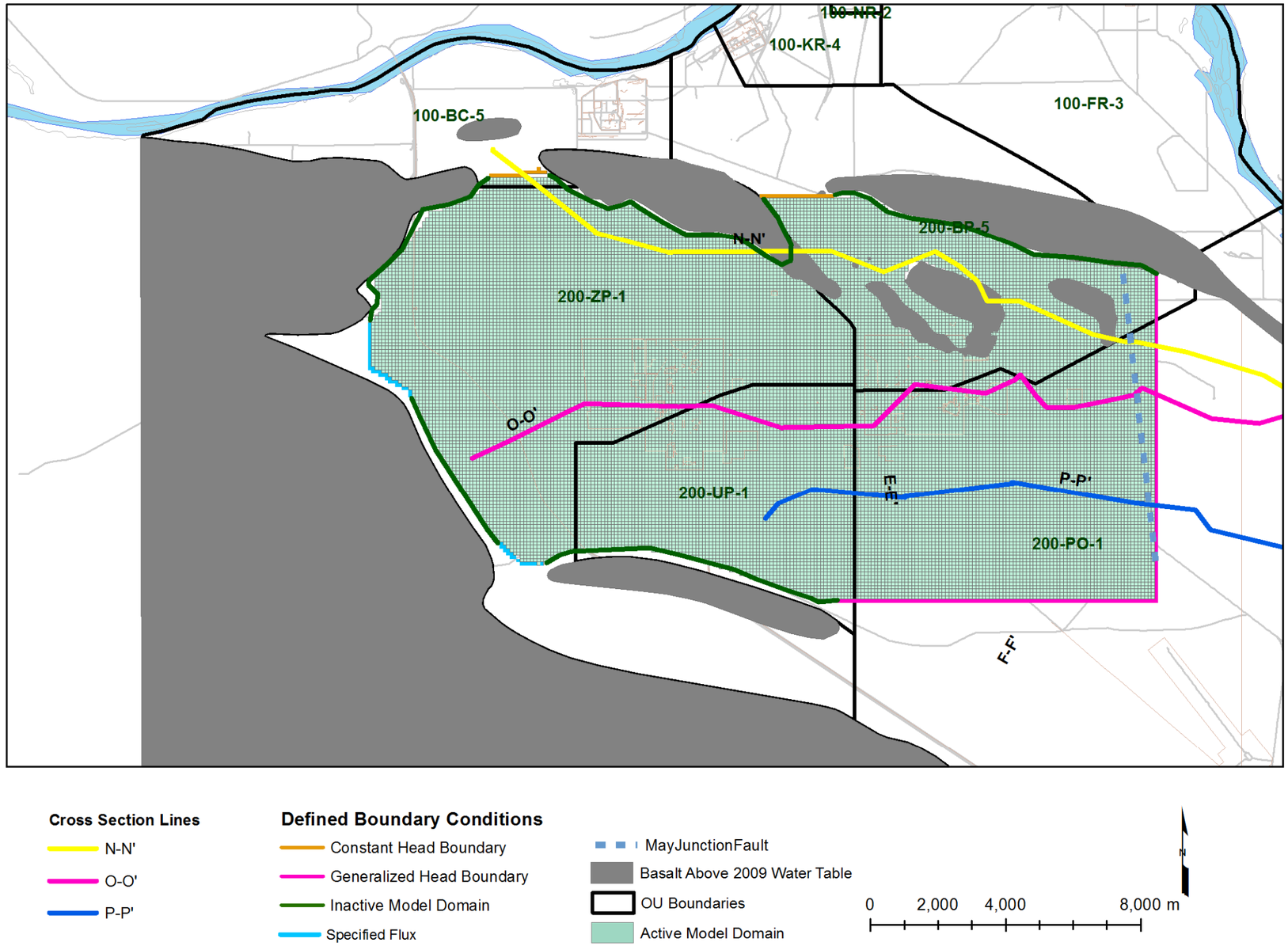

Figure 5-1. Plan View of Central Plateau MODFLOW Model Domain Boundary and Cross Section Locations

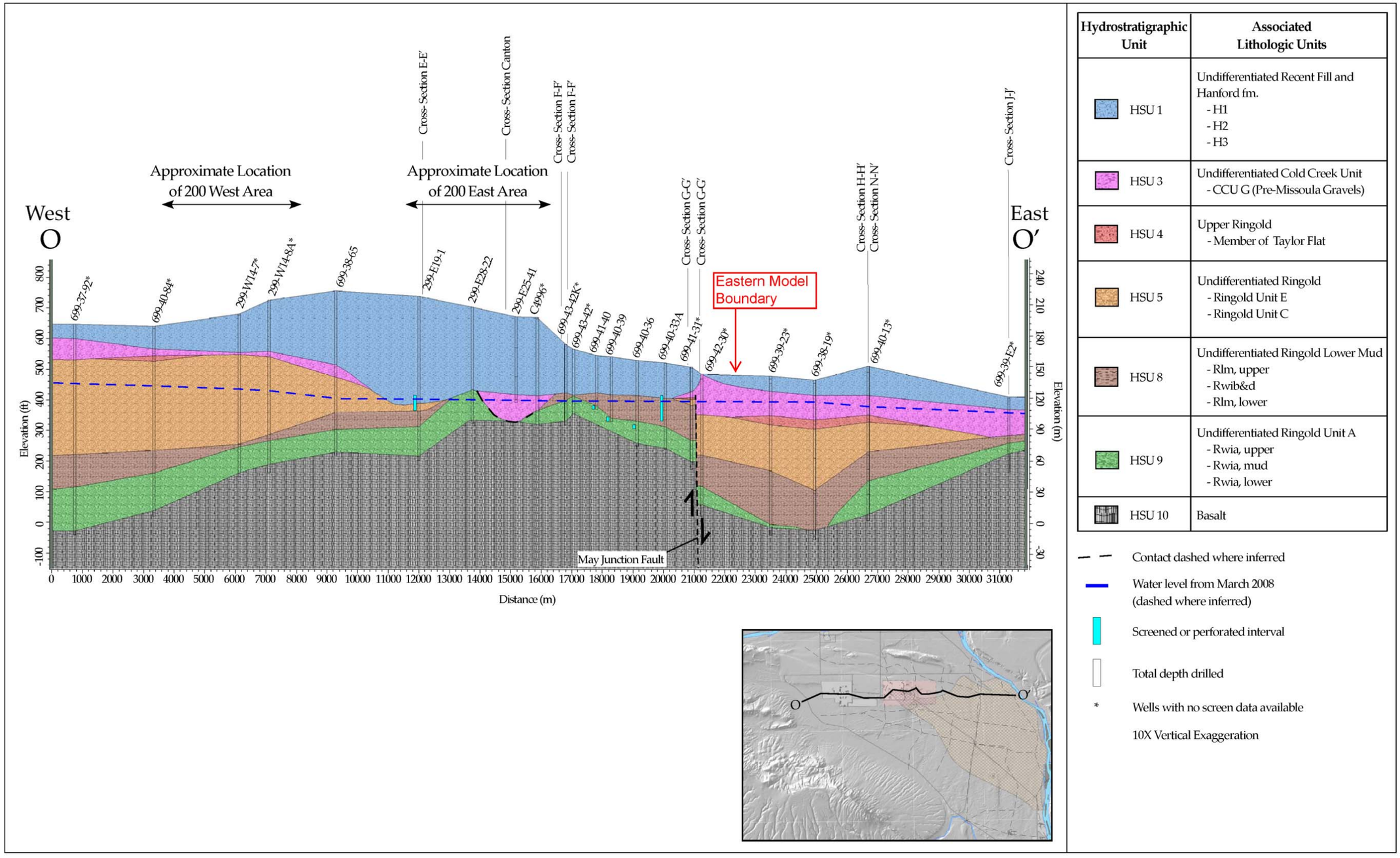

Figure 5-2. Geologic Cross Section O-O'

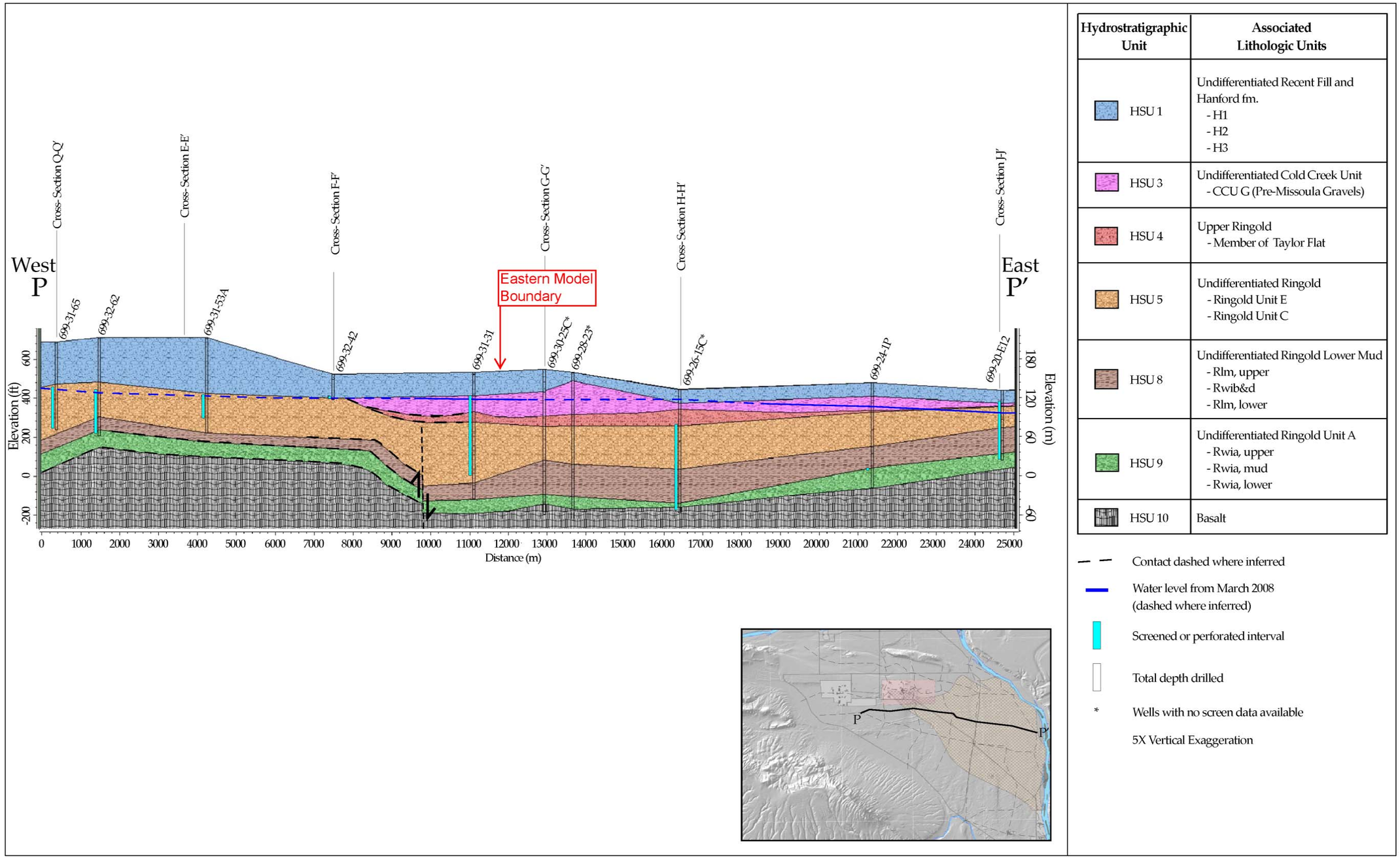

Figure 5-3. Geologic Cross Section P-P'

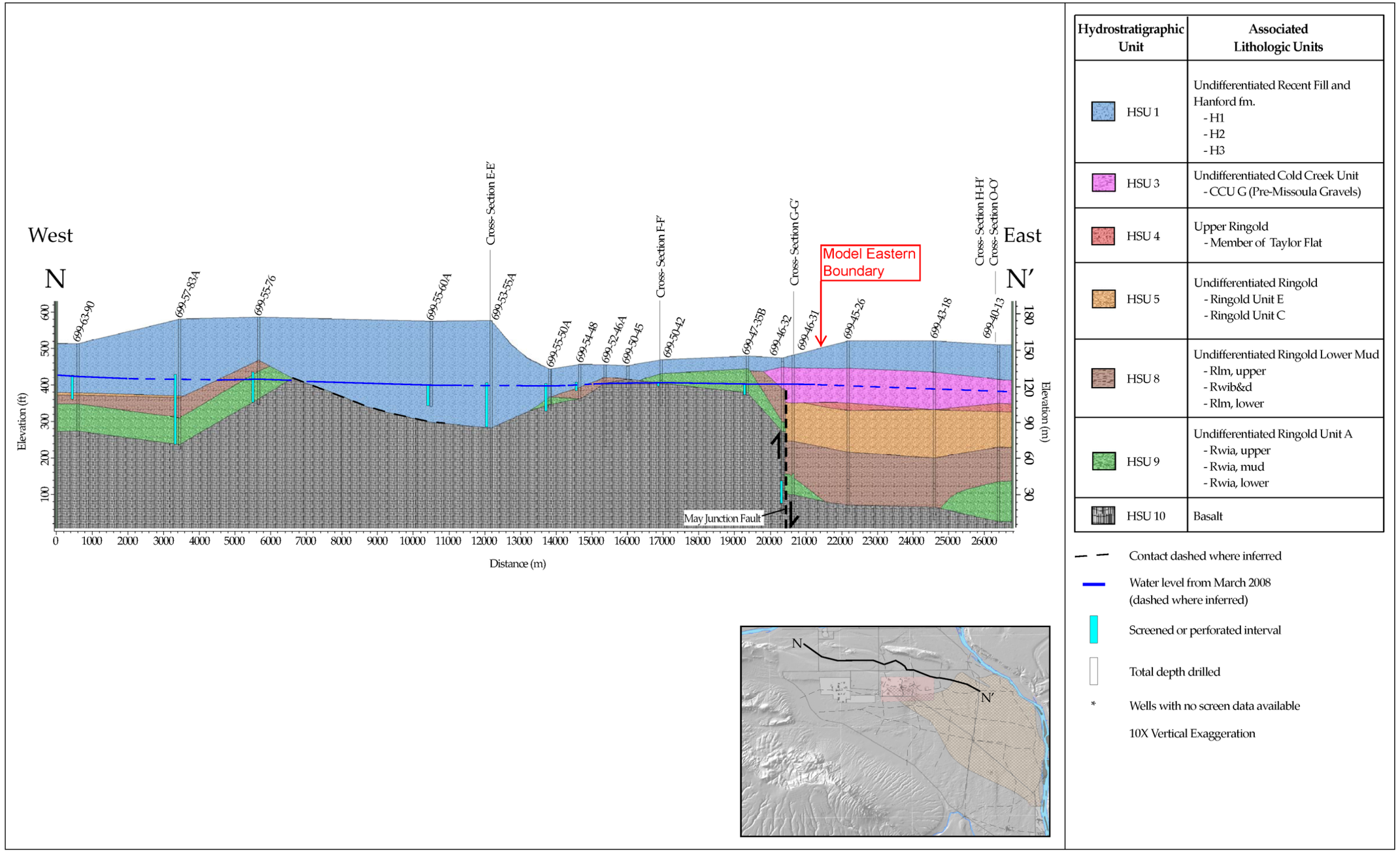

Figure 5-4. Geological Cross Section N-N'

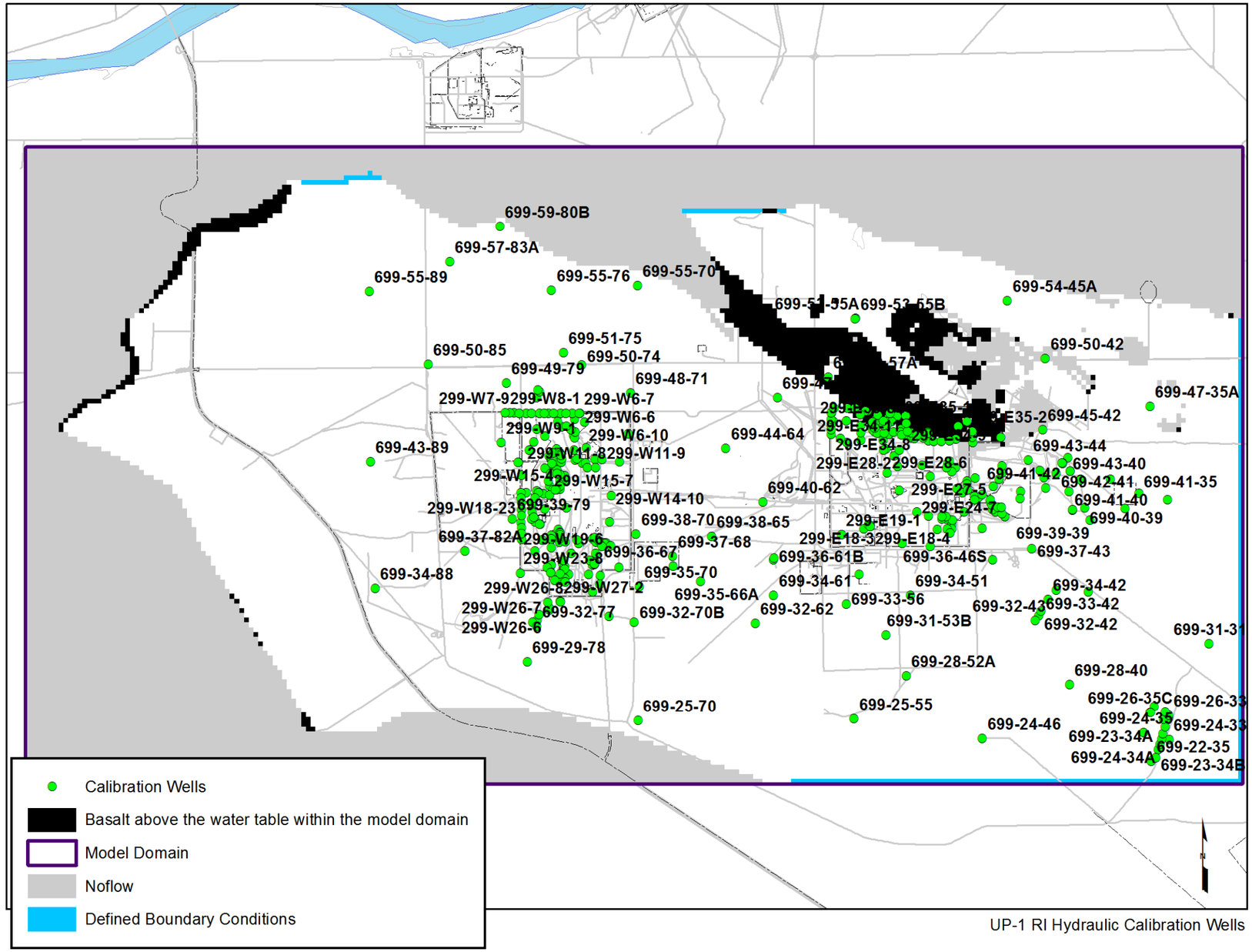

Figure 5-5. Wells Used for Model Calibration

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To establish representative hydraulic properties values for heterogeneous HSUs, calibration was performed using historical water level measurements. The Central Plateau has many monitored wells with long records of groundwater elevations and contaminant concentrations. Some of these records date back to 1948, when the weapons material production facilities were first being constructed on the Central Plateau. The representative hydraulic conductivity of the various HSUs was adjusted to match simulated hydraulic heads to well records.

The calibration was complicated by uncertainty about conditions along the southeastern and eastern boundaries. A mixed (Cauchy-type) boundary condition was applied to represent the hydraulic character of this long boundary. Mixed boundary conditions are known as general head boundary conditions in MODFLOW simulations. The boundary condition is specified by two terms: a reference head value and a conductance term representing the hydraulic connection of the reference head to the boundary. Along the eastern portion of the boundary, the average Columbia River stage was used for the reference head. The conductance was set so that flow directions through the boundary were consistent with those implied by historical contaminant plume maps, and the historical observed hydraulic heads at monitoring wells near the boundary were matched by the simulation. Along the southeastern boundary, two mixed boundary condition terms were superimposed to represent the net effect of two fluxes: one to the Columbia River, as for the eastern boundary, and another to represent inflow from the Dry Creek-Rattlesnake Ridge depression in the basalt bedrock. These two terms were set using the same criteria used for the eastern boundary.

With calibrated parameters established, the calibrated flow model was revised to support the contaminant transport simulations by changing boundary conditions to represent future conditions. Incoming stream flow, natural recharge rates, and the hydraulic heads at the two gaps were assumed to remain unchanged over the 1,000 years simulated for fate and transport. Future planned use of the SALDS and TEDF would be the only sources of artificial recharge, in contrast to the historical period used for model calibration, when many other large liquid discharges were included. Current and planned future uses of the 200 West P&T system were included. Current pumping for interim remediation of the 200-UP-1 U Plant and S-SX facility plumes was intentionally not included, nor was pumping for future 200-UP-1 (as yet unplanned) final remediation. The MODFLOW groundwater flow software creates a file of transient simulated fluxes to and from each cell in the flow model. These simulated fluxes and porosity values were used to calculate groundwater velocities in the MT3DMS transport simulations.

Five sources of contaminant distribution information were used in estimating the initial concentration distributions: measurements from screened wells, depth-discrete samples acquired during drilling or special sampling surveys, a composite dataset created for the 200-ZP-1 OU RI/FS, measurements acquired from Ecology, and contaminant plume contours interpreted for the 2008 and 2009 annual groundwater monitoring reports. Current contaminant distributions were prepared for the fate and transport simulations by interpolating measurements across the model domain using two calculation methods. The first method (Method 1) was used to determine initial concentrations for all of the COPCs; upon review, it was determined that for five of the COPCs, Method 1 was overly conservative. A second method (Method 2) was developed for the five COPCs: chromium, I-129, nitrate, uranium, and Tc-99.

Method 1. A kriging technique proposed in “Spatial Interpolation Methods for Nonstationary Plume Data” (Reed et al., 2004) was adopted for the interpolation algorithm to establish initial conditions.[1] This technique was previously used for the 200-ZP-1 RI/FS to define contaminant distributions.

[1] Kriging is a group of geostatistical techniques to interpolate the value of a random field (the elevation, z, of the landscape as a function of the geographic location) at an unobserved location from observations of its value at nearby locations.

A significant feature of this technique is the use of a transformation to limit the influence of very large concentration measurements, which is a common problem with contaminant data. Some significant differences exist between the application of kriging to the 200-ZP-1 OU and a similar application to the 200-UP-1 OU. The most important of these is that contaminant distributions were estimated within the entire model domain for the 200-UP-1 OU fate and transport simulations and only in the proximity of the 200-ZP-1 OU for the 200-ZP-1 RI/FS.

The 200-PO-1 and 200-BP-5 OUs tend to have a predominant groundwater flow direction that is almost perpendicular to the predominant flow directions in the 200-ZP-1 and 200-UP-1 OUs. To accommodate the tendency for contaminant plumes to align with predominant flow directions, the major principal kriging directions were oriented at 45 degrees east of North in the 200-ZP-1 and 200-UP-1 OUs and 135 degrees east of North in the 200-PO-1 and 200-BP-5 OUs. In both cases, the exponential variogram tended to be about twice as long in the major direction as in the minor direction.[2] Longer variograms were used to estimate the distribution of contaminants that tended to have large plumes; shorter variograms were used to estimate contaminants with smaller plumes.

Contours of contaminant concentration from the 2008 groundwater monitoring report were used to assess the kriged contaminant distributions and to guide the placement of control points. Control points were used to overcome the symmetry inherent in kriging variograms. Contaminant distributions tend to be high in a source area, diminish rapidly with distance upgradient of the source area, and diminish slowly with distance in the direction of flow. To force this tendency in the estimates of plume distributions, control points with small values were used to constrain the upgradient extent of contaminants from source areas. Contaminant contours from the 2008 groundwater monitoring report were used to identify source areas. Control points were used to connect high concentrations. Separate measurements of high values in the contaminant contours from the 2008 annual groundwater monitoring report indicated a single region of high concentration rather than isolated plumes. Therefore, the data input to define existing contaminant distributions is both complex and slightly subjective. Subjectivity enters from the choice of control point location and value and from the contaminant contours from the 2008 groundwater monitoring report, which themselves were guided subjectively by historical knowledge and familiarity with the source area processes.

The vertical profile of contaminant data was only sufficient to determine a three-dimensional distribution of carbon tetrachloride in the 200-UP-1 OU. As an expedient approximation for other contaminants, only measurements that were acquired from well screens or discrete samples taken in the Ringold unit E (HSU 5) were used to estimate a horizontal extent of the contamination. This estimate was then used as the initial contaminant distribution in Ringold unit E (HSU 5). Initial contamination was assumed to be absent in the Ringold lower mud unit and Ringold unit A (HSU 9) which comprise the confining aquitard and underlying Ringold confined aquifer, respectively. Future transport into these HSUs occurred via the three-dimensional flow fields.

Measurements of contaminant concentrations tend to be where contamination occurs at levels of concern. Hence, contaminant measurements at the scale of the 200-UP-1 OU are biased toward large values, leaving regions of low concentrations with sparse measurements. In addition, the treatment of nondetect measurements as one-half of the detection limit biases the measurements upward, away from contaminated areas. The kriging algorithm estimates tend toward the average of measured values where measurements are lacking. Therefore, away from regions of high concentration, the kriged results are

[2] In spatial statistics, the theoretical variogram $2\gamma(x,y)$ is a function describing the degree of spatial dependence of a spatial random field or stochastic process $Z(x)$. It is defined as the expected squared increment of the values between locations x and y (Wackernagel, 2003, *Multivariate Geostatistics: An Introduction with Applications*).

biased toward large values. To reduce the impact on the estimates of total contamination in the 200-UP-1 OU, the kriged estimates were truncated at values of one-half of the contaminant's MCL. Below one-half of the MCL value, contaminant concentrations were set to zero.

Method 2. Three-dimensional plume volumes were generated using three-dimensional software. The software uses radial basis functions (RBFs) to interpolate three-dimensional numerical models using X, Y, Z, and concentration data.[3]

Coordinate, elevation, and concentration data were provided for each COPC (SGW-46971, *200-UP-1 Depth Discrete Contaminant Cross Section Development*). All COPC data were retrieved from HEIS as depth-discrete samples and routine annual groundwater monitoring samples. Data from HEIS were queried for the 200-UP-1 OU monitoring wells from 1990 to 2009. Preference was placed on 2009 data, but where data were absent, the next closest year's data for each well were used. Three-dimensional plume volumes were produced at one-half the MCL, the MCL, 10 times the MCL, and 100 times the MCL thresholds for each COPC using the LeapFrog Hydro™ software. The plume models provided a method for visualizing concentration data in three dimensions, with each volume enclosing concentrations greater than or equal to its threshold or "contour" value. Concentration data were transformed into initial contaminant distributions by using the maximum concentration of the three-dimensional plume within each model cell. Below one-half the MCL value, contaminant concentrations were set to zero. The three-dimensional plume volumes were truncated at the upper surface of the Ringold lower mud unit (HSU 8) to reflect hydrologic interpretation that contamination has not migrated into this HSU. The Ringold lower mud unit (HSU 8) is a very low permeability unit (functioning essentially as an aquitard) from which it is difficult to extract water; hence, groundwater samples are unavailable to confirm this interpretation. Numerical simulations that begin with the contaminant mass adjacent to the lower mud unit HSU do not indicate appreciable migration of contaminant mass into the mud, lending further credence to this interpretation.

Initial contaminant distributions were combined with the groundwater flow solution from the modified MODFLOW program, along with porosity and the transport parameters described earlier in this section, to form the fate and transport model for the 200-UP-1 OU. The MT3DMS software was used to solve the groundwater advection-dispersion equations for the identified COPCs, to predict how the initial contamination in the 200-UP-1 OU may move during operation of the 200 West P&T system and up to 1,000 years in the future. It is important to understand that model simulations did not include source contributions for COPCs from the vadose zone soil column, located above the groundwater plumes. The OUs where these source conditions reside will be addressed within the CERCLA process by each specific OU.

5.2 Groundwater Impacts

Historical releases of liquid wastes within the Hanford Central Plateau area have affected groundwater, altering the flow system and creating contaminant plumes of varying sizes and concentrations. The fate and transport simulation techniques described in Section 5.1 were applied to the known groundwater plumes to create an estimate of future plume migration and concentration trends. The future impact evaluation assesses changes in the location and concentration of groundwater contaminants resulting from migration and attenuation.

Section 5.2.1 presents the results of fate and transport analysis for the 200-UP-1 portion of the Central Plateau. Section 5.2.2 presents a discussion of uncertainties in the estimates of future conditions.

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[3] A radial basis function is a real-valued function whose value depends only on the distance from the origin.

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5.2.1 Simulation of Flow

An overview of the flow solution is presented in this section. Figure 5-6 displays the initial (present day) hydraulic head (groundwater elevation) distribution used as the initial condition in the model. The outline of the model domain is shown with a dark band. The grey areas just inside the boundary are regions not actively used in the model, where basalt sub-crops above the water table. Small regions in the northern part of the model, between the domain boundary and the fixed hydraulic head boundaries of the model, are included.

The model interior is shown in white, black, and grey. White indicates regions where at least one layer in the model is partially saturated. Black is used for regions of the model domain where all the layers are unsaturated (above the water table) during the transport simulations. Black regions had saturated layers during the peak water table elevations during the historical period used for model calibration. Grey is used to depict small regions where the water table never rises above the basalt, even during the calibration period. Roads of the Central Plateau are also shown in grey. Within the model domain, red lines indicate boundaries of the active model that are open to flow. Contour lines with a 1 m (3 ft) interval for the simulated water table are shown in blue.

Prominent features of the head distribution are the relatively flat gradients in most of the 200-PO-1 OU, especially under the 200 East Area. In the northeastern portion of the 200-PO-1 OU, the gradients dip steeply to the northeast. These steep gradients indicate flow blockage caused by the Ringold lower mud unit (HSU 8) in this region. The extensive black regions in the northern portion of the model reveal that the connection of the 200 East Area to the northern flow boundary (Gable Gap) has been nearly severed by the water table's drop below the basalt surface. Thus, flow from the northern edge of the western portion of the model domain is simulated to move southeast rather than north, as was true in the past.

In and west of the 200 West Area, the gradient is mostly slightly north of east. The steeper gradient is caused by the much lower hydraulic conductivity of Ringold unit A (HSU 9) and Ringold unit E (HSU 5) compared to the Hanford (HSU 1) and the Cold Creek (HSU 3) HSUs.

Near the western gap, the influence of a small patch of saturated Hanford formation is causing the gradient to flatten next to the gap. Divergence of fluxes from the Cold Creek stream and the much smaller Dry Creek are clearly evident along the western boundary of the domain. The extreme northeastern corner of the model shows residual high heads because of the very low conductivity Ringold lower mud unit (HSU 8). The same phenomenon is causing elevated heads in the western portion of the model, just at the southern edge.

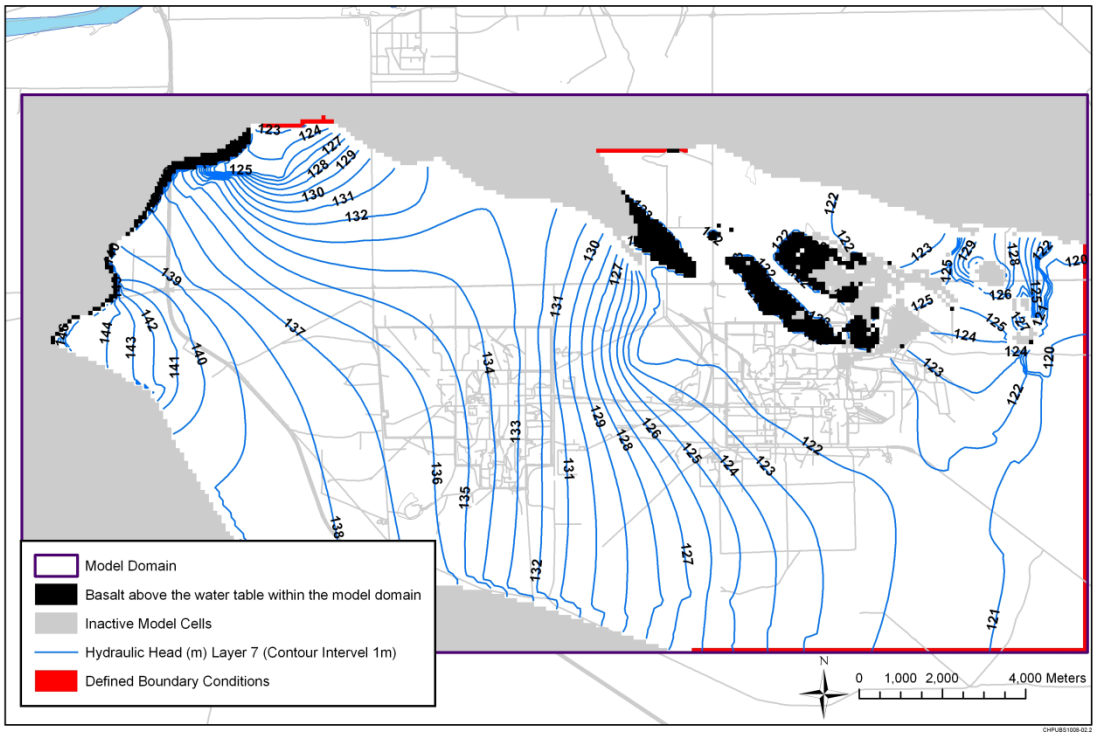
During the 200 West P&T operation, 25 years into the simulation (Figure 5-7), the pumping and extraction wells form prominent features in the hydraulic head distribution in the 200 West Area. Outside the 200 West P&T operation, a slight decline in the water table is noticeable. The model predicts the water table in the 200 East Area will drop below the top of basalt surface to the north, signifying a reduced flow path to the north through Gable Gap (Figure 5-7). After another 50 years (Figure 5-8), the predicted flow has completely recovered from the 200 West P&T operation. The basic pattern has the same shape as the initial condition, but the gradients in the western portion of the domain are slightly less steep. Figure 5-9 shows that the simulated water table in the 200 West Area has changed little from year 75 to year 125 of the simulation. At year 125, the Central Plateau aquifer simulation has almost entirely recovered from the water table built from the 200 West P&T operational period.

5.2.2 Simulation of Contaminant Migration

Fate and transport simulations were performed to prepare estimates of future groundwater contaminant concentrations within the unconfined aquifer in the 200-UP-1 OU. These simulations were performed using the numerical model implemented with MT3DMS. The following COPCs were simulated:

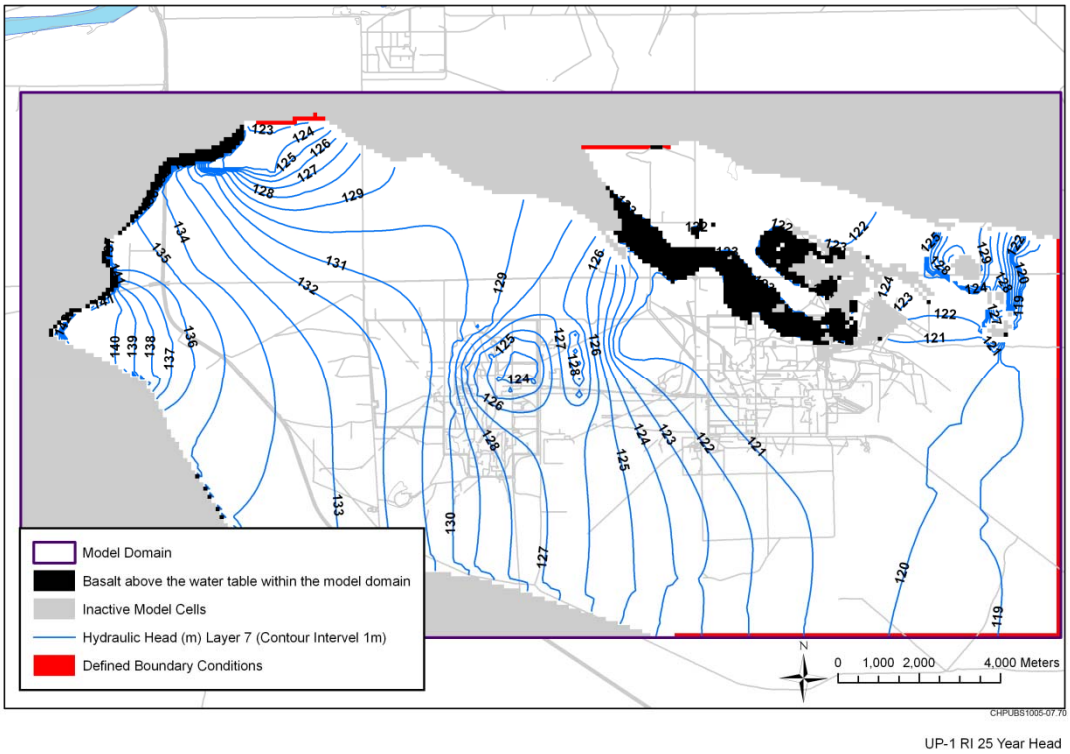
- Tritium
- Nitrate
- I-129
- TCE
- PCE
- Tc-99
- Sr-90
- Uranium
- Chromium (total and hexavalent)
- Fluoride
- Chloroform

Carbon tetrachloride was modeled in the 200-ZP-1 FS and was not remodeled for this 200-UP-1 RI/FS. The carbon tetrachloride in 200-UP-1 will be addressed in the alternatives presented in Chapter 9 of this report. The 200-UP-1 contributes to the overall carbon tetrachloride removal process.



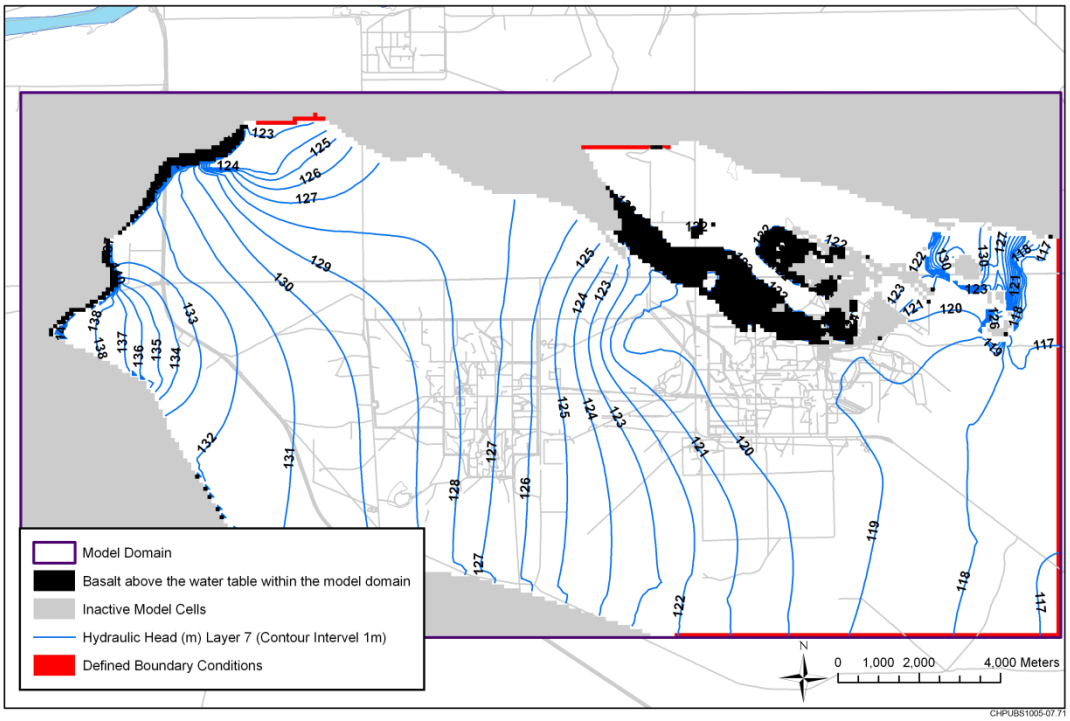
UP-1 RI Initial Condition Head

Figure 5-6. Initial Hydraulic Head Distribution (2009)



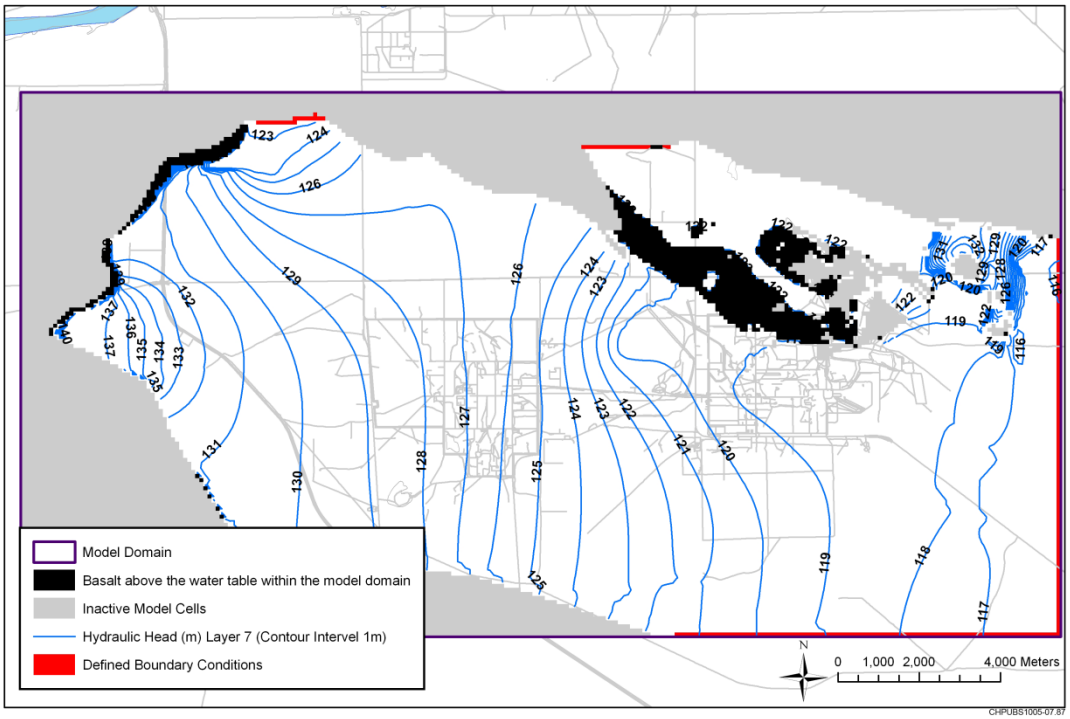
UP-1 RI 25 Year Head

Figure 5-7. Hydraulic Head Distribution for 2034



UP-1 RI 75 Year Head

Figure 5-8. Hydraulic Head Distribution for 2084



UP-1 RI 125 Year Head

Figure 5-9. Hydraulic Head Distribution for 2134

The estimated COPC concentrations in groundwater were developed at the initial condition. Predicted concentration values have been recorded at selected future time steps in the simulations. The plume maps at selected time steps are presented for each COPC, to provide a basis for comparison of future impacts on groundwater under conditions where no active groundwater remedial action is applied. The figures that display simulations of contaminant distributions over time (Figures 5-10 to 5-44) use the same color scheme. Green is used to display concentrations between one-half the MCL and the MCL. Pink is used to display concentrations between the MCL and 10 times the MCL. Purple is used to display from 10 times the MCL to 100 times the MCL. The concentration range, therefore, depends on the contaminant displayed in the figure, and the concentration range is reported in each figure's legend. Fluoride and chloroform displays are not presented because the areas of contamination from these COPCs in the 200-UP-1 OU are too small. The area of future Sr-90 contamination is also small, but the initial concentration for Sr-90 is shown for information purposes.

5.2.2.1 Tritium

Figure 5-10 presents the estimated current/initial tritium distribution. A very large plume of tritium in the 200-UP-1 OU above the MCL is shown, with a large region above 10 times the MCL. Figure 5-11 displays the simulated plume after 50 years (year 2059) of transport and decay, where it is below the MCL. This reduction results from the 12.3-year half-life of radioactive decay of tritium, although the influence of the 200 West P&T system is also significant.

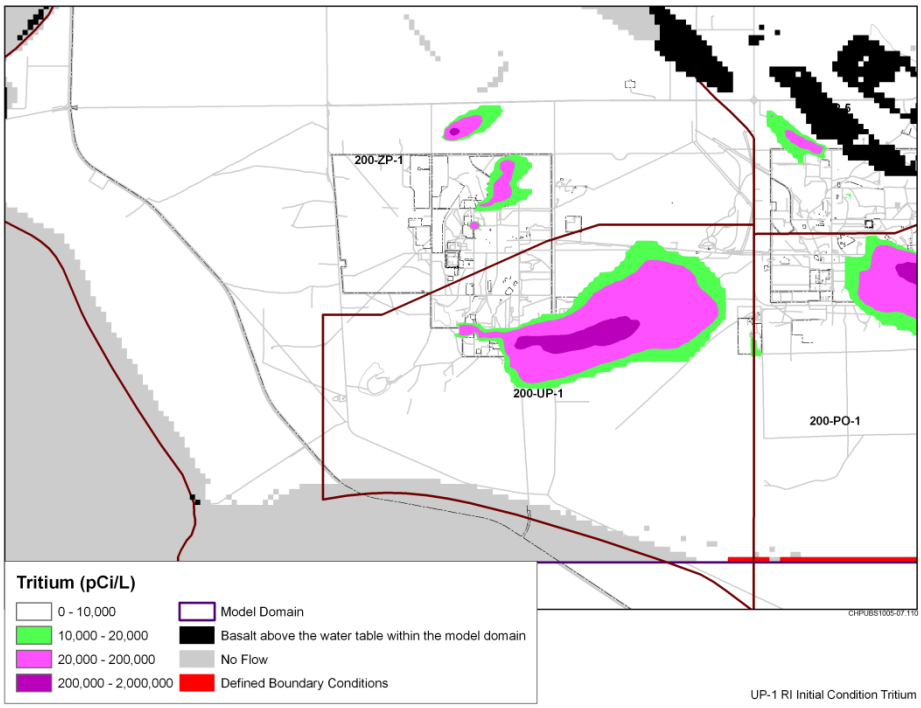


Figure 5-10. Initial Tritium Distribution

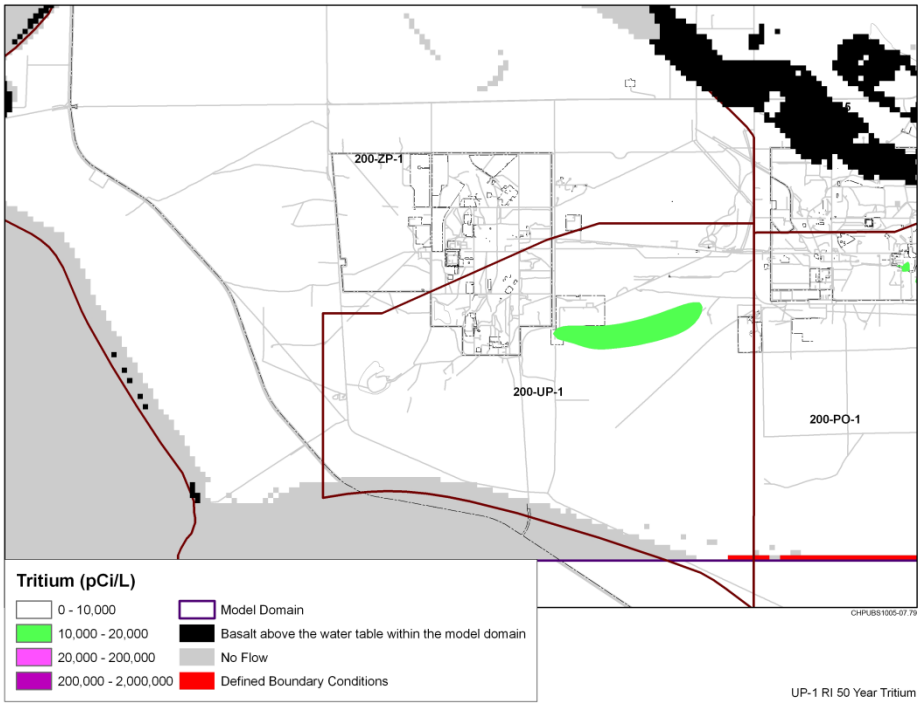


Figure 5-11. Tritium Distribution after 50 years (2059)

5.2.2.2 Nitrate

Within the 200-UP-1 OU, nitrate exists above the MCL in a vast area in and east of the 200 West Area and in smaller plumes within the 200 West Area as shown on Figure 5-12. The nitrate plume comingles with the tritium plume but is centered closer to the 200-ZP-1 OU and significantly larger. The blunt eastern edge of the plume is caused by the intersection of the water table with the Ringold lower mud unit (HSU 8), essentially blocking flow to the northeast at this location. Figure 5-13 indicates that 25 years of 200 West P&T operation will have a dramatic influence on the distribution of nitrate in the 200 West Area and in the northern edge of the 200-UP-1 OU. The simulated plume has begun to migrate around the southern limit of the intersection of the water table and the Ringold lower mud unit (HSU 8). Also, the plume has entered the highly conductive coarse-grained Hanford formation HSU in the 200-PO-1 OU, where it moves more rapidly and gets dispersed below one-half the MCL. The western edge of the plume has been pulled into the 200-ZP-1 OU.

The plume migrates eastward after 75 years of 200 West P&T operation and subsequent recovery of the unconfined aquifer flow system, as shown on Figure 5-14 (year 2084). After 125 years, in year 2134 (Figure 5-15), the plume has continued to move eastward into the Hanford formation. Some northern movement along the intersection of the water table and lower mud unit is also evident. The simulation shown on Figure 5-16 indicates continued northeastern and southeastern movement of the nitrate plume, dropping below the MCL everywhere by year 2184, but remaining above one-half the MCL for about 300 years, in year 2309 (Figure 5-17).

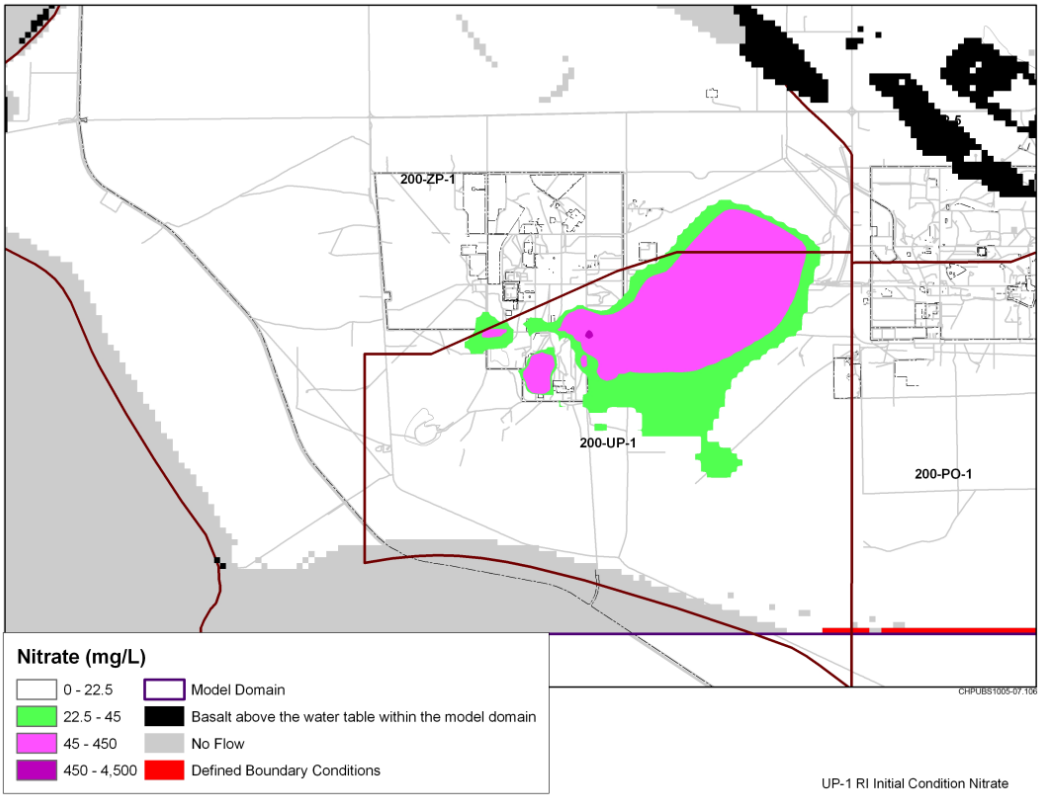


Figure 5-12. Initial Distribution of Nitrate (2009)

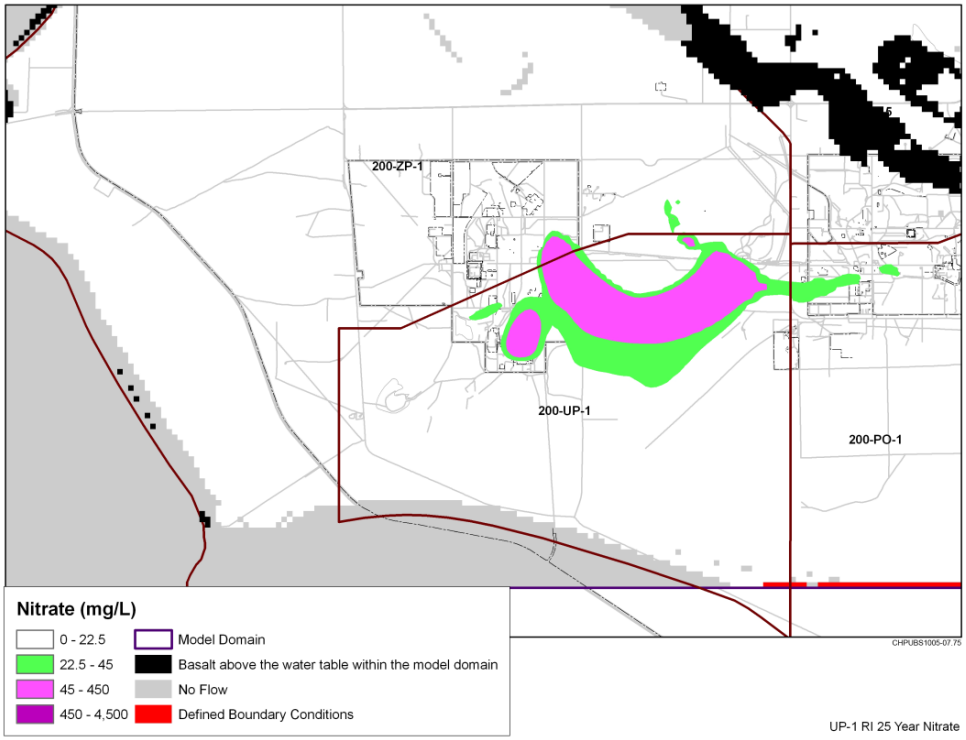


Figure 5-13. Distribution of Nitrate after 25 Years (2034)

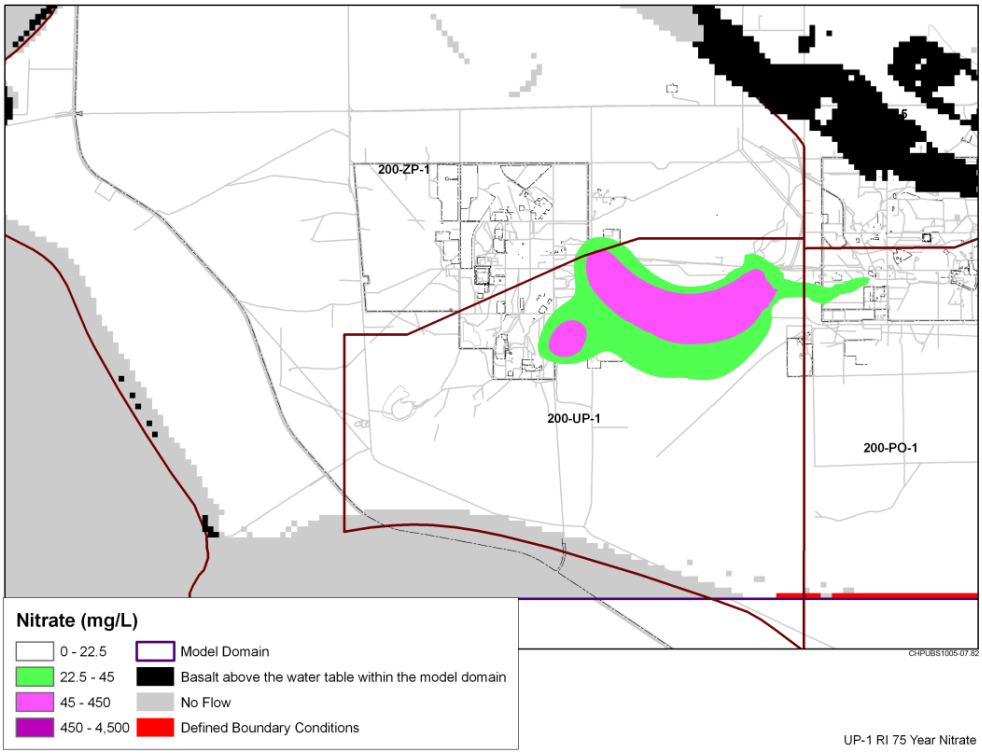


Figure 5-14. Distribution of Nitrate after 75 Years (2084)

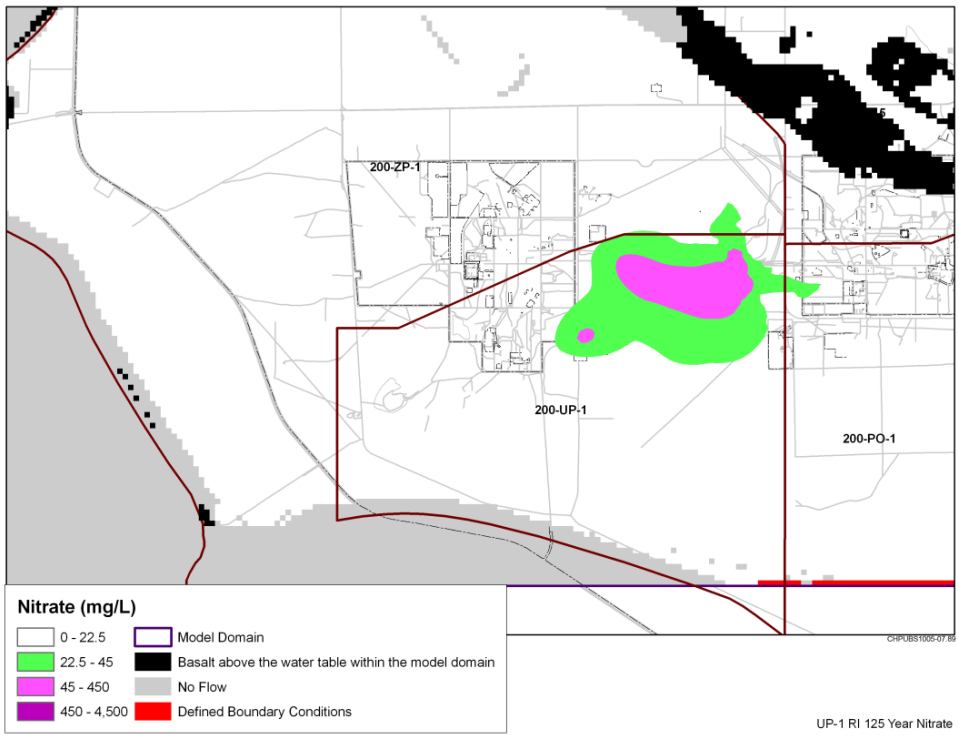


Figure 5-15. Distribution of Nitrate after 125 Years (2134)

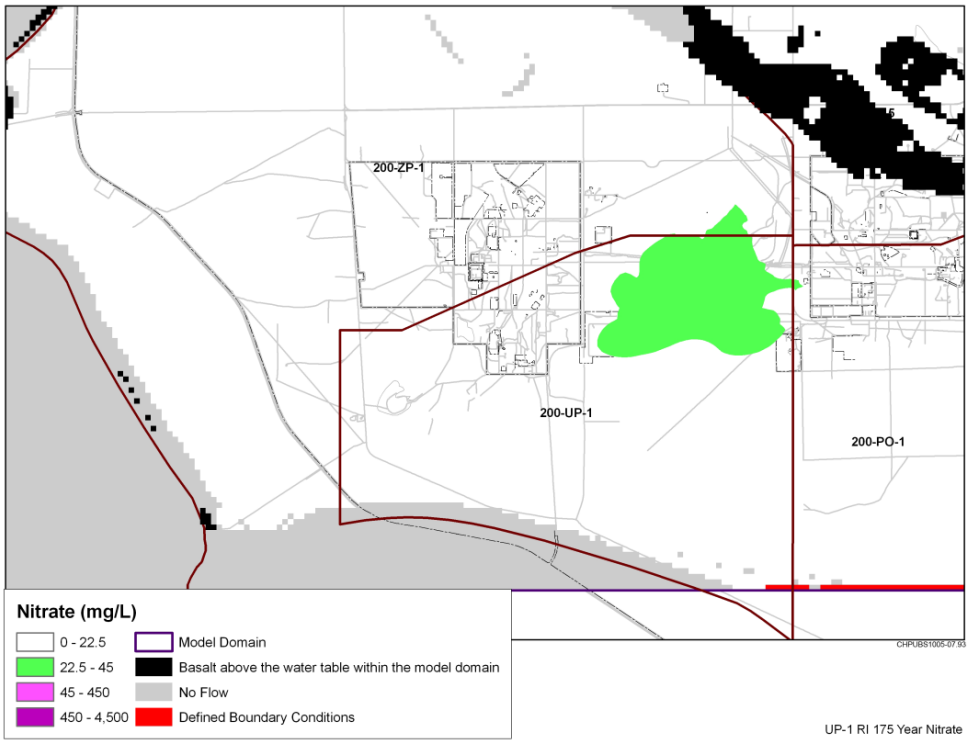


Figure 5-16. Distribution of Nitrate after 175 Years (2184)

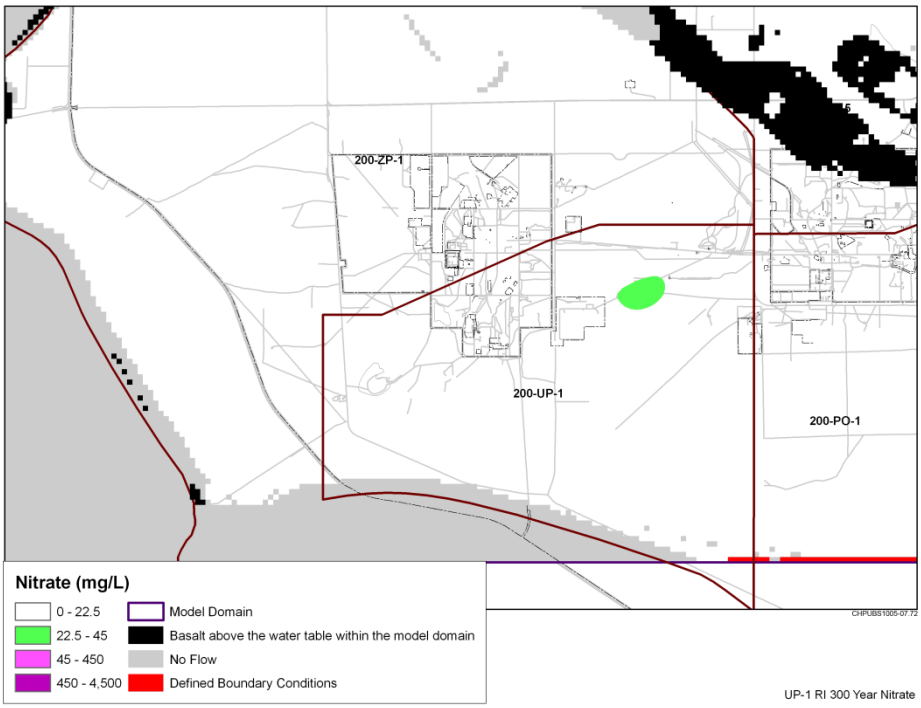


Figure 5-17. Distribution of Nitrate after 300 Years (2309)

5.2.2.3 Iodine-129

Figure 5-18 displays the initial iodine concentrations for the simulation. Iodine forms a large plume above the MCL in the 200-UP-1 OU, comingling with the tritium and nitrate plumes, but centered slightly south of the tritium plume. A large portion of the plume is above 10 times the MCL. The bulk of the plume is far enough south that the 200 West P&T operation is predicted to have only a small influence on most of the plume. As shown on Figure 5-19 (25 years, year 2034), the northwestern portion of the plume has been pulled north, and the eastern edge has been pushed southeast by 200 West P&T operations. By 2084, after 75 years (Figure 5-20), the groundwater flow has transported the plume's leading edge farther east so that it is close to the Hanford formation HSU 1 portion of the aquifer. After 125 years, in year 2134 (Figure 5-21), the eastern edge of the simulated plume is near the Hanford formation channel at concentrations above the MCL, with concentrations above 10 times the MCL in the 200-UP-1 OU. After 175 years, in year 2184 (Figure 5-22), the simulation still indicates a region of concentrations above 10 times the MCL and further expansion into the Hanford formation. The eastern edge of the iodine plume is predicted to move into the Hanford formation channel and the 200-PO-1 OU at concentrations above the MCL by year 2184. By year 2309 (Figure 5-23), the plume exceeds the MCL in a large portion of the 200-UP-1 and 200-PO-1 OUs. The simulation shows this plume moving north of a residual body of un-eroded Ringold unit E (HSU 5). As shown on Figure 5-24 (500 years, year 2509), extensive concentrations in the 200-UP-1 OU persist and have moved east. The simulated concentrations above the MCL have nearly surrounded the patch of Ringold unit E (HSU 5) with concentrations above one-half the MCL, entering the southwestern high conductivity channel. Figure 5-25 displays the plume after 1,000 years of transport. Concentrations in the patch of Ringold unit E (HSU 5) are above the MCL, but the concentrations surrounding this patch are reduced below one-half the MCL before entering the southwestern high conductivity channel.

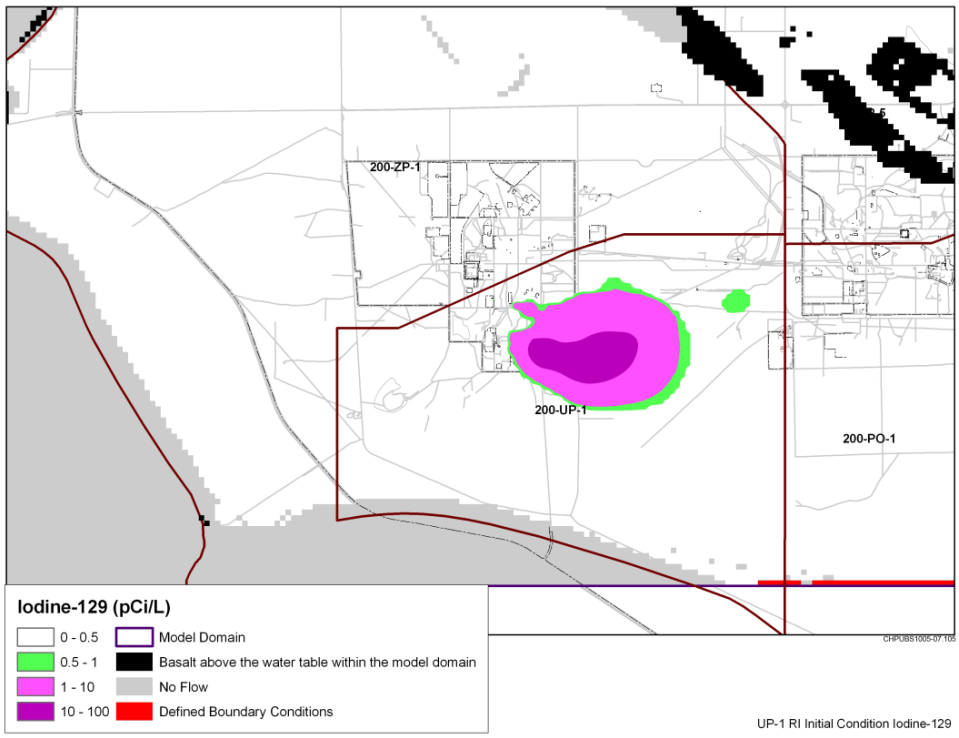


Figure 5-18. Initial Distribution of Iodine-129 (2009)

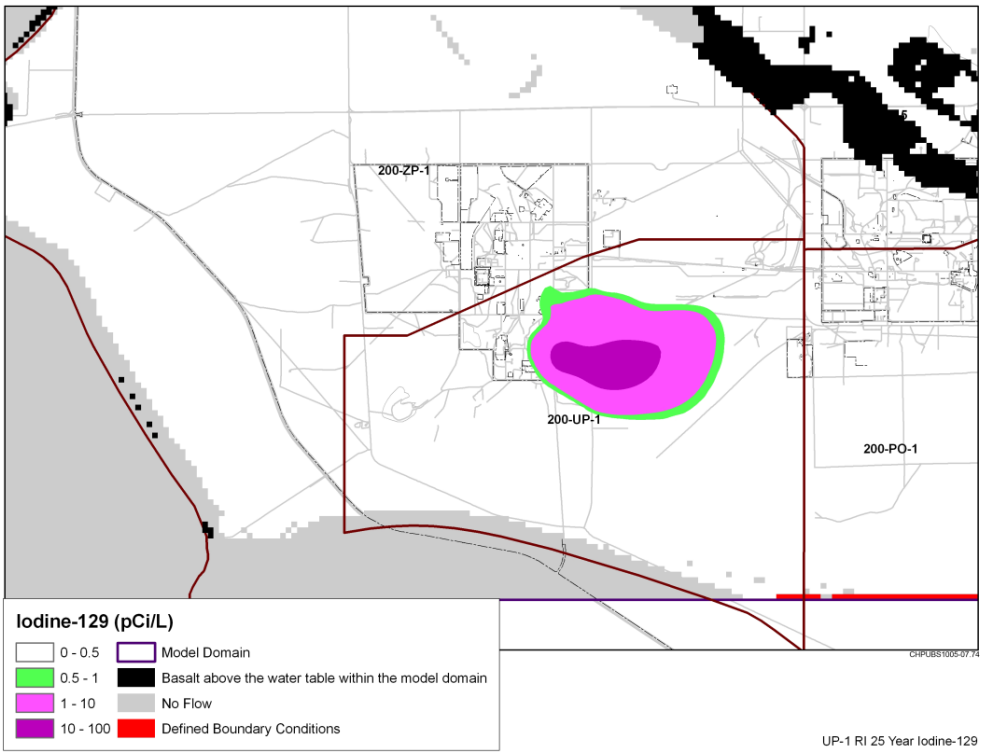


Figure 5-19. Distribution of Iodine-129 after 25 Years (2034)

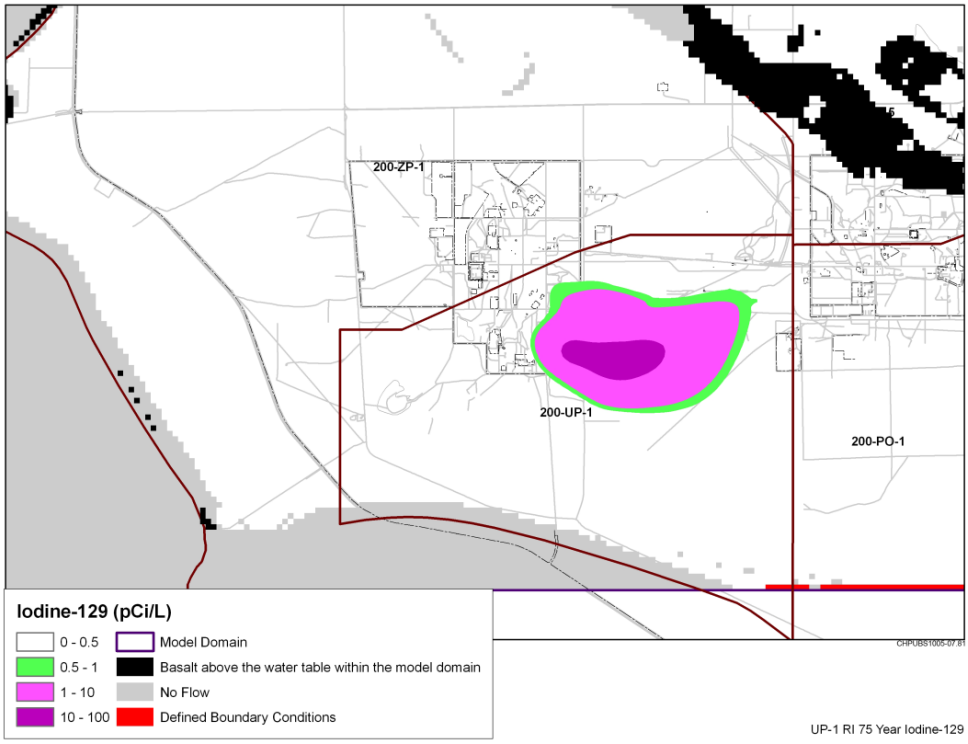


Figure 5-20. Distribution of Iodine-129 after 75 Years (2084)

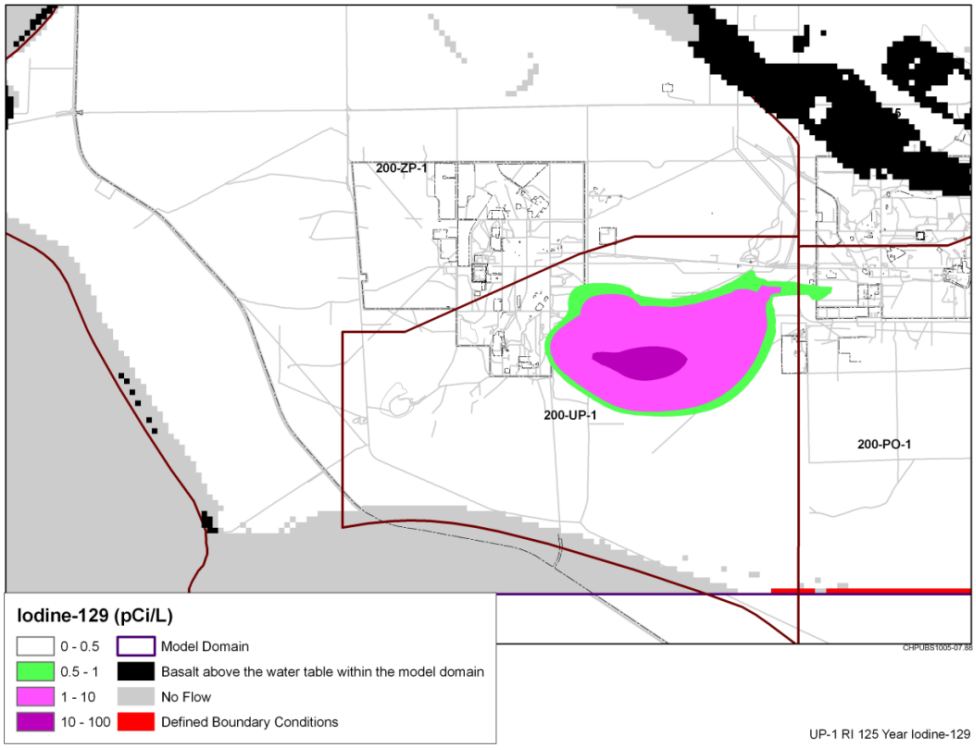


Figure 5-21. Distribution of Iodine-129 after 125 Years (2134)

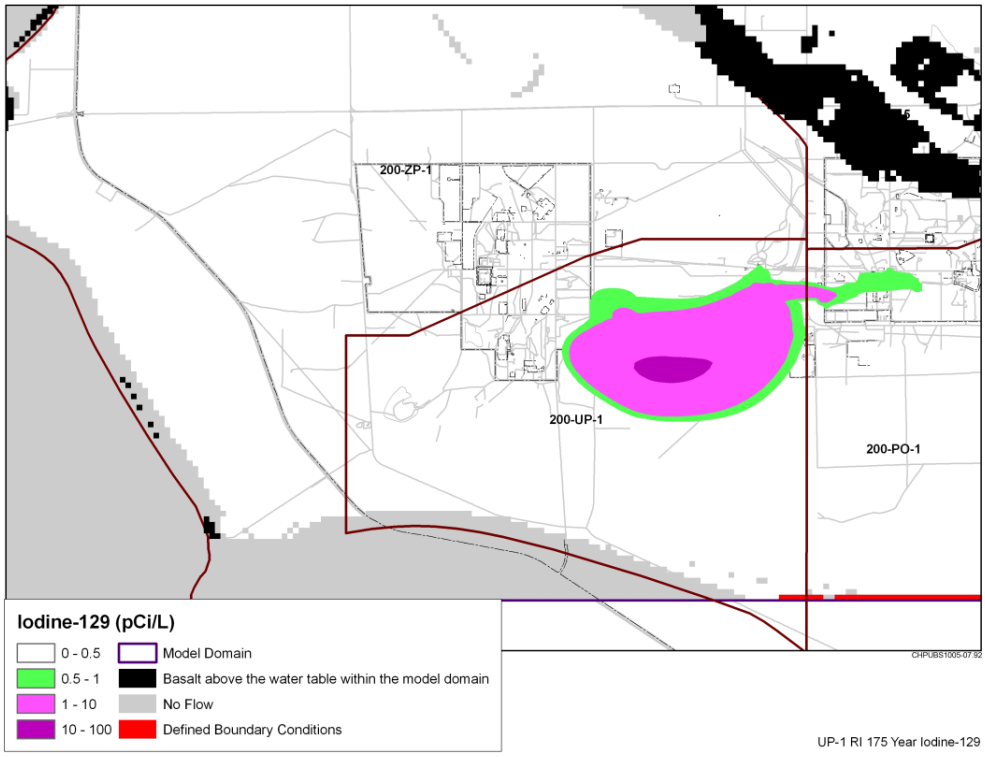


Figure 5-22. Distribution of Iodine-129 after 175 Years (2184)

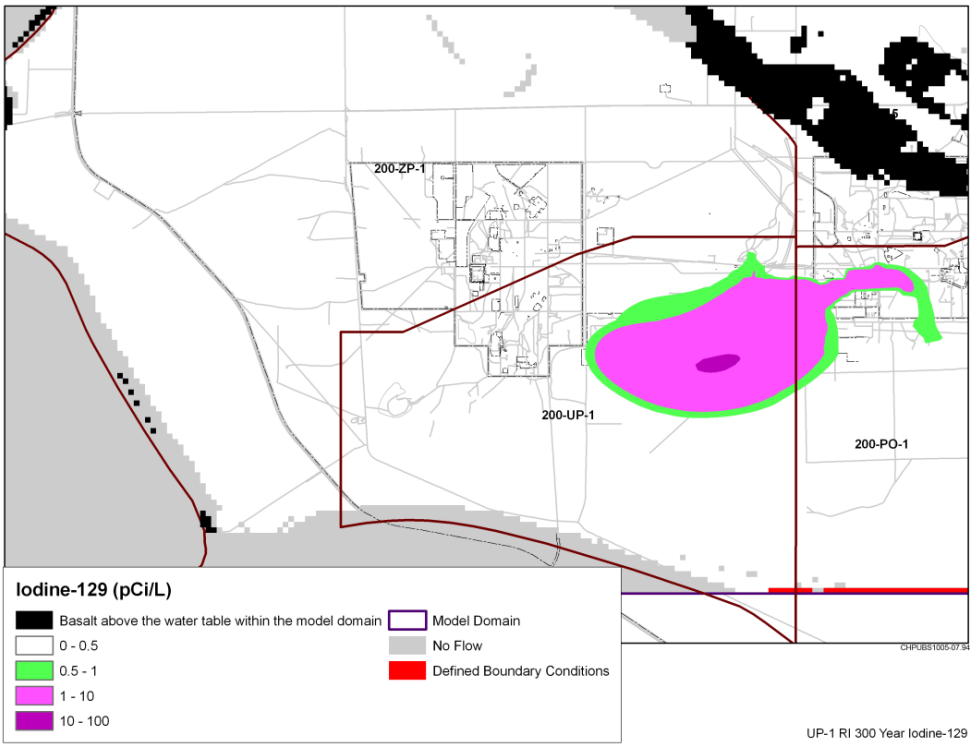


Figure 5-23. Distribution of Iodine-129 after 300 Years (2309)

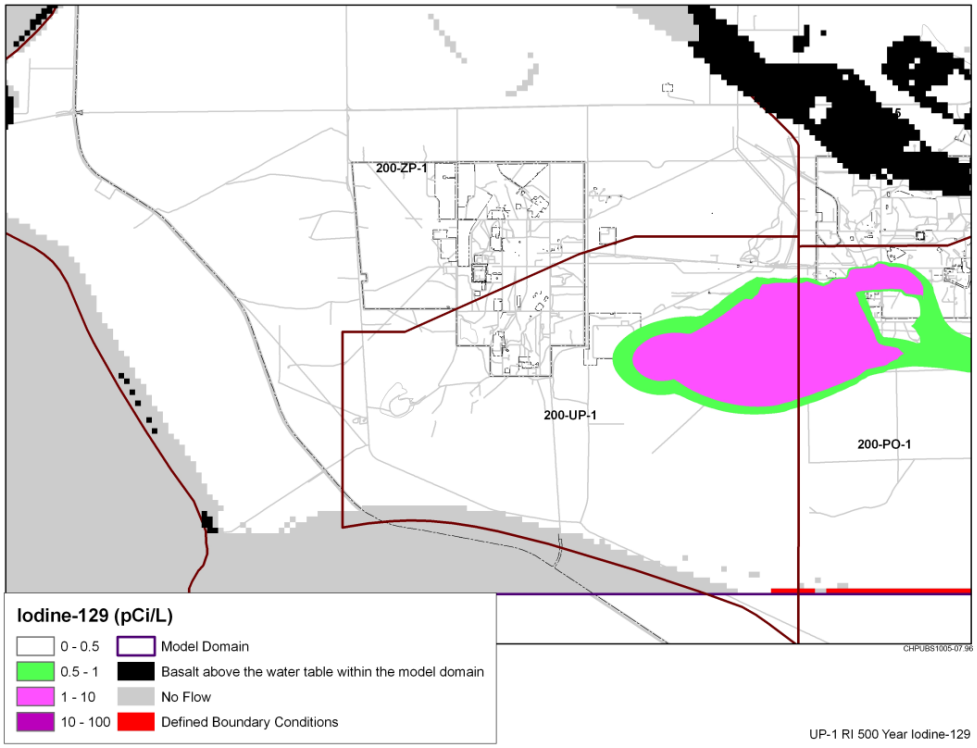


Figure 5-24. Distribution of Iodine-129 after 500 Years (2509)

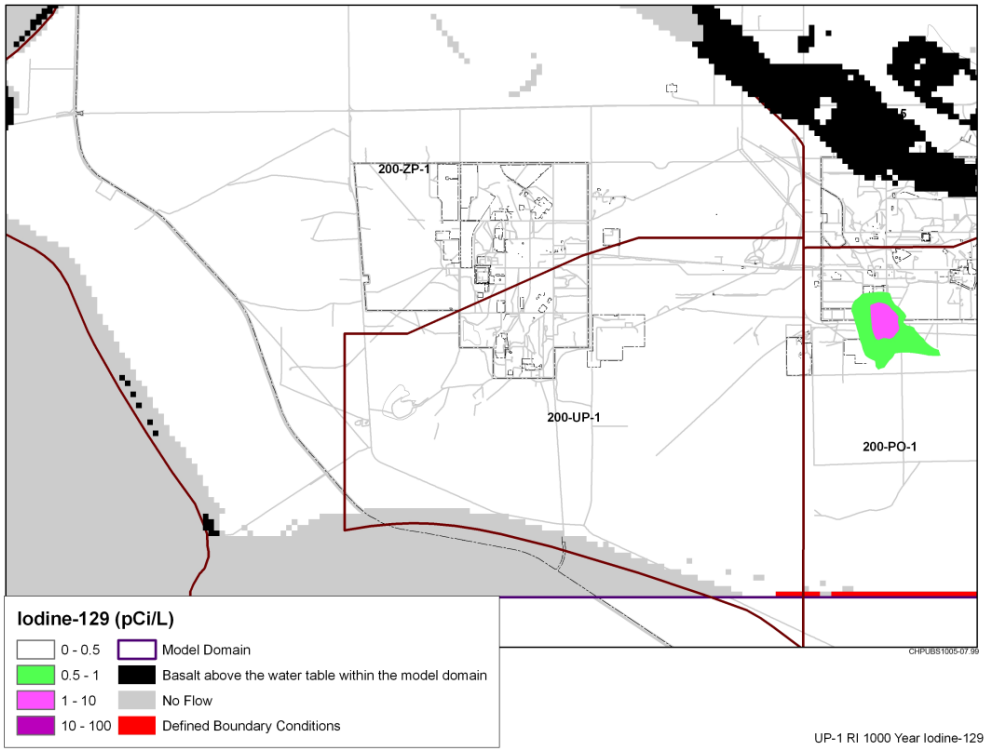


Figure 5-25. Distribution of Iodine-129 after 1,000 Years (3009)

5.2.2.4 Trichloroethene

TCE contamination (Figure 5-26) within the 200-UP-1 OU is at depth under 21-W-LWC (near the 200-UP-1/200-ZP-1 boundary) and under UPR-600-20 (just south of the boundary). These plumes do not contain concentrations near the MCL at the water table, but the plumes have been conservatively introduced into the simulation throughout the Ringold unit E (HSU 5). The plumes are in a region that lies within the 200 West P&T system capture zone, and therefore, they show a significant reduction in concentrations to below the MCL after 25 years of operation (Figure 5-27, year 2034). Within 50 years (no figure presented), the maximum TCE concentration in 200-UP-1 OU is estimated to be less than one-half the MCL.

5.2.2.5 Technetium-99

Tc-99 exists in groundwater in the 200-UP-1 OU in concentrations above the MCL in a number of small plumes (Figure 5-28). Only the southernmost of these plumes have Tc-99 concentrations above the MCL after 25 years of operation of the 200 West P&T (Figure 5-29). These plumes have moved eastward and merged to form a single plume containing concentrations above one-half the MCL. Figure 5-30 depicts concentrations in 2084 (75 years) and indicates the plume has drifted to the east and no longer has concentrations above the MCL.

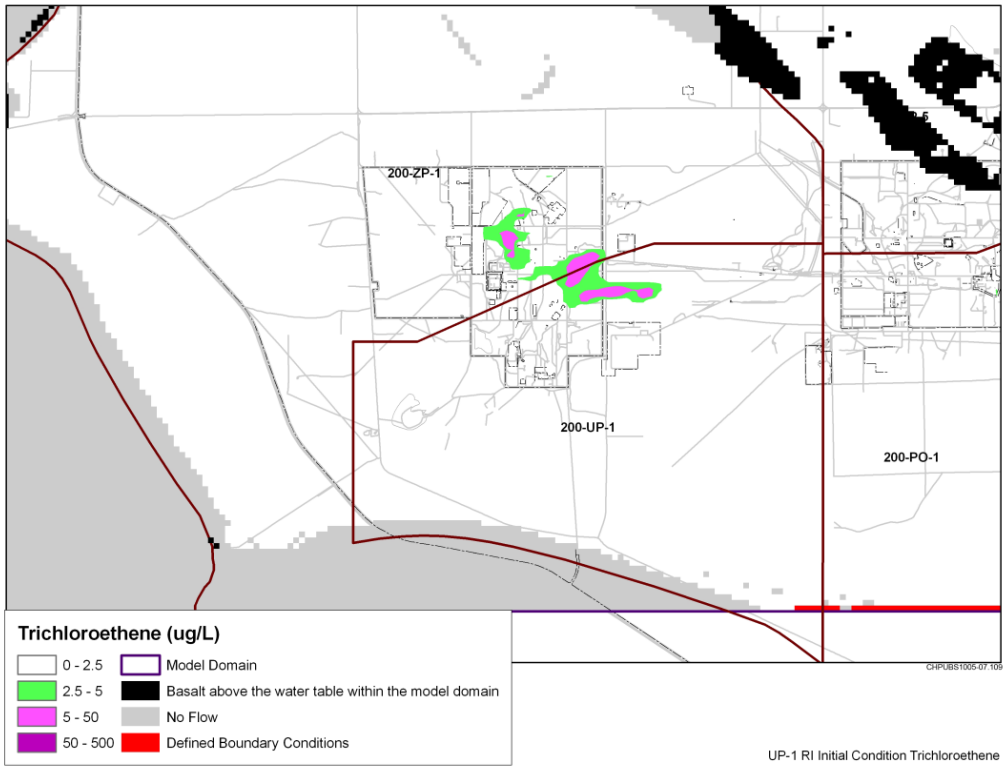


Figure 5-26. Initial Distribution of Trichloroethene (2009)

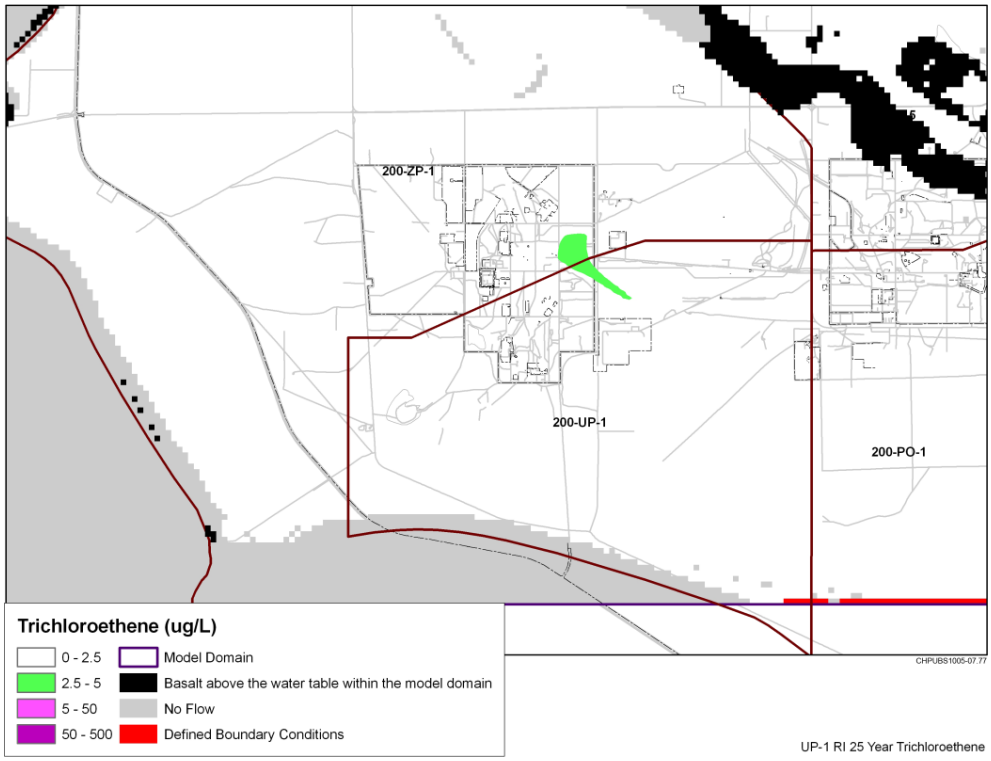


Figure 5-27. Distribution of Trichloroethene after 25 Years (2134)

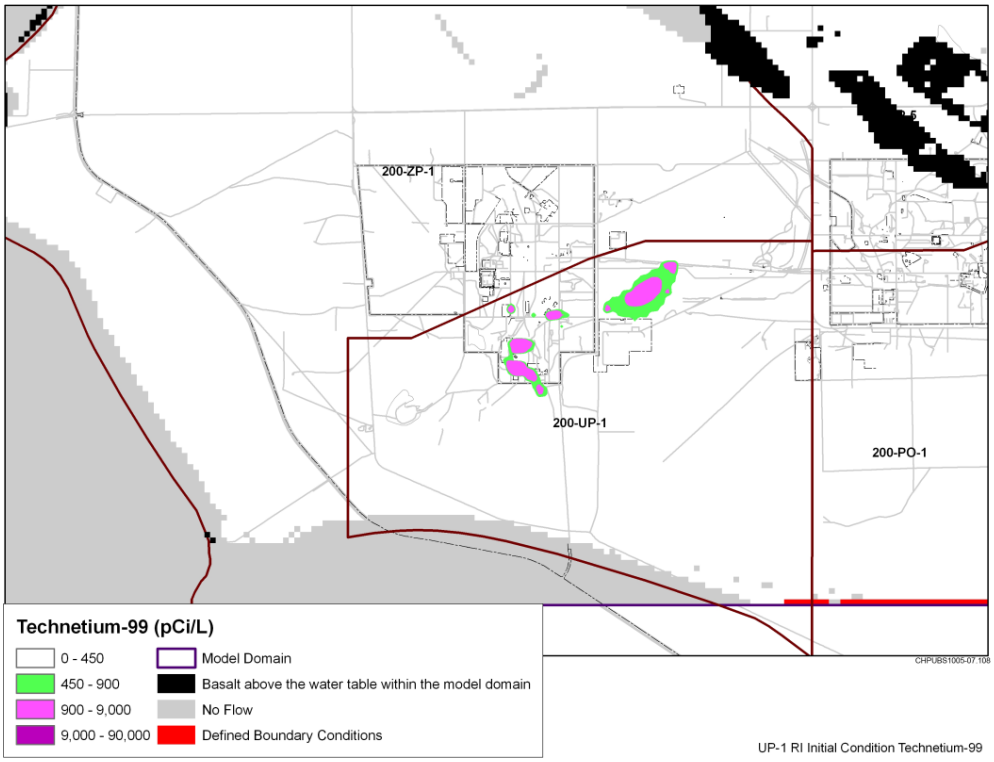


Figure 5-28. Initial Distribution of Technitium-99 (2009)

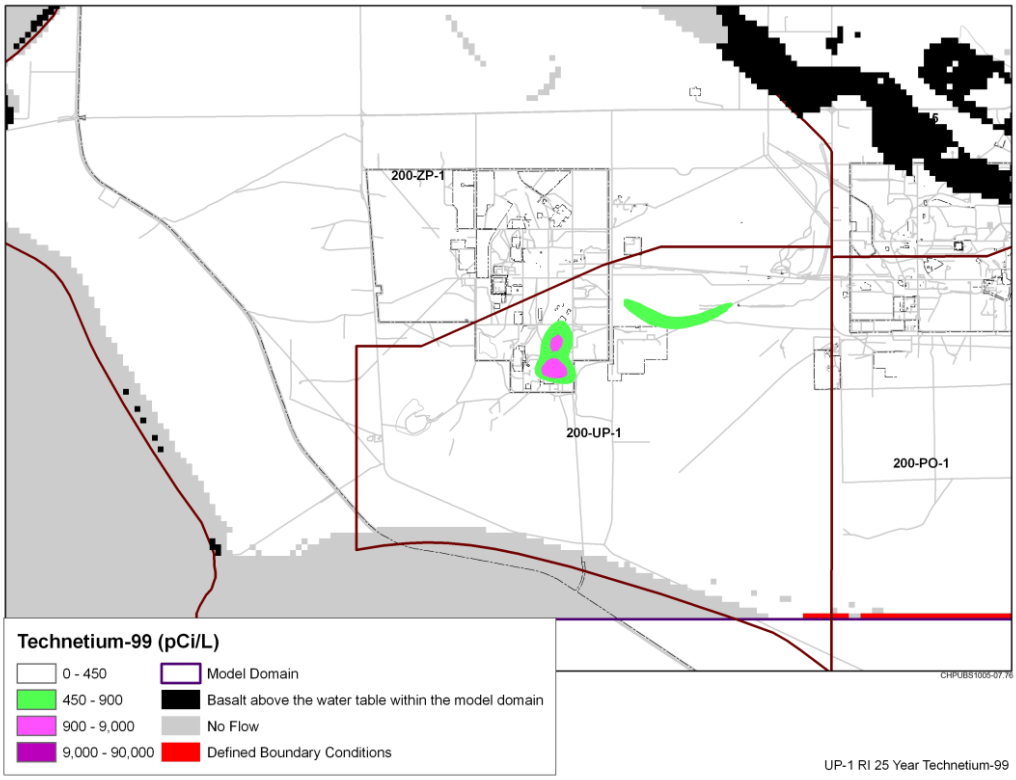


Figure 5-29. Distribution of Technitium-99 after 25 Years (2034)

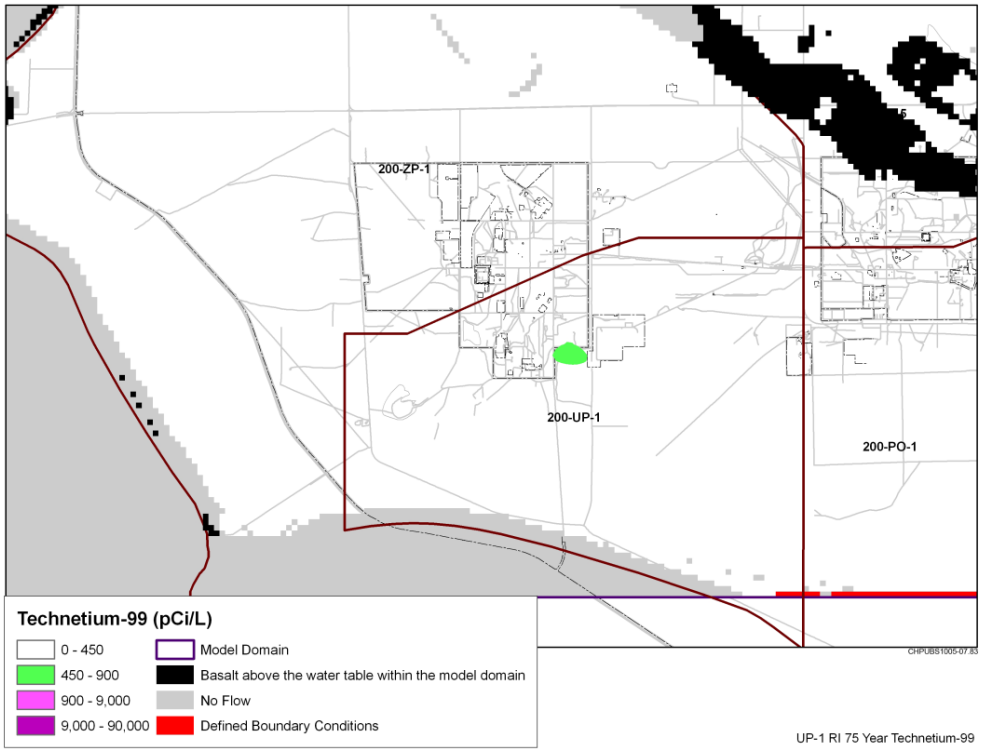


Figure 5-30. Distribution of Technitium-99 after 75 Years (2084)

5.2.2.6 Uranium

Uranium exists in concentrations above the MCL in a large plume below the 241-U-361 and down gradient of the 216-U-1 and U-2 Cribs source areas, where concentrations reach 10 times the MCL (Figure 5-31). A plume below the U Pond area contains uranium concentrations above one-half the MCL to the MCL. Figure 5-32 shows the extent of the uranium plumes after 25 years of 200 West P&T system operation. The northward flux of water toward the 200 West P&T extraction wells has broadened the outline of the plume with concentrations above the MCL to the north. The plume around the U Pond has concentrations reduced to below one-half the MCL.

Figure 5-33 shows the uranium plume (sourced at the 216-U-1 and U-2 cribs) that is currently under 216-U-17 has concentrations reduced in the footprint to10 times the MCL, to a single cell by 2084 (75 years), but the concentrations remain above the MCL with roughly the same footprint. Some movement to the east is evident by year 2134 (125 years, Figure 5-34), but the retardation of uranium transport has limited the eastward movement of the MCL region to a barely discernible amount. By year 2309 (300 years), the scenario is similar—slow eastward movement (Figure 5-35). Figure 5-36 shows the reduction of the MCL footprint, caused by spreading, which is evident 500 years into the simulation. The MCL is not met after 1,000 years of simulation. Figure 5-37 and Figure 5-38 present the 800- and 1,000-year simulation plots, respectively.

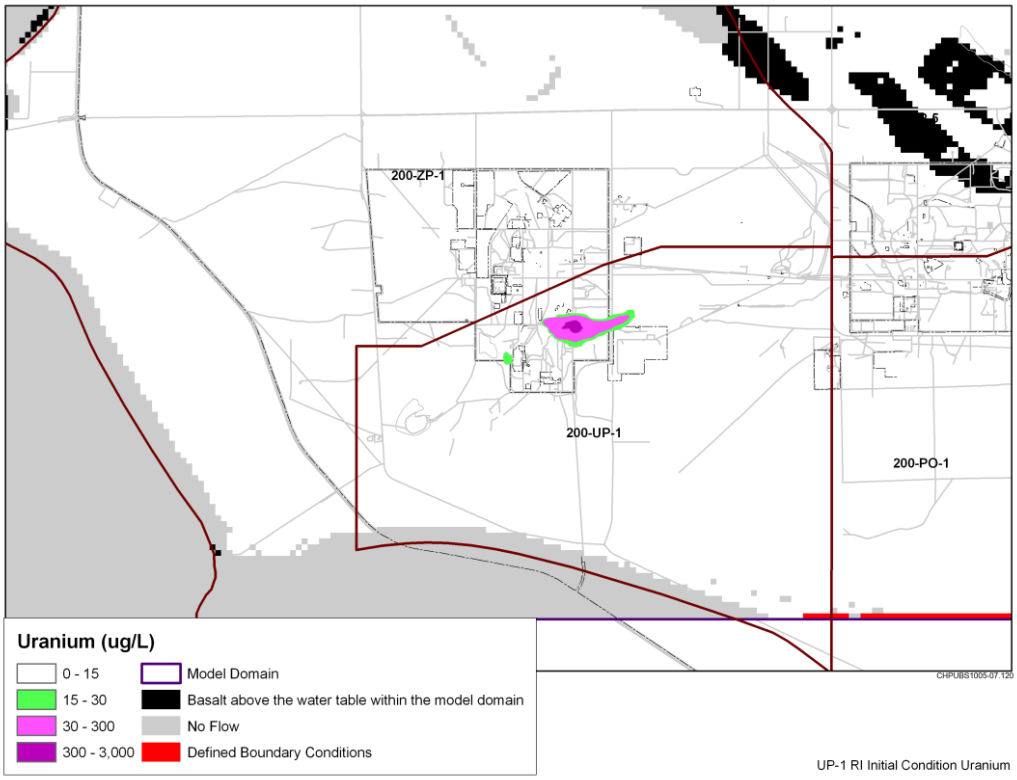


Figure 5-31. Initial Distribution of Uranium (2009)

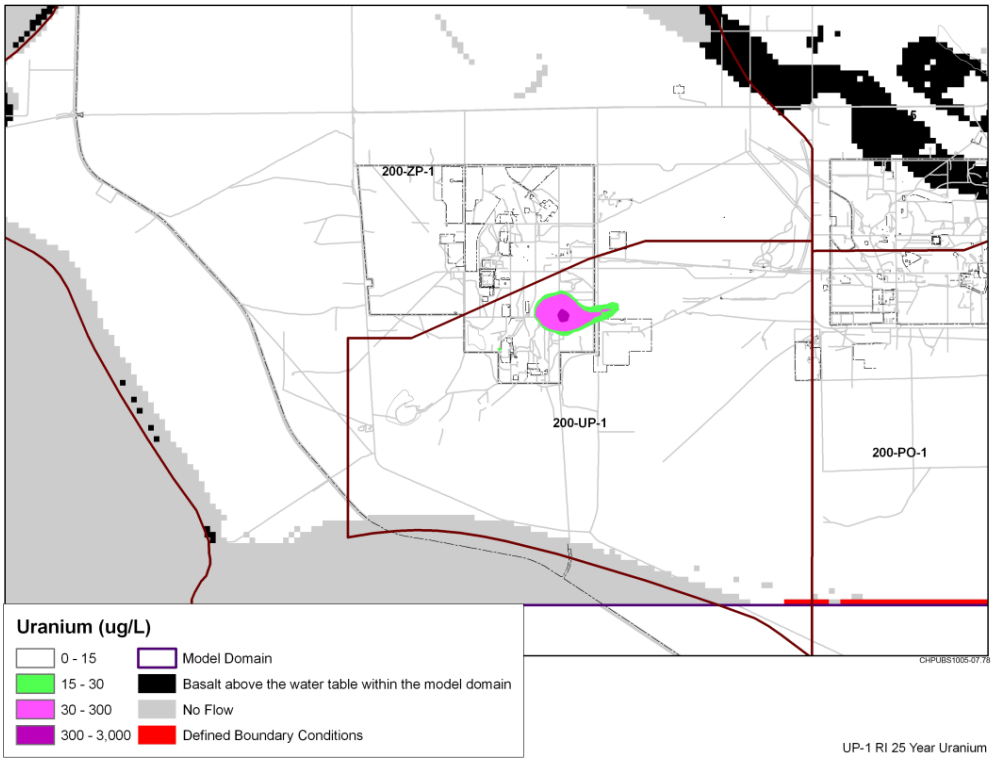


Figure 5-32. Distribution of Uranium after 25 Years (2034)

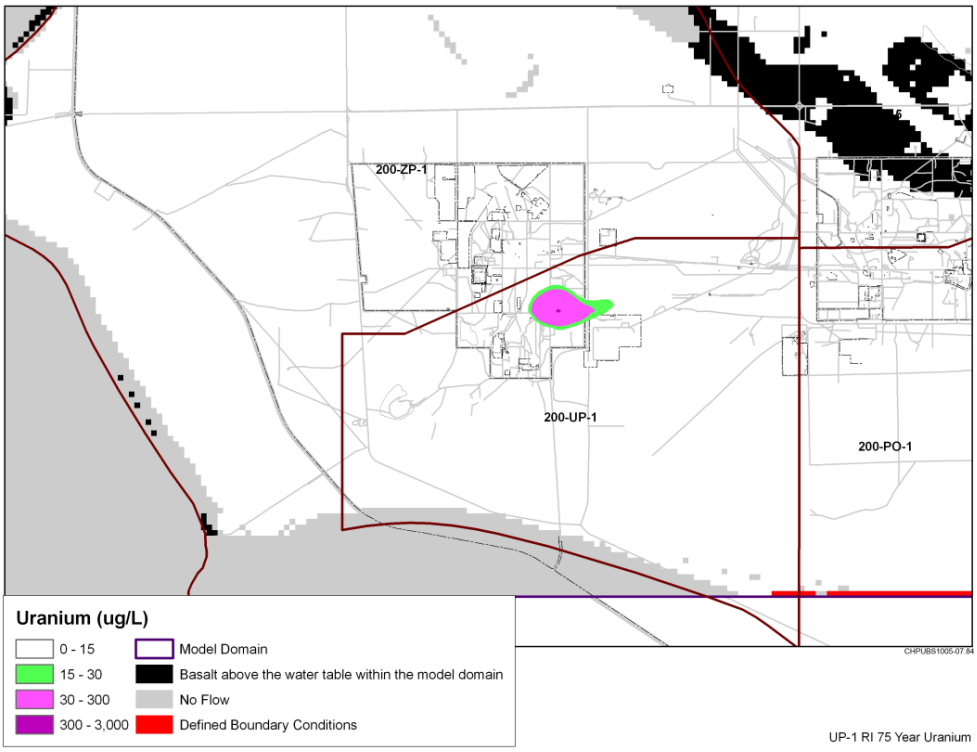


Figure 5-33. Distribution of Uranium after 75 Years (2084)

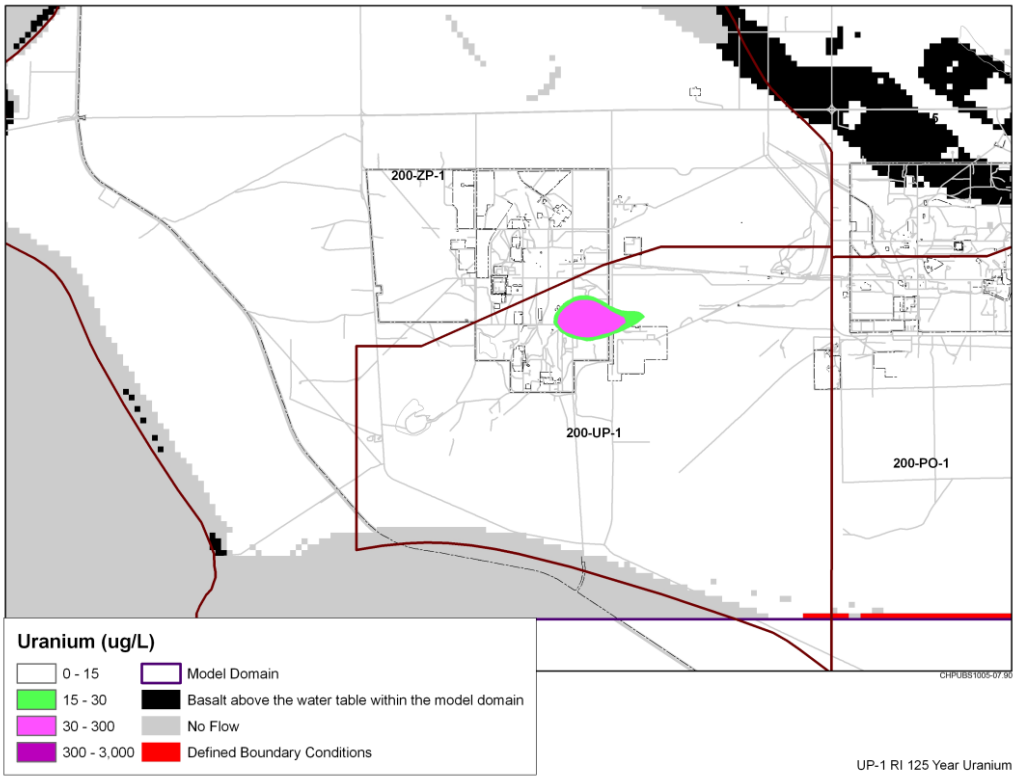


Figure 5-34. Distribution of Uranium after 125 Years (2134)

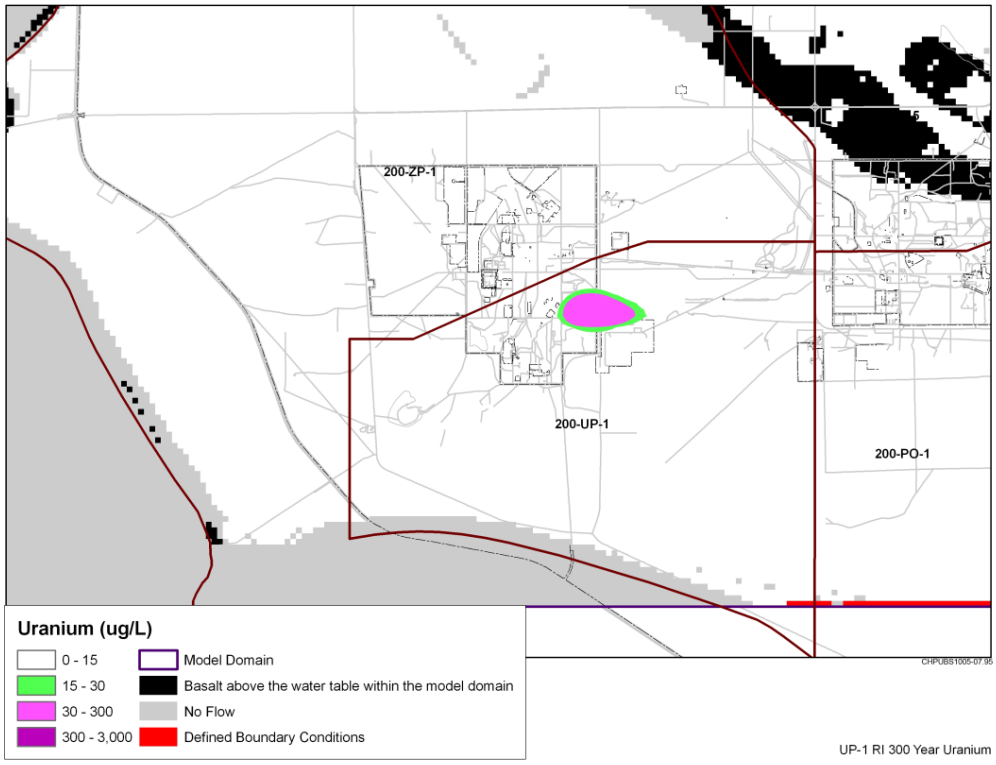


Figure 5-35. Distribution of Uranium after 300 Years (2309)

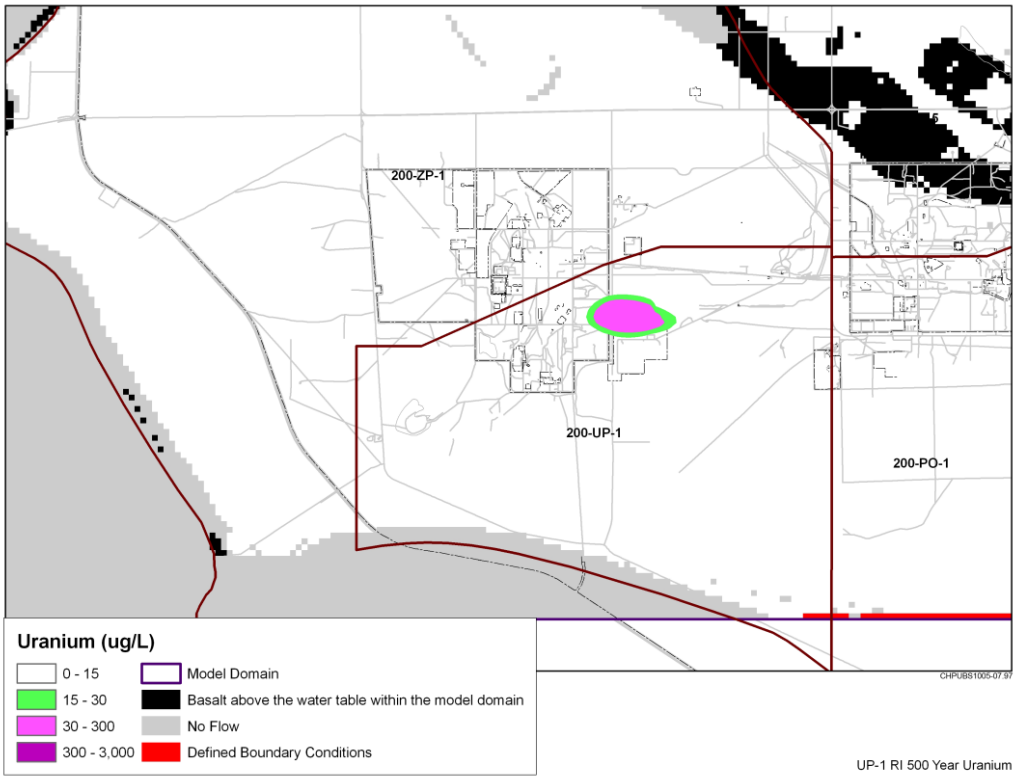


Figure 5-36. Distribution of Uranium after 500 Years (2509)

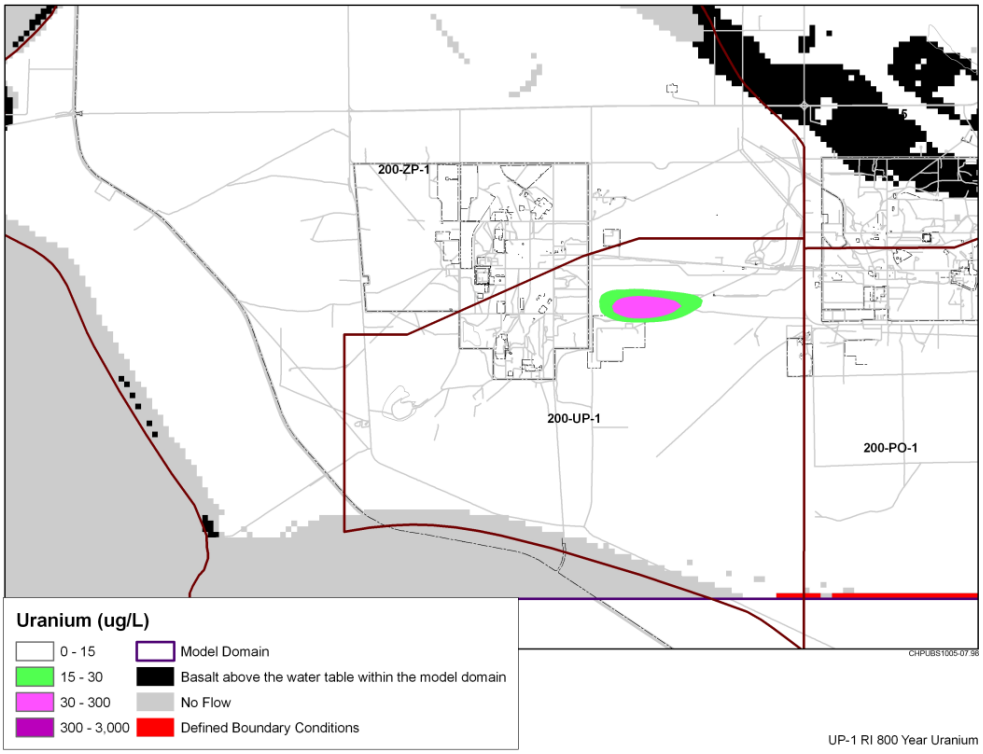


Figure 5-37. Distribution of Uranium after 800 Years (2809)

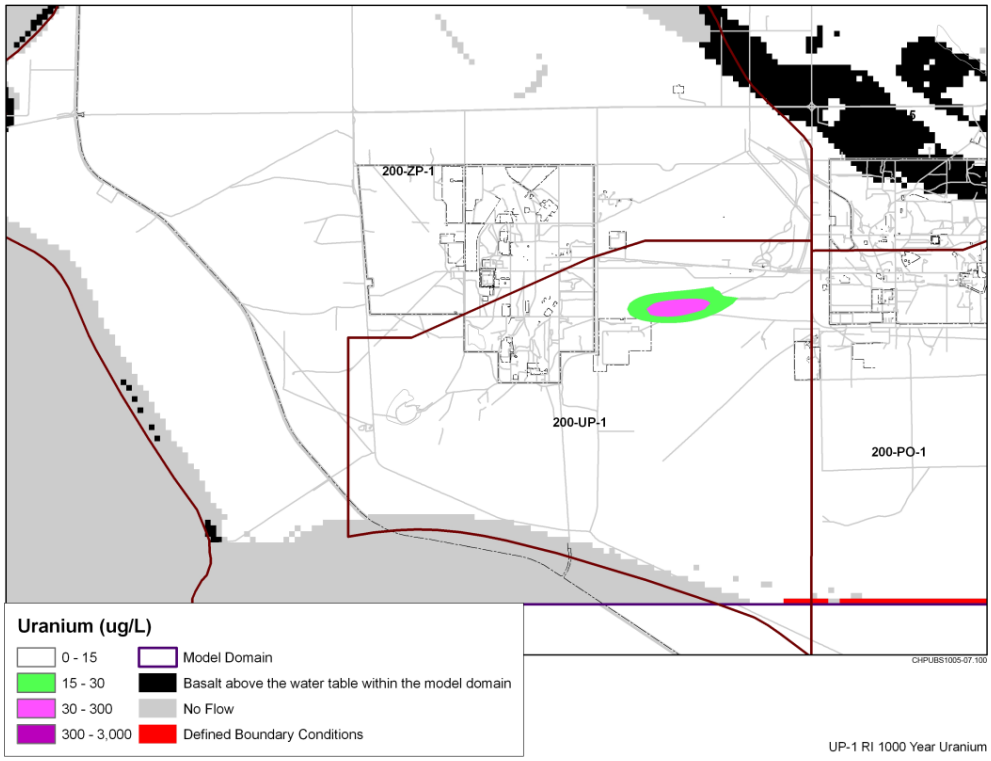


Figure 5-38. Distribution of Uranium after 1,000 Years (3009)

5.2.2.7 Strontium-90

In 2008, the Sr-90 level was measured above the MCL in only one 200-UP-1 OU monitoring well (Well 299-W22-10) and is represented in the initial distribution above the MCL in a single model cell (Figure 5-39). The simulated concentration in this cell is estimated to be below one-half the MCL after 1 year of operation of the 200 West P&T system. Representation of contamination with a single cell is below the scale of resolution for the transport simulations.

5.2.2.8 Chromium

Chromium has been interpreted to exist in concentrations above the MCL within three defined plumes in the 200-UP-1 OU. Disposal of water in U Pond transported the largest plume some distance from its presumed source. Figure 5-40 (initial conditions) shows this plume straddling the boundary between the 200-UP-1 and 200-PO-1 OUs. Two smaller plumes are further upgradient in the vicinity of the 216-S-25 and 216-S-1/S-2 Cribs. The transport simulation predicts that these two smaller plumes' chromium concentrations will be reduced below the MCL by the operation of the 200 West P&T system (Figure 5-41, 25 years). Figure 5-42 shows the continued east-northeast movement of the larger plume, which reaches the Hanford formation (HSU 1) portion of the aquifer after 75 years of simulation at concentrations above the MCL. Figure 5-43 indicates that transport into the HSU 1 will significantly reduce the footprint of this greater-than-MCL plume between the years 2084 and 2134. After 175 years (Figure 5-44, year 2184), simulated chromium concentrations of this plume are below the MCL at all locations.

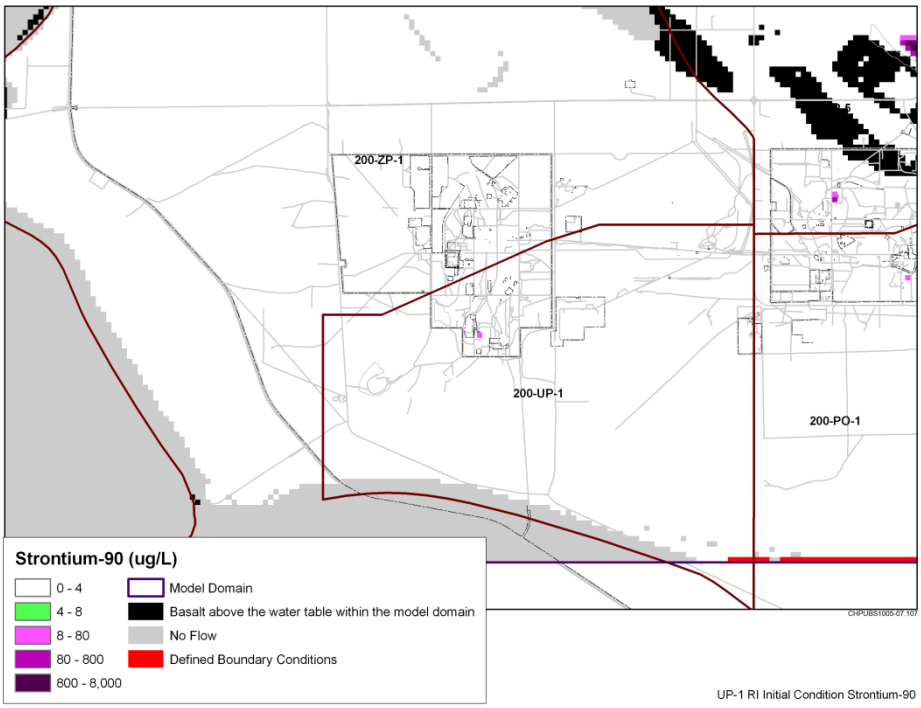


Figure 5-39. Initial Distribution of Strontium-90

The footprint of the largest chromium plume (106 ha [261 ac]) in the 200-UP-1 OU is currently defined based on data from monitoring Wells 699-30-66 and 699-32-62 (Figures 4-1 and 4-20). Based on the limited spatial characterization data available, the actual size and persistence of this plume may be less than that portrayed by the simulations presented on Figures 5-40 to 5-44. These two monitoring wells are screened in Layer 3 (Well 699-30-66) and Layer 2 (Well 699-32-62) of the Central Plateau Groundwater Model.

Time series chromium concentration charts (Figure 5-45) for these two monitoring wells were prepared to compare observed versus simulated chromium concentration trends. The relationship between sampling method (filtered or unfiltered) and valence state of chromium (total or hexavalent only) is not absolute but is correlated sufficiently to draw necessary inferences from these data. Unfiltered sample (representative of total chromium) and filtered sample (representative of hexavalent chromium) concentrations were plotted for the observed values while a composite value was portrayed for the Central Plateau Groundwater Model.

At monitoring Well 699-30-66 (Figure 5-45), the unfiltered data show an increase in concentrations for the 2004 to 2009 time period, with the most recent concentration values rising just above the total chromium MCL of 100 µg/L. The filtered measurements also show an increase in concentrations for the 2004 to 2005 time period and are generally consistent with those observed for the unfiltered measurements. The model simulation (assuming no change in current conditions) shows a decrease in the composite concentration from 102 to less than 48 µg/L (MTCA groundwater cleanup level for hexavalent chromium) after 25 years (year 2034), as the chromium plume is transported east in the unconfined aquifer. Qualitatively, the plume is expected to move in a direction from Well 699-30-66 to Well 699-32-62. As the plume moves past Well 699-30-66, an increase in concentration followed by a decrease over time may be expected. The observed concentrations and the model predictions support

this expectation. However, this increasing/decreasing trend does not help with delineation of the plume size (Figure 4-20).

At Well 699-32-62 (Figure 5-45), filtered chromium concentrations steadily declined from approximately 250 µg/L in 1992 to about 150 µg/L in 2009. Central Plateau Groundwater Model predicted that concentrations at the same location are projected to drop at a much slower rate. The difference between the observed and projected rates suggests the following:

1. The interpreted plume size (used in the model) is significantly larger than the actual size. To obtain a close match between the decline rates of the observed and model-predicted concentrations, the plume interpretation would have to be reduced in size.

2. Based on the observed rate of decline at Well 699-32-62, chromium concentrations at this location are estimated to decline below the MTCA groundwater cleanup level in less than 20 years. Therefore, the model-predicted time of 80 years shown on Figure 5-45 appears to be conservative. The CPGM predicts that chromium concentrations will drop below the 48 µg/L MTCA groundwater cleanup level throughout the aquifer in about 240 years under a no action alternative. This prediction overestimates the restoration time frame by a factor of two or more. Accounting for this factor, a more realistic restoration time frame for chromium is believed to be about 125 years.

3. The delineation of a single large plume based on observations from two wells is one possible interpretation. Another interpretation is that data from Wells 699-32-66 and 699-32-62 suggest two separate chromium plumes exist. This interpretation aligns more closely with the fact that two smaller plumes currently lay immediately upgradient.

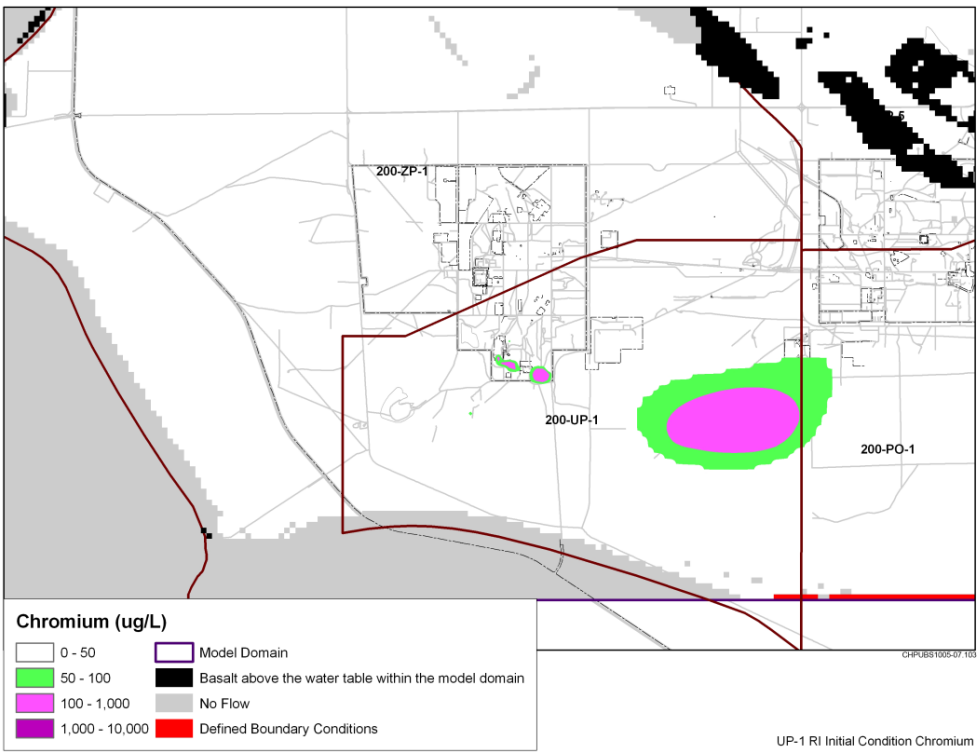


Figure 5-40. Initial Distribution of Chromium (2009)

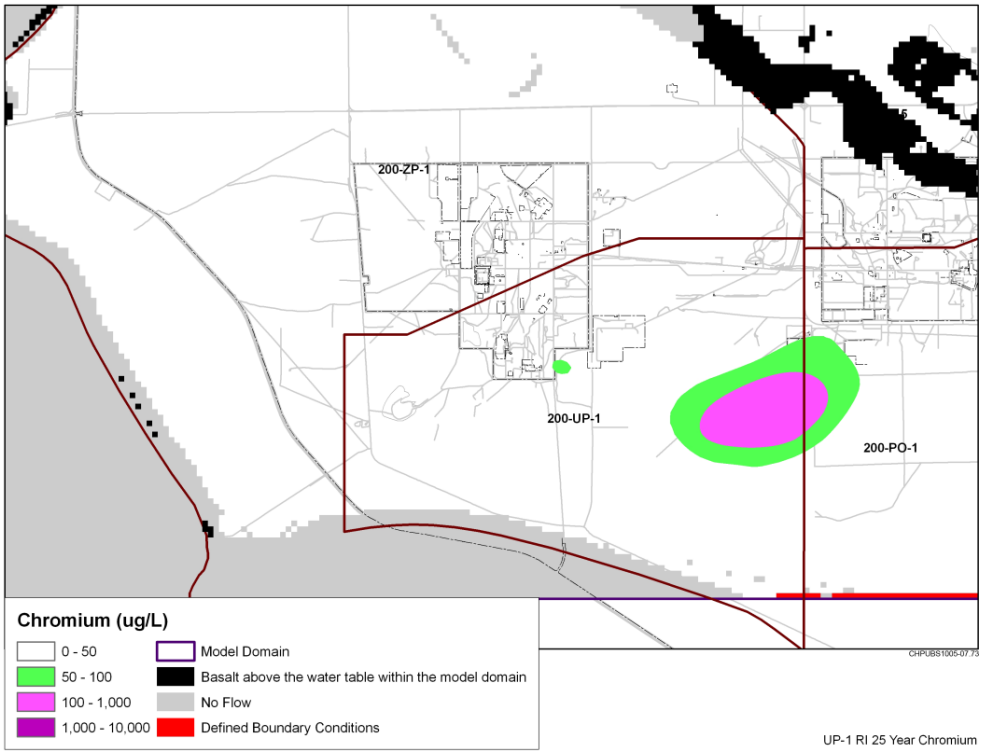


Figure 5-41. Distribution of Chromium after 25 Years (2034)

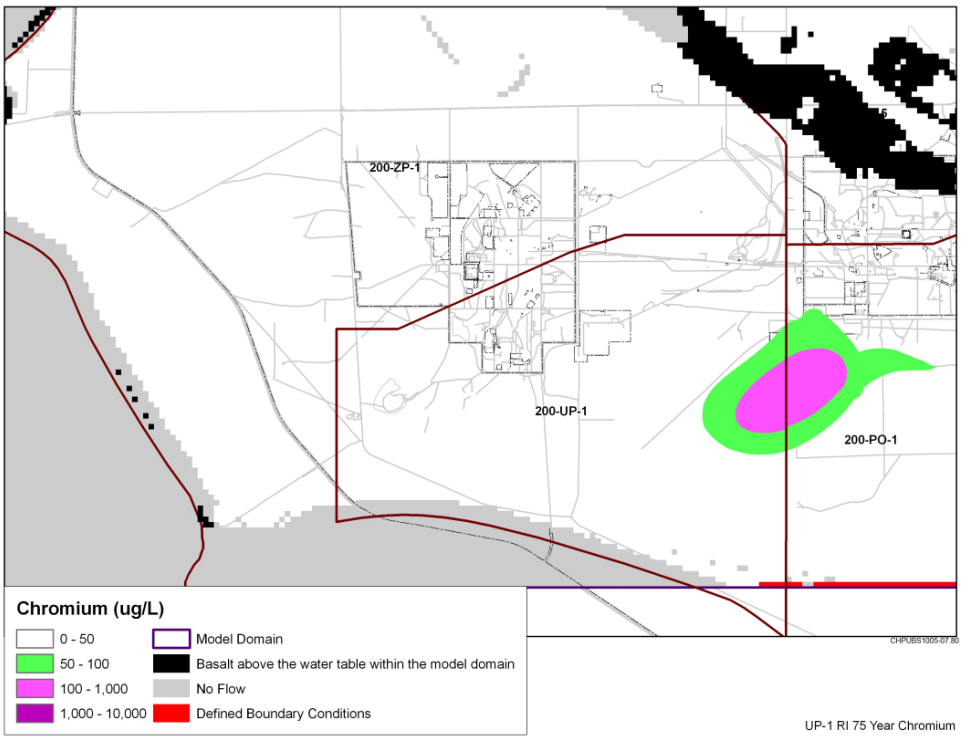


Figure 5-42. Distribution of Chromium after 75 Years (2084)

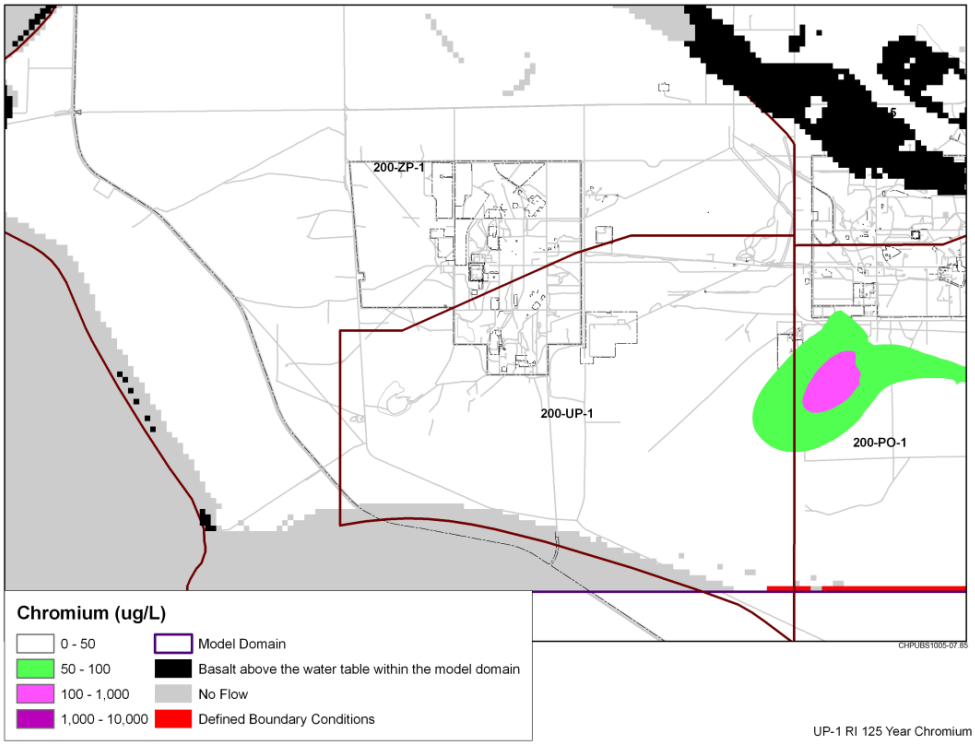


Figure 5-43. Distribution of Chromium after 125 Years (2134)

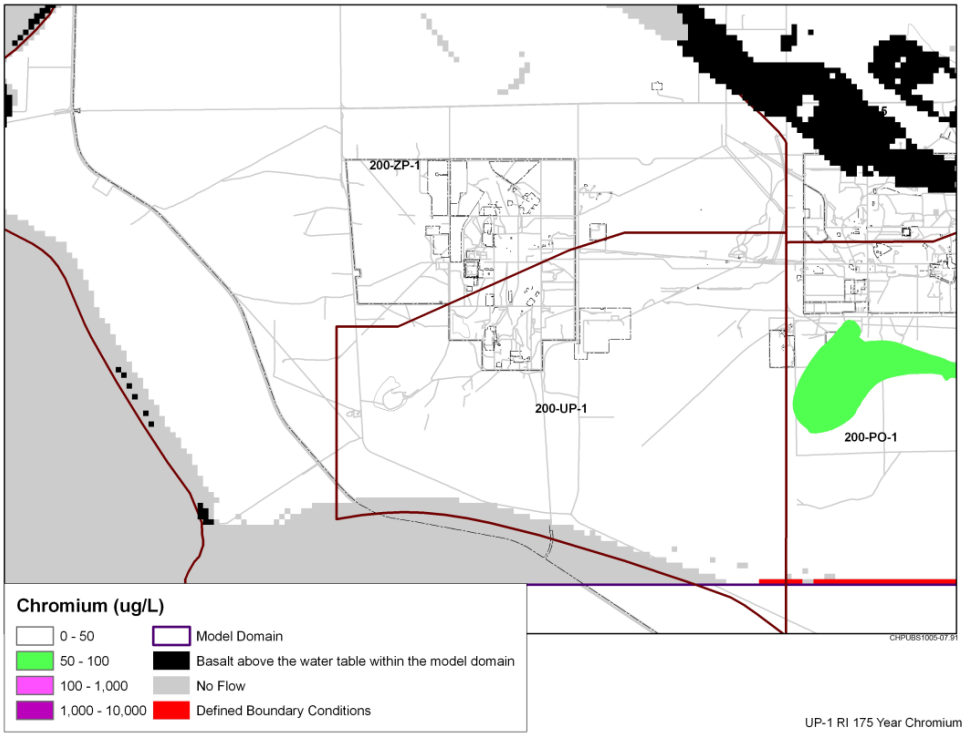
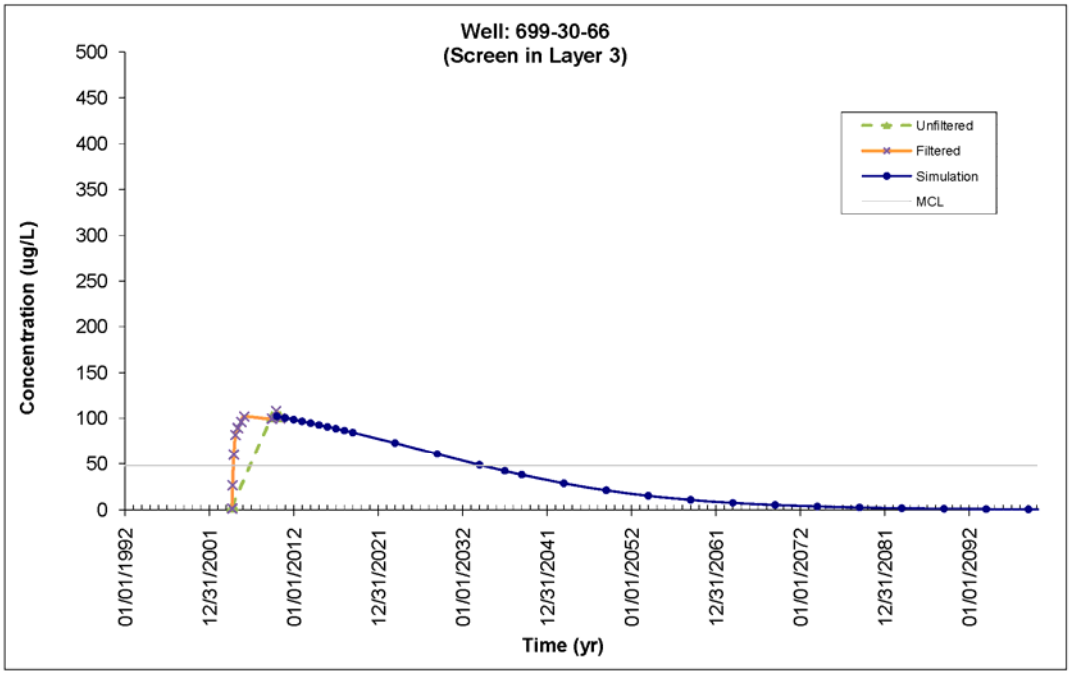


Figure 5-44. Distribution of Chromium after 175 Years (2184)



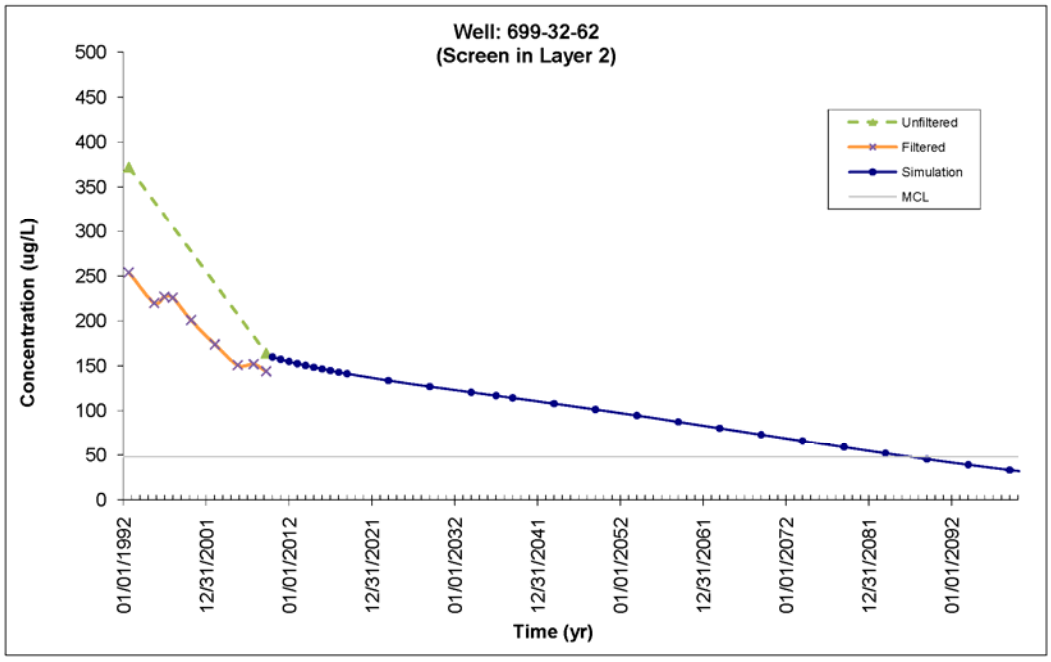


Figure 5-45. Chromium Concentration Trends at Wells 699-30-66 and 699-32-62

5.2.2.9 Concentrations along Selected Locations

Figures 5-46 through 5-52 present the path of the point of maximum concentration over time from the present forward as predicted in the fate and transport modeling for each contaminant simulated. Additional perspective on the projected fate and transport of simulated contaminants is available in Appendix F, ECF-200UP1-10-0373 where projected future concentrations at locations chosen to bracket these pathways are shown.

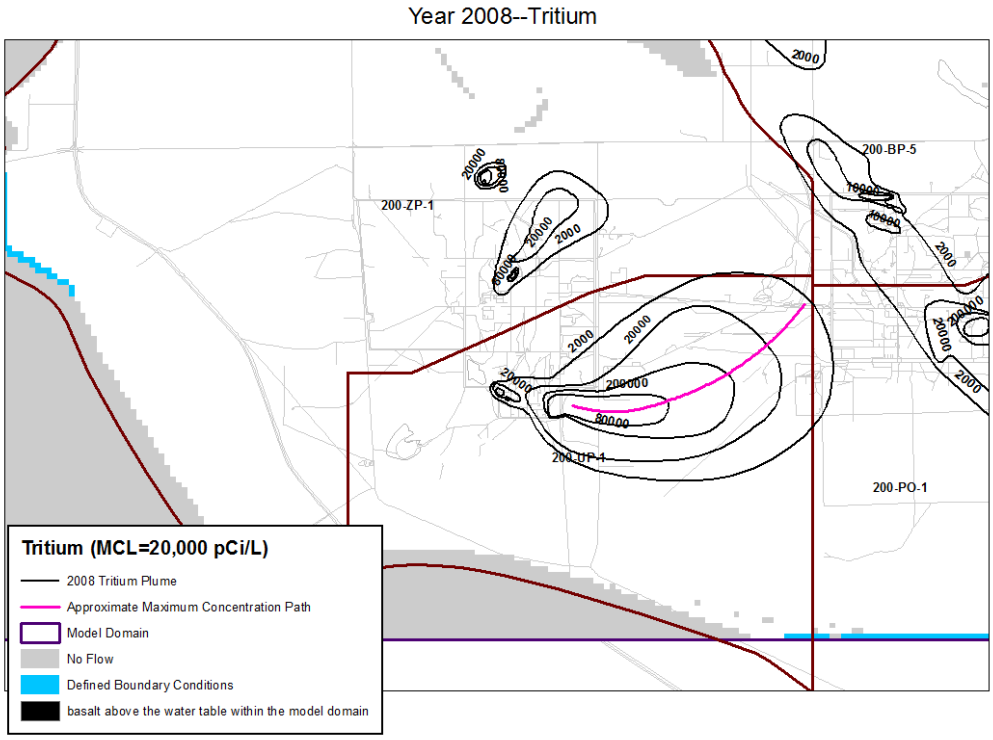


Figure 5-46. Path of Approximate Maximum Concentration, Tritium

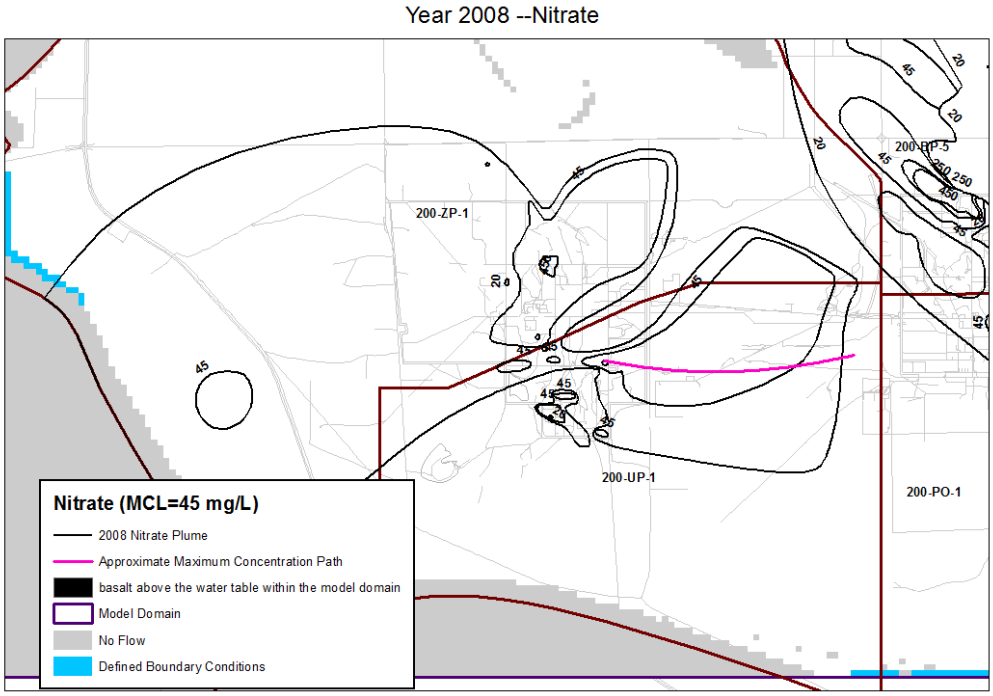


Figure 5-47. Path of Approximate Maximum Concentration, Nitrate

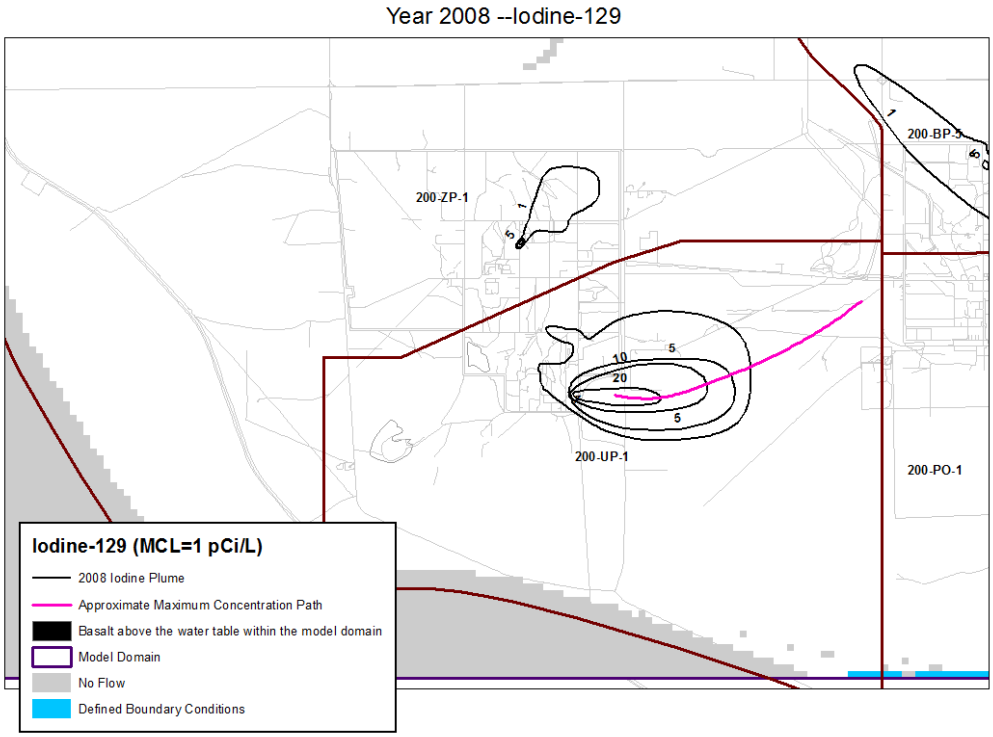


Figure 5-48. Path of Approximate Maximum Concentration, Iodine-129

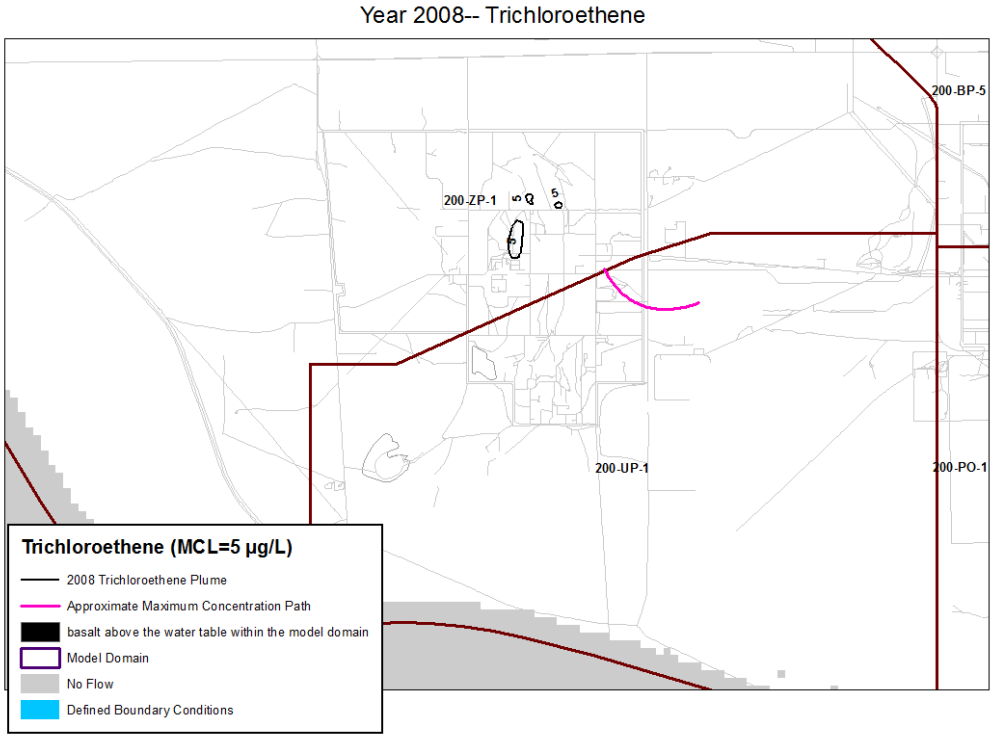


Figure 5-49. Path of Approximate Maximum Concentration, Trichloroethene

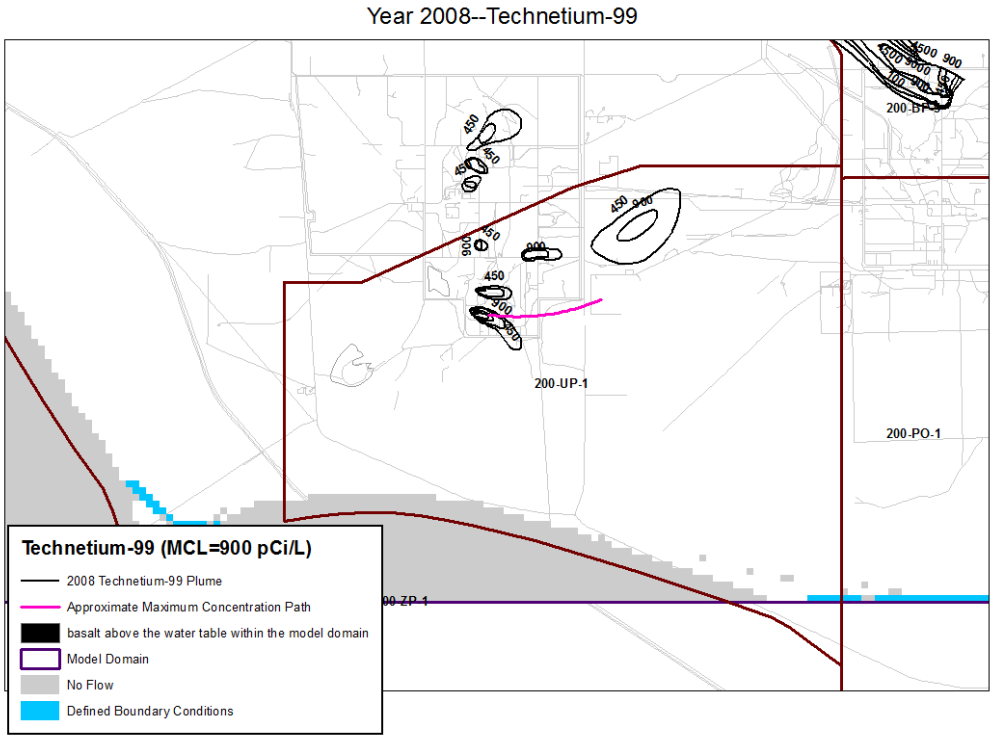


Figure 5-50. Path of Approximate Maximum Concentration, Technetium-99

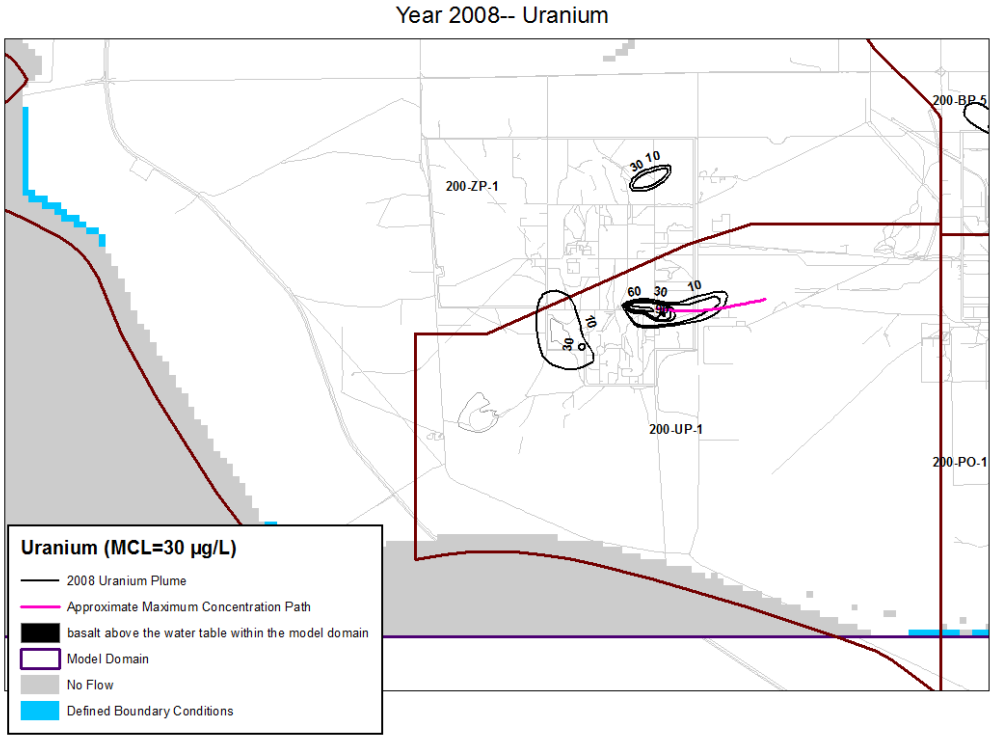


Figure 5-51. Path of Approximate Maximum Concentration, Uranium

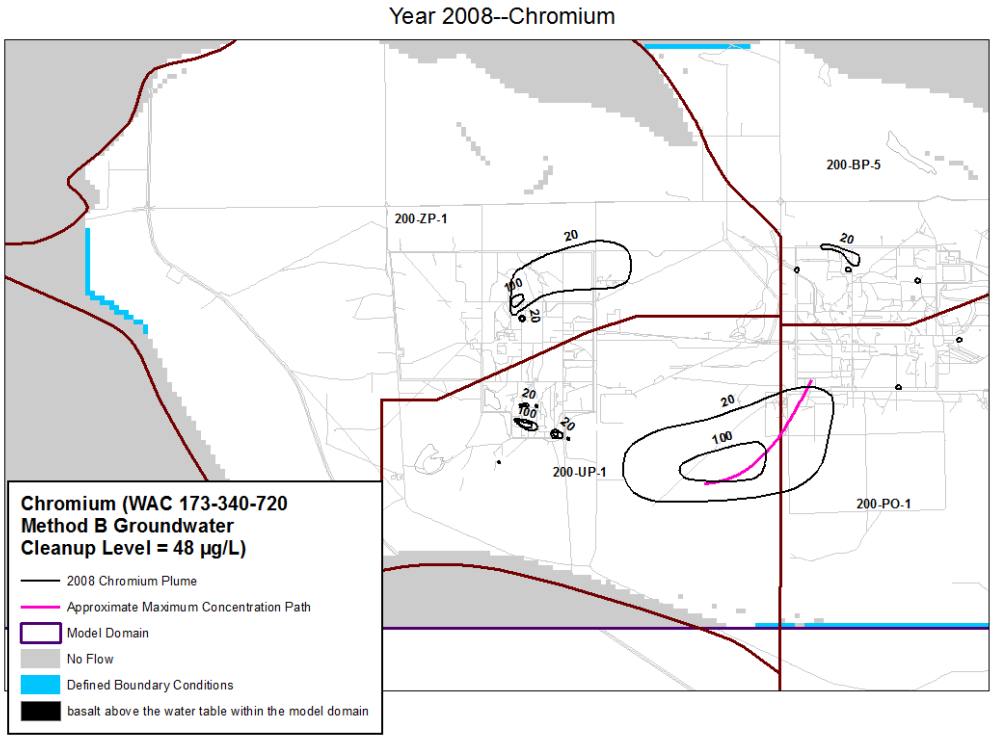


Figure 5-52. Path of Approximate Maximum Concentration, Chromium

5.2.2.10 Uncertainty in Simulated Future Conditions

This report does not attempt to quantify uncertainty in the fate and transport simulations. A qualitative discussion of sources of uncertainty in the simulations and how those uncertainties might influence the predictions of future contaminant distributions follows. Five sources of uncertainty are identified that can affect the fate and transport calculation results: (1) uncertainty in representing initial contaminant concentration distribution; (2) uncertainty caused by neglecting future contaminant sources; (3) conceptual model uncertainty in flow and transport modeling; (4) hydraulic parameter value uncertainty; and (5) parameter uncertainty.

The uncertainty discussion is based on the current modeling objectives, using the model to evaluate future conditions under a no action scenario and to demonstrate whether a need for action exists. As the model is used in FSs to compare remedial alternatives, a more thorough calibration will be undertaken to support these evaluations. Further refinements of the model are also expected, as the model is used for design of remedial alternatives. At that stage, a formal quantitative evaluation of model uncertainties will be presented.

5.2.2.11 Uncertainty in Initial Contaminant Distribution

The representation of initial distribution of contaminant concentrations is affected by the following uncertainties:

- Uncertainties in reported concentration measurements
- Errors in reported concentration measurements
- Variability in estimates of measurement detection limits

- Method used to assimilate nondetect measurements into the measurement dataset
- Representativeness of individual samples with respect to the region surrounding the sample
- Biases and variability introduced by the kriging algorithm
- Choice and influence of control points
- Truncation of the kriging estimates below one-half the MCL
- Lack of three-dimensional contaminant concentration measurements and modeling assumptions made to define the initial plumes in three dimensions

For most contaminants, uncertainty in measurements is probably a negligible factor when interpreting the results of fate and transport calculations. The exception may be I-129, for which large uncertainties exist even with a large number of measurements. The probability of large measurement errors is typically very low because of stringent quality controls applied by various analytical laboratories. However, sometimes measurement errors do occur. For example, one 2009 measurement of technetium that has a very large value in the data from HEIS has been identified as an error. The same sample is now reported to be below the detection limit.

The method used to accommodate samples with measurements below detection limits is uncertain. Nondetect measurements are identified as such in the data received from HEIS. If the nondetect flag is set, the measurement value in the data is set to the nondetect value for nonradioactive constituents. Concentrations that are not measured by radioactive decay products are treated as if the contaminant level were one-half of the measurement detection limit, except for nitrate, which is treated as if the contaminant level were at the detection limit. Measurements using decay products are treated as if the reported measurement is correct, unless the reported value is negative. These rules create an intentional bias toward larger estimates in regions where contamination is detected, rather than treating nondetects as having zero concentrations. It also introduces a similar bias in measurements that are distant from known regions of contamination. The distal bias contributes to overestimation of contaminant concentrations beyond the region that would be deemed as acceptable. Therefore, the estimated contaminant concentrations are truncated at levels below one-half the MCL.

Truncation greatly reduces uncertainty introduced by measurement detection limits and the treatment of samples below the detection limits. For contaminants with typical nondetect values larger than the MCL, the intentional bias toward larger estimates of contaminated regions is retained. If the detection limits are below one-half the MCL, uncertainty because of the treatment of nondetect measurements is probably overwhelmed by the bias introduced by truncation of the contamination estimates at one-half the MCL.

Representativeness of groundwater samples acquired from a wellbore with respect to defining contamination in the region of the wellbore is a complex issue. Contaminant concentrations may be affected by disturbances in the aquifer resulting from well emplacement. The actual placement of a monitoring well within the aquifer may induce local changes to the flow regime and migration of contaminants. Also, a larger proportion of the samples may come from high conductivity layers in the formation. This condition could introduce a bias in concentration if there are local variations in concentrations because of contaminant migration pathways. Representativeness of samples could be a source of uncertainty in individual measurements and could introduce consistent biases in a region.

Another component of the representativeness and comparability of samples is related to collection of samples at varying times. To establish initial plume concentrations for performing fate and transport calculations, a simple selection criterion was introduced. The selection criterion was to apply the 2008

sample data preferentially, rather than averaging all the data acquired at a location. For locations that do not have 2008 sample data, the most recent measurement was used if it was after 2005. In all cases, multiple samples acquired during a given year were averaged. The strategy of reducing temporal uncertainty is consistent with the assumption that individual measurement uncertainties are small. Given the scale and dynamics of contaminant migration, the time-based sampling strategy has probably reduced uncertainty to negligible levels because of the time when samples were acquired.

Developing initial plume configuration (geometry and size) from a limited spatial dataset also leads to uncertainty in initial concentration. This uncertainty is especially applicable to the large chromium plume in the southeastern corner of the 200-UP-1 OU, discussed in Section 5.2.1.7. The kriging-based interpolation routine was introduced to reduce this uncertainty. The issue is how far a sample result can be extrapolated away from the wellbore or model cell containing the wellbore. Kriging uses a diminishing influence with distance as defined by the exponential variogram structure. Kriging reduces but cannot eliminate uncertainty because of sparse sampling, because kriging does not represent the physics of the processes that cause contaminants to migrate in the subsurface. It is instead an interpolation algorithm. To reflect the influence of fluid flow direction on contaminant distribution shape, a bias in the kriging algorithm was introduced by making the variogram longer in the average direction of flow than in other directions, and the shortest perpendicular to this direction. The average groundwater flow direction was determined to be consistent with contaminant contours within about 30 degrees of azimuth. This flow direction was kept constant within the eastern and western portions of the Central Plateau Groundwater Model domain. Thus, the variogram only approximates flow direction at the scale of the individual contaminant plume, sometimes inadequately. A particular problem with using kriging to define contaminant distributions is that while flow is in a particular direction, kriging is symmetric with respect to the measurement point (the influence is the same in the direction of flow as it is in the opposite direction). One of the reasons for using control points was to reduce the influence of this limitation.

Control points allow the imposition of the analyst's subjective bias into the interpolation. Control points were used to accomplish the following four goals:

- Overcome the directionality problem described previously.
- Connect regions of large concentrations that were shown connected in the plume maps presented in the 2008 groundwater annual report.
- Force very small regions of contamination above the MCL (often few single cell blocks in the finite difference grid) to be represented above the MCL.
- Define contaminant plumes that have been inferred by limited measurements and knowledge of distributions or process knowledge as represented in the 2008 groundwater annual report contaminant contours.

Control points introduce bias and uncertainty because their placement and the interpretation of their influence are subjective. Control points are mainly used to apply professional judgment where insufficient data exist to fully describe site conditions. The net effect of control points is to reduce bias and uncertainty, while defining plume configurations that are consistent with the 2008 groundwater annual report.

As with the introduction of control points, truncation of the plume estimates at one-half the MCL reduces the overall bias and uncertainty in the contaminant distribution but also introduces its own bias. Where measurements do not exist, concentrations are set to zero. Truncation does not affect regions of large contaminant concentrations, but it does result in a probable underestimate of total contaminant mass to

avoid a much larger overestimate that would occur if truncation were not used. A counter bias could be the use of plume configuration in the topmost three layers in the transport model. This is more likely to overestimate the simulated plume mass, discussed as follows.

There are more measurements that represent contaminant concentrations in near water table conditions than there are from deeper within the thick aquifer. Only carbon tetrachloride was deemed to have enough measurements at depth to provide a basis for determining separate concentrations for each model layer and only in the western part of the model domain. For other contaminants, measurements representative of the upper three layers were used to define a single contaminant distribution that was then applied equally to the top three layers of the model. The larger number of measurements near the surface bias the estimated contamination toward concentrations representative of conditions near the water table, and this bias is propagated vertically downward as estimates are applied at greater depth in the model. It is expected that this propagated bias results in an overestimate of total contaminant mass. In contrast, assuming no contamination exists in the Ringold Formation lower mud unit (HSU 8) and Ringold Formation unit A (HSU 9) biases the contaminant estimates in these lower confining units in a nonconservative fashion, but this assumption is supported by the absence of observed concentrations in the parts of the confined groundwater aquifers.

5.2.2.12 Uncertainty from Neglecting Future Contribution from Vadose Contaminant Sources to Groundwater

The current analysis is limited to the estimation of the effects of current groundwater contamination on future groundwater contamination and the resultant risk to human health and the environment. The influence of the future movement of contaminants currently in the vadose zone down to the saturated aquifer is outside the scope of this analysis and, therefore, does not account for the magnitude and timing of any future or continuing contaminant contributions from this source. Not all of the observed groundwater contaminant plumes in the 200-UP-1 OU are associated with continuing vadose source contributions. For example, the chromium plume, in the southeastern portion of the 200-UP-1 OU, does not underlie potential continuing source contributions. The evaluation and remediation of secondary contaminant sources within the vadose zone fall under the responsibility of the specific source OUs. Because the direct contribution of residual vadose zone sources to future contaminant concentrations is outside the scope of this analysis, the major source of uncertainty within the scope of the analysis is the possible nonlinear influences on fate and transport. The conceptual model for transport of current contamination assumes that important processes are linear; that is, changes in the magnitude of contamination propagate as changes in magnitude only, not as changes in the process. For small concentrations, this is a good assumption. It is doubtful that additional discharge from the vadose zone to the aquifer will affect the validity of assumptions about linearity. Continuing contributions from vadose zone sources, however, could affect the overall magnitude of contaminant mass (as resulting concentration) in groundwater and the longevity of the high concentration portions of groundwater plumes. Inclusion of a potential continuing vadose zone source would be unlikely to affect a decision regarding the need for remedial action.

5.2.2.13 Conceptual Model Uncertainty

It is argued that conceptual model uncertainty is the dominant form of uncertainty in a modeling exercise, which may hold true for this model as well. The most important source of uncertainty is the future planned industrial use of the Central Plateau. Changes in use of the Central Plateau could alter the current artificial and natural recharge estimates in the model and thus affect the groundwater flow velocities.

The next most important source of uncertainty is the assumption of spatially invariant hydraulic properties of the HSUs. The fluvial environments that lead to deposition of most of the aquifer are associated with heterogeneous structures, especially for the Hanford and Cold Creek units. Local variations in properties can cause local regions of large flow rates and faster transport of contaminants. These can be significant, as evidenced by the experience obtained from calibrating the model. During the calibration, the CCU near the 200 East Area was found to be more permeable than a representative value would allow.
The hydrologic unit definition of this portion of the CCU was changed to the Hanford formation to provide a more accurate reflection of the very permeable, coarse-grained nature of this portion of the CCU. This region was identified because it was very important to the flow calibration. Other, smaller regions may have had less impact on the hydraulic calibration but still could have a strong but more localized influence on flows.

A source of uncertainty in the transport predictions derives from the assumption of a constant effective porosity value for a given HSU. The effective porosity is used in converting water mass flux calculated by MODFLOW to groundwater velocity used in MT3DMS for fate and transport calculations. Heterogeneity in the form of lenses of variable sediment lithologies, and small scale structural features, (i.e., bar structures) is common at a scale below the 100 m (328 ft) by 100 m (328 ft) grid size of the Central Plateau Groundwater Model and could lead to varying effective porosity values and groundwater velocities. Furthermore, some of these features can create preferential pathways and lead to faster contaminant movement locally than predicted by the current model.

The conceptual model and parameterization of boundary conditions has a major influence on groundwater flow and transport of contaminants. Representing the two gaps along the northern border of the model with specified heads is uncertain because the values must be predicted from past trends. Two major sources of uncertainty influence the importance of the gap. The first is the uncertainty of how much flow is entering the model domain from the western streams, from surface infiltration, and through leakage upward from the basalt. Of these, flux from the western streams dominates. The values obtained from calibration of the 200-ZP-1 groundwater flow model were used for these terms. The second source of uncertainty is nonequilibrium storage in the aquifer. The Central Plateau is not in equilibrium with respect to inflow and outflow. The Central Plateau unconfined aquifer still exhibits more outflow than inflow because of the remaining fraction of the tremendous buildup of stored water in the aquifer during the operational period of the Site. The aquifer is still attenuating this buildup that ended with termination of production activities at the Site in 1989.

Fluid flow and transport are extremely sensitive to the interpretation of geology in the entire portion of the model east and southeast of the 200 East Area. This region is complex geologically and there is not a one-to-one correspondence between geologic formation and proper hydraulic representation, as previously described in this section. Strict reliance on geologic characterization was found to be incorrect. Almost as much variation of hydraulic conductivity may exist within the Hanford formation and CCU as exists between representative values for these HSUs. To create a model that matched historical head data, interpretation of some drilling logs required re-examination, and many of the logs that were re-examined could be, and needed to be, interpreted differently. The conceptual model of hydrostratigraphy was influenced by historic contaminant plume interpretations that indicate the presence of a large conductive channel, from just south of the 200 East Area to the southeastern corner of the Central Plateau Groundwater Model domain. The hydraulic head data strongly correlate with this interpretation; however, few geologic data from well log interpretation exist to corroborate this interpretation. While there is enough evidence to support a highly conductive channel, there is insufficient evidence to accurately define its shape and size. This uncertainty implies that there is insufficient evidence to provide good constraint of the velocity of groundwater flow in the channel. Potentially, examination of historic plume movement could help constrain flow velocities in the channel, but this examination has not been done.

5.2.2.14 Hydraulic Parameter Value Uncertainty

The conceptualization of HSUs as homogeneous entities with effective single-valued properties has been discussed. The present discussion focuses on the selection of the effective values. Hydraulic parameters comprise hydraulic conductivity, specific storage, and specific yield. Hydraulic conductivity values were established through calibration. The match to hydraulic head difference between Well 299-E23-1 near the 200 East Area and Well 699-24-33 was very sensitive to the hydraulic conductivity of the Hanford unit. This well pair was selected because of the perceived importance of the Hanford unit in defining the conductive channel. The sensitivity ensured that only a narrow range of effective hydraulic conductivity of the Hanford formation would result in a good match. However, because the fluid flux moving through the channel is uncertain, and the size of the channel is uncertain, the representativeness of the effective parameter for the hydraulic conductivity of the Hanford formation is also uncertain. In terms of transport velocity uncertainty, the uncertainty in a value of the hydraulic conductivity for the Hanford unit is relatively unimportant compared to the fluid mass flux uncertainty and uncertainty about the size of the channel.

The existence of a channel, as indicated by maps of historic contaminant distributions, reveals a significant difference between the Hanford formation (HSU 1) hydraulic conductivity and the effective hydraulic conductivity of the CCU (HSU 3). The calibration resulted in an effective hydraulic conductivity of 100 m/day (328 ft/day) for the CCU and 8,500 m/day (27,887 ft/day) for the Hanford formation. The hydraulic head difference between Well 299-E23-1 and Well 699-24-33 was not sensitive to changes in the hydraulic conductivity of the CCU, as long as the hydraulic conductivity of the CCU was significantly less than that of the Hanford formation. It is expected that, in terms of the most important aspects, contaminant transport is not sensitive to CCU hydraulic conductivity.

The effective values for hydraulic conductivity of the Ringold unit A (HSU 9) and Ringold unit E (HSU 5) were selected in the calibration by matching the hydrograph of Well 299-W12-1 during 1976. This was done after selection of values for the Hanford unit and the CCU (HSU 3). It is expected that effective values are less well constrained than for the Hanford formation in the channel but much better than for the CCU. The relative hydraulic conductivity between the Ringold unit A (HSU 9) and Ringold unit E (HSU 5)is probably not well constrained and is important to assessing transport uncertainty. However, the resultant uncertainty is probably much smaller than the uncertainty resulting from effective porosity.

The calibration was insensitive to changes in the conductivity of the Ringold lower mud unit (HSU 8). The Ringold lower mud unit may act as a much greater barrier to flows into the Ringold unit A (HSU 9) than is currently simulated. While it is unlikely that the Ringold lower mud unit would have much influence on transport in the 200-PO-1 OU, it may have a nonconservative impact on transport from the 200-UP-1 OU to the 200-PO-1 OU.

5.2.2.15 Uncertainty in Transport Parameters

As advection is the primary transport mechanism in the current modeling study, the transport parameters of interest are effective porosity, bulk density, and K_d. These parameters are used to determine the retardation factor that is applied to various COPCs. Only best estimate values are considered in the modeling study because of lack of available information on spatial variability of these parameters.

The effective porosity and bulk density values applied in the transport model are representative of the sandy gravel sediment type of the Hanford formation and the Ringold Formation (PNNL-18564). Although HSUs are composed of sediment layers of varying grain sizes (from gravel to mud size), applying the sandy gravel sediment property to the HSUs is deemed adequate because the transport of contaminants is expected to occur along the coarser-grained, higher hydraulic conductivity portion of the

aquifer. Furthermore, averaging of the properties over large rock volumes is reasonable because of the long transport distances modeled and because averaging leads to a reduced uncertainty range.

The K_d of the contaminants is highly variable and depends primarily on the available sorption sites on the sorbent (function of surface area), dissolved concentration of contaminant, and chemical parameters such as pH, partial pressure of CO_2, and so forth. Each of these parameters can vary over time and space and affect the K_d of the contaminant and thereby the uncertainty in its estimate. Because of the large transport distances considered and the coarse discretization of the model grid, the best estimate approach for K_d is considered. The K_d values for COPCs reported for the uncontaminated sandy gravel sediment type are used in the model to be consistent with the effective porosity and bulk density estimates. For carbon tetrachloride, the K_d values were calculated based on the batch sorption experiments on uncontaminated sediments (rather than desorption experiments on the contaminated sediments), while for other chlorinated VOCs, K_d is based on an empirical calculation assuming a low organic carbon fraction. Estimation of K_d values is also based on an assumption that contaminant concentrations in groundwater are sufficiently diluted so that interactions with uncontaminated sandy gravel sediments are linear, reversible, and instantaneous.

The degradation of chlorinated hydrocarbons is also uncertain and depends on the biogeochemical conditions in the aquifer. A conservative assumption that there is no degradation of chlorinated hydrocarbons (except for carbon tetrachloride) was used for the current modeling.

5.2.2.16 Summary of Uncertainty in Fate and Transport Simulations

A review of sources of simulation uncertainty has been presented. The most important sources are listed as follows (the list is not in a ranked order):

- Initial contaminant distribution, especially with respect to depth
- Effective transport porosity
- Distribution coefficients
- Heterogeneity in HSU properties
- Future use of the Central Plateau

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6 Baseline Risk Assessment

A baseline risk assessment (BRA) was conducted to analyze the potential human health effects that would be caused by exposure to 200-UP-1 OU contaminated groundwater. The risk evaluation was performed assuming exposure to groundwater in its current state (current baseline risk conditions) and also assuming that no remedial action is implemented to reduce the present contamination over time (future risk conditions). The BRA is a key step in the CERCLA RI and site characterization process in establishing COPCs and the need for remedial action (EPA/540/1-89/002, *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A): Interim Final*).

There are four components in the BRA process:

- **Identification of COPCs (Section 6.1).** This component is an evaluation of the groundwater data to identify initial COPCs. This component also defines action levels (see Section 6.1.2) required for identification of final COPCs to focus subsequent efforts in the risk assessment process.
- **Exposure assessment (Section 6.2).** The exposure assessment component of the risk assessment identifies the populations that may be exposed, the routes of exposure, and the magnitude, frequency, and duration of the potential exposures.
- **Toxicity assessment (Section 6.3).** The toxicity assessment component evaluates the relationship between the magnitude of exposure to a contaminant and the likelihood of adverse health effects to potentially exposed populations.
- **Risk characterization (Section 6.4).** The risk characterization component characterizes baseline risk and defines where and for which contaminants the risk thresholds have been exceeded. Future exposure estimates are used to provide decision makers with an understanding of potential future exposures and threats assuming no remedial action.

This chapter also presents the results for exposure associated with use of groundwater as a tap water source, including the confirmation of final COPCs and their contribution to overall risk (Section 6.5). Future groundwater conditions are addressed (Section 6.6). The ecological risk is addressed (Section 6.7). A discussion of BRA uncertainties follows (Section 6.8) and conclusions are presented (Section 6.9).

6.1 Identification of Contaminants of Potential Concern

The first step in a BRA is an evaluation of the data to identify the COPCs . A detailed description of the methodology used and the results of the process are provided in Appendix D (ECF-200UP1-10-0231, *Identification of Contaminants of Potential Concern for Groundwater Risk Assessment at the 200-UP-1 Operable Unit*). Figure 6-1 presents a summary of the COPC identification process. The left side of the Figure 6-1 illustrates the two steps of identifying initial and final COPCs. The right side of Figure 6-1 illustrates how the results of the tap water scenario analysis are used to confirm that final COPCs are the major risk and hazard drivers.

The process used to identify data for COPC selection and the selection of action levels for this BRA are described in Sections 6.1.1 and 6.1.2, respectively. Based on evaluation of individual concentration measurements, the first series of steps identifies the initial COPCs to be carried forward into the final COPC identification process. The process used to select the initial set of COPCs is described in Section 6.1.3. The second series of steps identifies the final COPCs based on whether calculated exposure point concentrations (EPCs) exceed action levels (Section 6.1.4).

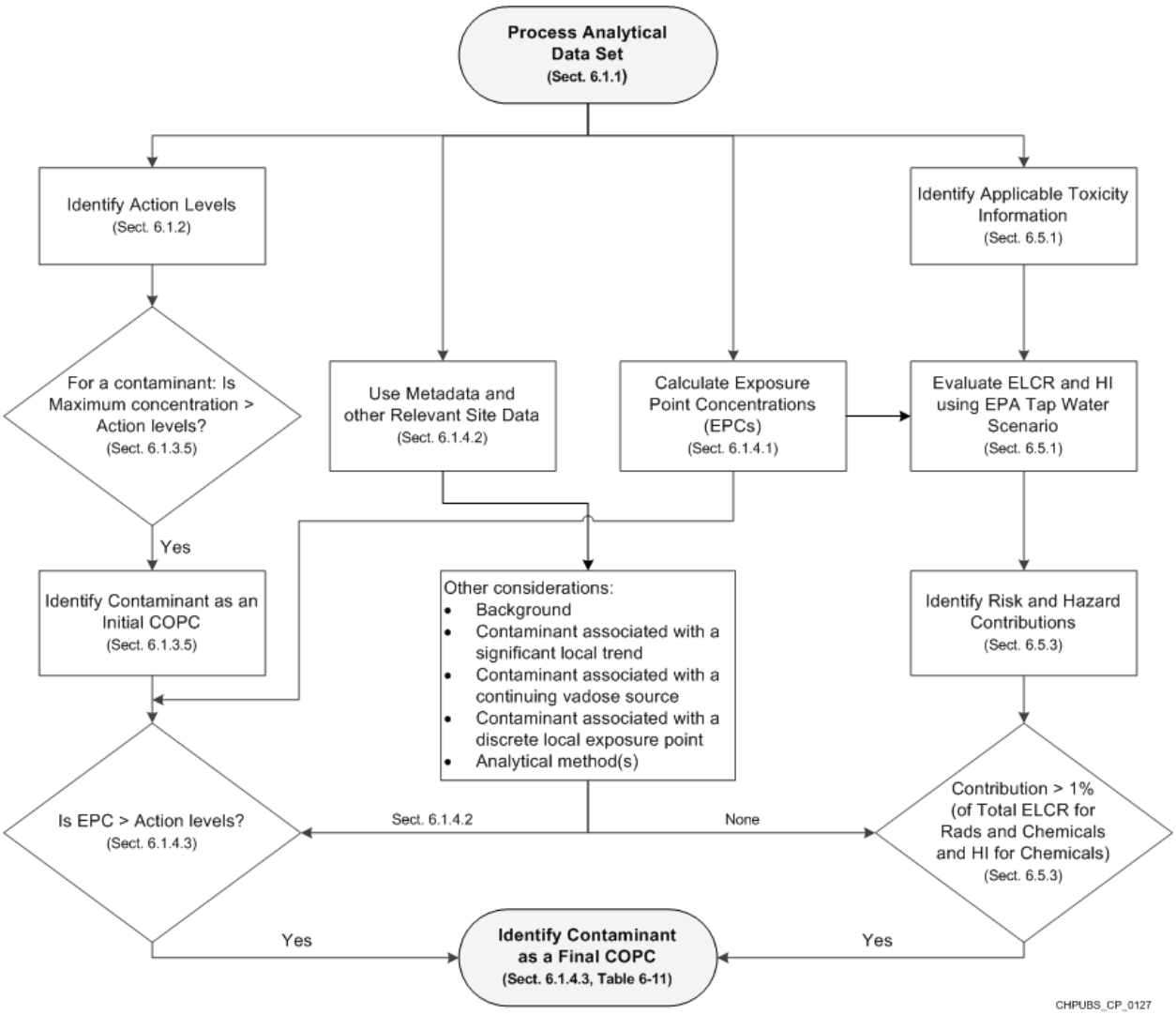

Figure 6-1. Overview of COPC Identification Process

6.1.1 Data Used to Identify Contaminants of Potential Concern

Data from 2004 to 2009 (samples collected between January 12, 2004, and April 28, 2009) for 93 wells screened in the unconfined aquifer were used. Unconfined aquifer wells are the most likely locations in the aquifer for eventual use as domestic water wells. In addition, the wells are screened where the contamination is known to be present.

The analytical data were extracted from HEIS and processed to obtain a single set of results per sampling location and sample collection time. In total, 67,806 records were obtained from HEIS, and 237 contaminants were included in the dataset before data processing occurred. After data processing, the final dataset used contained 44,133 records, with 237 contaminants.

6.1.1.1 Analytical Data Processing

The HEIS dataset included the following types of information:

- Analytical results from unfiltered and filtered samples
- Data qualification and data validation flags, including rejected results

- Results for a given contaminant reported by more than one analytical method
- QC sample results (field duplicate and field splits)

The analytical data were processed to eliminate unusable results and thus identify a final dataset per sample location and date (see Figure 6-2).

6.1.1.2 Unfiltered Sample Results

Filtered (dissolved) and unfiltered (total) results are available in HEIS for some metals. Only unfiltered results were used because filtered results would underestimate chemical and radiological concentrations. There are generally more filtered metals results than unfiltered; however, exclusion of the filtered results did not eliminate any metals from the COPC selection process, nor did it underestimate the EPCs.

EPA/540/1-89/002 provides guidance on estimating EPC concentrations in groundwater using filtered samples. The guidance states that filtering groundwater samples can provide useful information for understanding chemical transport within an aquifer but that such samples may underestimate chemical concentrations. Therefore, data from unfiltered samples for 200-UP-1 were used to estimate EPCs.

Laboratory and Data Validation Flags. Analytical data were received from the laboratory with data qualification flags. In addition, data validation flags are assigned during the data validation process. The following rules were applied to determine how the sample results could be used for COPC selection:

- All sample results flagged with a U qualifier or combination of qualifiers that include a U, such as a UJ, are considered an undetected concentration.
- All sample results without a U qualifier are considered detected concentrations, including results with other qualifiers (such as J).
- All sample results that are rejected and flagged with an R are not used.

Contaminants Reported by Numerous Analytical Methods. Often, contaminants are reported by more than one analytical method, resulting in multiple results for the same contaminant from the same location. When contaminants are reported by more than one analytical method, the data are processed to select the method that provides the most reliable results. For example, the gamma spectroscopy method provides concentration results for the uranium isotopes; however, uranium concentrations reported by a uranium-isotope-specific method are preferred.

Field Duplicate and Field Split Results. Field QC samples (duplicates and splits) are collected in the field and analyzed as unique samples. The parent sample and QC samples are collected from the same location on the same day and time, resulting in more than one sample per location and date. The following criteria were used to reduce multiple sample results for an individual location to a single result:

- If two or more detections exist, the maximum concentration is used.
- If at least one detection and one or more nondetected results exist, the detected concentration is used.
- If only (two or more) nondetected results exist, the lowest detection limit is used.

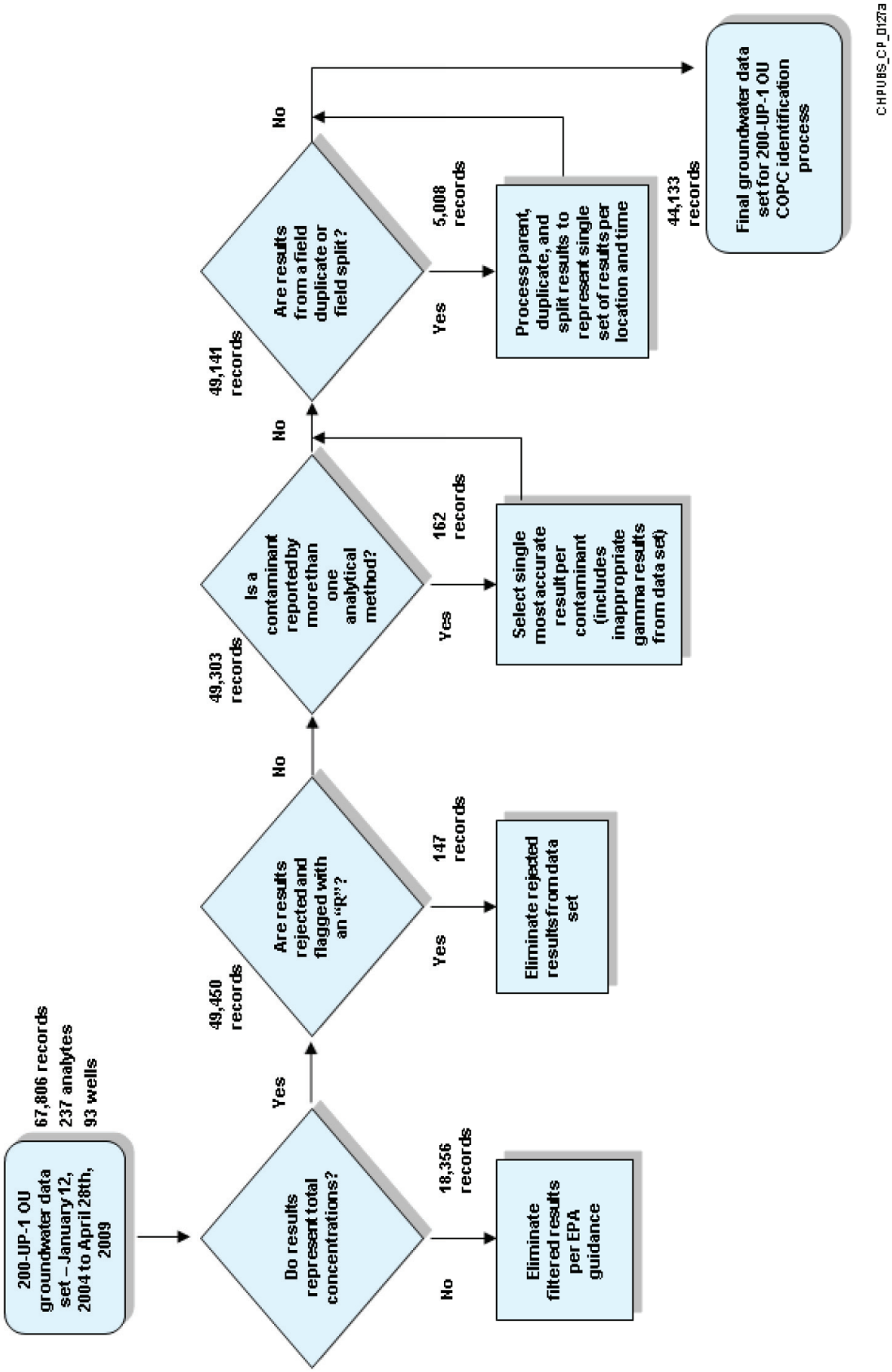

Figure 6-2. Analytical Dataset Processing

6.1.2 Identification of Action Levels

A major part of this baseline risk assessment is to compare observed concentrations to promulgated state and federal concentration levels (no site-specific exposure scenarios are used to define these levels). Sources of the concentration levels from federal regulations are MCLs (40 CFR 141.61, 141.62, and 141.66), secondary MCLs (40 CFR 143.3), and nonzero MCL goals (40 CFR 141.50, 141.51, 141.52, 141.53, and 141.54) established under the Safe Drinking Water Act of 1974. Sources from State of Washington Administrative Code (WAC) are MCLs and MRDLs (WAC 246-290-310, Group A Public Water Supplies, Maximum Contaminant Levels and Maximum Residual Disinfectant Levels) or Groundwater Cleanup Levels (WAC 173-340-900 Method A and WAC 173-340-720 Method B).

Because of the variety of sources for these levels and in order to simplify the terminology, the term "Action Level" is used to identify the lowest concentration obtained from these sources. The sources of state and federal concentration values are listed in Table 6-1 for the contaminants evaluated in this Chapter, along with the selected Action Level. Groundwater in the 200-UP-1 OU is not likely to move off the Central Plateau and enter the Columbia River at significant concentrations (see Chapter 5), thereby limiting the potential exposure scenarios to a future drinking water source only. Therefore, the Action Levels identified in Table 6-1 are selected based on protection of human health, not aquatic receptors or surface water standards.

6.1.3 Initial Contaminants of Potential Concern Identification Process.

The initial COPC identification process was used to select those contaminants that will be carried forward into the final COPC identification process. This step of the process used sampling and analytical data collected from the 93 wells defined previously. The purpose of grouping all the data together is to identify those contaminants with concentrations above the lowest available action level before an EPC is calculated. A detailed description of the initial screening process is provided in Appendix D (ECF-200UP1-10-0231). The initial COPC screening process steps, number of records, and number of contaminants associated with each step are presented on Figure 6-3. The first step, "identify action levels," is covered in Section 6.1.2.

- Identify action levels.
- Apply exclusion criteria.
- Identify contaminants with no action levels.
- Identify nondetected contaminants.
- Identify contaminants with maximum detected concentrations less than action levels.
- Identify contaminants with maximum detected concentrations greater than action levels.

The results of the initial COPC selection process identified 36 of the initial 237 contaminants to be carried into the final COPC identification process. The following subsections define how this selection was performed.

6.1.3.1 Apply Exclusion Criteria

The first step in the groundwater COPC identification process was to apply certain exclusion criteria to the dataset. Contaminants that met one or more of the exclusion criteria were eliminated. The eliminated contaminants are listed in Table 6-2. The contaminants that did not meet any of the exclusion criteria were carried forward. The exclusion criteria are the following:

- Naturally occurring radionuclides associated with background radiation
- Radionuclides that have half-lives less than 3 years and are not significant daughter products
- Essential nutrients or minerals

Potassium-40, a naturally occurring radionuclide was eliminated. Radioisotopes with half-lives of less than or equal to 3 years were eliminated from further consideration because only a small fraction of activity remains today. Four radioisotopes (antimony-125, beryllium-7, cesium-134, and ruthenium-106) meet this criterion and were eliminated. Each of these radioisotopes was reported with nondetectable concentrations.

6.1.3.2 Identify Contaminants with No Action Levels

In addition to the exclusion criteria, contaminants without promulgated standards are identified below in Table 6-3. The EPA tap water scenario analysis in Section 6.5 will be used to evaluate contribution from these contaminants to overall risk and hazard. If that analysis shows that any of these contaminants is a major risk driver, the contaminant will be evaluated using the "indicator chemicals" approach (EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final*).

In total, 59 contaminants and indicator parameters were eliminated as COPCs because they do not have action levels (Table 6-3). Of these contaminants, 23 have not been detected. In addition, 14 water quality indicator parameters (such as temperature, total dissolved solids, pH) are also eliminated from further consideration as COPCs. Although the 22 remaining contaminants were eliminated as COPCs, the risk associated with their detected levels is further evaluated as part of the tap water analysis. For example, three uranium isotopes and selenium-79 do not have chemical-specific ARARs published in the federal and state regulations. However, these contaminants do have available toxicity information that was used in the EPA tap water scenario presented in Section 6.5.

The federal DWS for gross beta is based on the 4 mrem/yr annual dose and was used to indicate the presence of a general group of beta emitters. This standard is available, but it requires a conversion from an activity based level (pCi/L) to an annual dose-based rate (mrem/yr). So, beta-emitting radioisotopes such as strontium-90, technetium-99, and tritium were compared to their isotope-specific standards, which are based on a 4 mrem/yr annual dose and are considered more protective than the overall standard for gross beta. In addition, the gross beta standard provides a measure for the daughter products of uranium, which are also beta emitters. Although the 4 mrem/yr standard for gross beta exists, gross beta is not carried forward.

6.1.3.3 Identify Nondetected Contaminants

Chemicals and radionuclides that have been analyzed for, but not detected in any sample (using methods with adequate detection limits), were eliminated as COPCs. All contaminants detected at least once were carried forward.

In total, 94 contaminants were not detected in the 93 wells sampled. The 94 contaminants are listed in Table 6-4 with sampling dates, minimum and maximum method detection limits, the action level, and the basis of the action level. The level of exceedance is also presented and is defined as the ratio between the minimum detection level and the action level. When this ratio is less than 1, the analytical method is defined as adequate for risk quantification and characterization. However, when the ratio is greater than 1, different analytical methods are required for that particular contaminant. Values greater than or equal to 1 are highlighted in Table 6-4.

Table 6-1. Action Levels for the 200-UP-1 OU

CAS No.	Contaminant Name	Contaminant Class	Units	Federal MCL or MCL Goal	WAC 246-290-310 MCL or Maximum Residual Disinfectant Level (MRDL)	WAC 173-340-720 Method B Groundwater Cleanup Levels	WAC 173-340-900 Method A	Action Level	Action Level Basis
7429-90-5	Aluminum	Metal	µg/L	5.00E+01	--	1.60E+04	--	5.00E+01	40 CFR 143.3
7440-36-0	Antimony	Metal	µg/L	6.00E+00	6.00E+00	6.40E+00	--	6.00E+00	40 CFR 141.62
7440-38-2	Arsenic	Metal	µg/L	1.00E+01	1.00E+01	5.83E-02	--	5.83E-02	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-39-3	Barium	Metal	µg/L	2.00E+03	2.00E+03	3.20E+03	--	2.00E+03	40 CFR 141.62
7440-41-7	Beryllium	Metal	µg/L	4.00E+00	4.00E+00	3.20E+01	--	4.00E+00	40 CFR 141.62
7440-69-9	Bismuth	Metal	--	--	--	--	--	--	--
7440-42-8	Boron	Metal	µg/L	--	--	3.20E+03	--	3.20E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-43-9	Cadmium	Metal	µg/L	5.00E+00	5.00E+00	8.00E+00	--	5.00E+00	40 CFR 141.62
7440-70-2	Calcium	Metal	--	--	--	--	--	--	--
7440-47-3	Chromium	Metal	µg/L	1.00E+02	1.00E+02	2.40E+04	--	1.00E+02	40 CFR 141.62
7440-48-4	Cobalt	Metal	µg/L	--	--	4.80E+00	--	4.80E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-50-8	Copper	Metal	µg/L	1.30E+03	--	6.40E+02	--	6.40E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
18540-29-9	Hexavalent Chromium	Metal	µg/L	--	--	4.80E+01	--	4.80E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
7439-89-6	Iron	Metal	µg/L	3.00E+02	3.00E+02	1.12E+04	--	3.00E+02	40 CFR 143.3
7439-92-1	Lead	Metal	µg/L	1.50E+01	--	--	1.50E+01	1.50E+01	40 CFR 141.62
7439-93-2	Lithium	Metal	µg/L	--	--	3.20E+01	--	3.20E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
7439-95-4	Magnesium	Metal	--	--	--	--	--	--	--
7439-96-5	Manganese	Metal	µg/L	5.00E+01	5.00E+01	2.24E+03	--	5.00E+01	40 CFR 143.3
7439-97-6	Mercury	Metal	µg/L	2.00E+00	2.00E+00	2.56E+00	--	2.00E+00	40 CFR 141.62
7439-98-7	Molybdenum	Metal	µg/L	--	--	8.00E+01	--	8.00E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-02-0	Nickel	Metal	µg/L	--	1.00E+02	3.20E+02	--	1.00E+02	WAC 246-290-310
7723-14-0	Phosphorus	Metal	--	--	--	--	--	--	--
7440-09-7	Potassium	Metal	--	--	--	--	--	--	--
7782-49-2	Selenium	Metal	µg/L	5.00E+01	5.00E+01	8.00E+01	--	5.00E+01	40 CFR 141.62
7440-21-3	Silicon	Metal	--	--	--	--	--	--	--
7440-22-4	Silver	Metal	µg/L	1.00E+02	1.00E+02	8.00E+01	--	8.00E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-23-5	Sodium	Metal	--	--	--	--	--	--	--
7440-24-6	Strontium	Metal	µg/L	--	--	9.60E+03	--	9.60E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table 6-1. Action Levels for the 200-UP-1 OU

CAS No.	Contaminant Name	Contaminant Class	Units	Federal MCL or MCL Goal	WAC 246-290-310 MCL or Maximum Residual Disinfectant Level (MRDL)	WAC 173-340-720 Method B Groundwater Cleanup Levels	WAC 173-340-900 Method A	Action Level	Action Level Basis
7440-28-0	Thallium	Metal	µg/L	2.00E+00	2.00E+00	--	--	2.00E+00	40 CFR 141.62
7440-31-5	Tin	Metal	µg/L	--	--	9.60E+03	--	9.60E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-61-1	Uranium	Metal	µg/L	3.00E+01	--	4.80E+01	--	3.00E+01	40 CFR 141.62
7440-62-2	Vanadium	Metal	µg/L	--	--	8.00E+01	--	8.00E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-66-6	Zinc	Metal	µg/L	5.00E+03	5.00E+03	4.80E+03	--	4.80E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
OIL/GREASE	Oil and grease	Oil/Grease	--	--	--	--	--	--	--
88-85-7	Dinoseb(2-secButyl-4,6-dinitrophenol)	PEST	µg/L	7.00E+00	--	1.60E+01	--	7.00E+00	40 CFR 141.61
14234-35-6	Antimony-125	RAD	pCi/L	3.00E+02	--	--	--	3.00E+02	40 CFR 141.66
13966-02-4	Beryllium-7	RAD	--	--	--	--	--	--	--
14762-75-5	Carbon-14	RAD	pCi/L	2.00E+03	--	--	--	2.00E+03	40 CFR 141.66
13967-70-9	Cesium-134	RAD	pCi/L	8.00E+01	--	--	--	8.00E+01	40 CFR 141.66
10045-97-3	Cesium-137	RAD	pCi/L	2.00E+02	--	--	--	2.00E+02	40 CFR 141.66
10198-40-0	Cobalt-60	RAD	pCi/L	1.00E+02	--	--	--	1.00E+02	40 CFR 141.66
14683-23-9	Europium-152	RAD	pCi/L	2.00E+02	--	--	--	2.00E+02	40 CFR 141.66
15585-10-1	Europium-154	RAD	pCi/L	6.00E+01	--	--	--	6.00E+01	40 CFR 141.66
14391-16-3	Europium-155	RAD	pCi/L	6.00E+02	--	--	--	6.00E+02	40 CFR 141.66
12587-46-1	Gross alpha	RAD	pCi/L	1.50E+01	--	--	--	1.50E+01	40 CFR 141.66
12587-47-2	Gross beta	RAD	--	--	--	--	--	--	--
15046-84-1	Iodine-129	RAD	pCi/L	1.00E+00	--	--	--	1.00E+00	40 CFR 141.66
13994-20-2	Neptunium-237	RAD	pCi/L	1.50E+01	--	--	--	1.50E+01	40 CFR 141.66
13966-00-2	Potassium-40	RAD	--	--	--	--	--	--	--
14331-85-2	Protactinium-231	RAD	pCi/L	1.50E+01	--	--	--	1.50E+01	40 CFR 141.66
13982-63-3	Radium-226	RAD	pCi/L	5.00E+00	--	--	--	5.00E+00	40 CFR 141.66
13967-48-1	Ruthenium-106	RAD	pCi/L	3.00E+01	--	--	--	3.00E+01	40 CFR 141.66
15758-45-9	Selenium-79	RAD	--	--	--	--	--	--	--
10098-97-2	Strontium-90	RAD	pCi/L	8.00E+00	--	--	--	8.00E+00	40 CFR 141.66
14133-76-7	Technetium-99	RAD	pCi/L	9.00E+02	--	--	--	9.00E+02	40 CFR 141.66

Table 6-1. Action Levels for the 200-UP-1 OU

CAS No.	Contaminant Name	Contaminant Class	Units	Federal MCL or MCL Goal	WAC 246-290-310 MCL or Maximum Residual Disinfectant Level (MRDL)	WAC 173-340-720 Method B Groundwater Cleanup Levels	WAC 173-340-900 Method A	Action Level	Action Level Basis
ALPHA-RA	Total alpha energy emitted from Radium	RAD	--	--	--	--	--	--	--
10028-17-8	Tritium	RAD	pCi/L	2.00E+04	--	--	--	2.00E+04	40 CFR 141.66
13966-29-5	Uranium-234	RAD	--	--	--	--	--	--	--
15117-96-1	Uranium-235	RAD	--	--	--	--	--	--	--
U-238	Uranium-238	RAD	--	--	--	--	--	--	--
120-82-1	1,2,4-Trichlorobenzene	SVOC	µg/L	7.00E+01	--	1.51E+00	--	1.51E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)
106-46-7	1,4-Dichlorobenzene	SVOC	µg/L	7.50E+01	--	8.10E+00	--	8.10E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)
872-50-4	1-Methyl-2-pyrrolidinone	SVOC	--	--	--	--	--	--	--
58-90-2	2,3,4,6-Tetrachlorophenol	SVOC	µg/L	--	--	4.80E+02	--	4.80E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
95-95-4	2,4,5-Trichlorophenol	SVOC	µg/L	--	--	8.00E+02	--	8.00E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
88-06-2	2,4,6-Trichlorophenol	SVOC	µg/L	--	--	3.98E+00	--	3.98E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)
120-83-2	2,4-Dichlorophenol	SVOC	µg/L	--	--	2.40E+01	--	2.40E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
105-67-9	2,4-Dimethylphenol	SVOC	µg/L	--	--	1.60E+02	--	1.60E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
51-28-5	2,4-Dinitrophenol	SVOC	µg/L	--	--	3.20E+01	--	3.20E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
121-14-2	2,4-Dinitrotoluene	SVOC	µg/L	--	--	2.82E-01	--	2.82E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
87-65-0	2,6-Dichlorophenol	SVOC	--	--	--	--	--	--	--
606-20-2	2,6-Dinitrotoluene	SVOC	µg/L	--	--	1.60E+01	--	1.60E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
111-76-2	2-Butoxyethanol	SVOC	µg/L	--	--	4.00E+03	--	4.00E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
91-58-7	2-Chloronaphthalene	SVOC	µg/L	--	--	6.40E+02	--	6.40E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
95-57-8	2-Chlorophenol	SVOC	µg/L	--	--	4.00E+01	--	4.00E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
91-57-6	2-Methylnaphthalene	SVOC	µg/L	--	--	3.20E+01	--	3.20E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
95-48-7	2-Methylphenol (cresol, o-)	SVOC	µg/L	--	--	4.00E+02	--	4.00E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
88-74-4	2-Nitroaniline	SVOC	µg/L	--	--	1.60E+02	--	1.60E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
88-75-5	2-Nitrophenol	SVOC	--	--	--	--	--	--	--
91-94-1	3,3-Dichlorobenzidine	SVOC	µg/L	--	--	1.94E-01	--	1.94E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
1620-98-0	3,5-Di-tert-butyl-4-hydroxybenzaldehyde	SVOC	--	--	--	--	--	--	--
65794-96-9	3,4 Methylphenol (cresol, m+p)	SVOC	--	--	--	--	--	--	--

Table 6-1. Action Levels for the 200-UP-1 OU

CAS No.	Contaminant Name	Contaminant Class	Units	Federal MCL or MCL Goal	WAC 246-290-310 MCL or Maximum Residual Disinfectant Level (MRDL)	WAC 173-340-720 Method B Groundwater Cleanup Levels	WAC 173-340-900 Method A	Action Level	Action Level Basis
99-09-2	3-Nitroaniline	SVOC	µg/L	--	--	4.17E+00	--	4.17E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)
534-52-1	4,6-Dinitro-2-methylphenol	SVOC	µg/L	--	--	1.60E+00	--	1.60E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)
101-55-3	4-Bromophenylphenyl ether	SVOC	--	--	--	--	--	--	--
59-50-7	4-Chloro-3-methylphenol	SVOC	µg/L	--	--	1.60E+03	--	1.60E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
106-47-8	4-Chloroaniline	SVOC	µg/L	--	--	2.19E-01	--	2.19E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
7005-72-3	4-Chlorophenylphenyl ether	SVOC	--	--	--	--	--	--	--
106-44-5	4-Methylphenol (cresol, p-)	SVOC	µg/L	--	--	4.00E+01	--	4.00E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
100-01-6	4-Nitroaniline	SVOC	µg/L	--	--	4.38E+00	--	4.38E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)
100-02-7	4-Nitrophenol	SVOC	µg/L	--	--	1.28E+02	--	1.28E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
83-32-9	Acenaphthene	SVOC	µg/L	--	--	9.60E+02	--	9.60E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
208-96-8	Acenaphthylene	SVOC	--	--	--	--	--	--	--
120-12-7	Anthracene	SVOC	µg/L	--	--	4.80E+03	--	4.80E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
56-55-3	Benzo(a)anthracene	SVOC	µg/L	--	--	1.20E-01	--	1.20E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
50-32-8	Benzo(a)pyrene	SVOC	µg/L	2.00E-01	--	1.20E-02	--	1.20E-02	WAC 173-340-720(4)(b)(iii)(A) and (B)
205-99-2	Benzo(b)fluoranthene	SVOC	µg/L	--	--	1.20E-01	--	1.20E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
191-24-2	Benzo(ghi)perylene	SVOC	--	--	--	--	--	--	--
207-08-9	Benzo(k)fluoranthene	SVOC	µg/L	--	--	1.20E-01	--	1.20E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
95-16-9	Benzothiazole	SVOC	--	--	--	--	--	--	--
108-60-1	Bis(2-chloro-1-methylethyl)ether	SVOC	µg/L	--	--	6.25E-01	--	6.25E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
111-91-1	Bis(2-Chloroethoxy)methane	SVOC	µg/L	--	--	4.80E+01	--	4.80E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
111-44-4	Bis(2-chloroethyl) ether	SVOC	µg/L	--	--	3.98E-02	--	3.98E-02	WAC 173-340-720(4)(b)(iii)(A) and (B)
117-81-7	Bis(2-ethylhexyl) phthalate	SVOC	µg/L	6.00E+00	--	6.25E+00	--	6.00E+00	40 CFR 141.61
85-68-7	Butylbenzylphthalate	SVOC	µg/L	--	--	4.61E+01	--	4.61E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
86-74-8	Carbazole	SVOC	µg/L	--	--	4.38E+00	--	4.38E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)
218-01-9	Chrysene	SVOC	µg/L	--	--	1.20E+00	--	1.20E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)
53-70-3	Dibenz[a,h]anthracene	SVOC	µg/L	--	--	1.20E-01	--	1.20E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
132-64-9	Dibenzofuran	SVOC	µg/L	--	--	1.60E+01	--	1.60E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table 6-1. Action Levels for the 200-UP-1 OU

CAS No.	Contaminant Name	Contaminant Class	Units	Federal MCL or MCL Goal	WAC 246-290-310 MCL or Maximum Residual Disinfectant Level (MRDL)	WAC 173-340-720 Method B Groundwater Cleanup Levels	WAC 173-340-900 Method A	Action Level	Action Level Basis
84-66-2	Diethylphthalate	SVOC	µg/L	--	--	1.28E+04	--	1.28E+04	WAC 173-340-720(4)(b)(iii)(A) and (B)
131-11-3	Dimethyl phthalate	SVOC	--	--	--	--	--	--	--
84-74-2	Di-n-butylphthalate	SVOC	µg/L	--	--	1.60E+03	--	1.60E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
117-84-0	Di-n-octylphthalate	SVOC	--	--	--	--	--	--	--
206-44-0	Fluoranthene	SVOC	µg/L	--	--	6.40E+02	--	6.40E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
86-73-7	Fluorene	SVOC	µg/L	--	--	6.40E+02	--	6.40E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
118-74-1	Hexachlorobenzene	SVOC	µg/L	1.00E+00	--	5.47E-02	--	5.47E-02	WAC 173-340-720(4)(b)(iii)(A) and (B)
87-68-3	Hexachlorobutadiene	SVOC	µg/L	--	--	5.61E-01	--	5.61E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
77-47-4	Hexachlorocyclopentadiene	SVOC	µg/L	5.00E+01	--	4.80E+01	--	4.80E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
67-72-1	Hexachloroethane	SVOC	µg/L	--	--	3.13E+00	--	3.13E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)
193-39-5	Indeno(1,2,3-cd)pyrene	SVOC	µg/L	--	--	1.20E-01	--	1.20E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
91-20-3	Naphthalene	SVOC	µg/L	--	--	1.60E+02	--	1.60E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
98-95-3	Nitrobenzene	SVOC	µg/L	--	--	1.60E+01	--	1.60E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
621-64-7	n-Nitrosodi-n-dipropylamine	SVOC	µg/L	--	--	1.25E-02	--	1.25E-02	WAC 173-340-720(4)(b)(iii)(A) and (B)
86-30-6	n-Nitrosodiphenylamine	SVOC	µg/L	--	--	1.79E+01	--	1.79E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
87-86-5	Pentachlorophenol	SVOC	µg/L	1.00E+00	--	7.29E-01	--	7.29E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
85-01-8	Phenanthrene	SVOC	--	--	--	--	--	--	--
108-95-2	Phenol	SVOC	µg/L	--	--	2.40E+03	--	2.40E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
64743-03-9	Phenols	SVOC	--	--	--	--	--	--	--
129-00-0	Pyrene	SVOC	µg/L	--	--	4.80E+02	--	4.80E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
1319-77-3	Total cresols	SVOC	µg/L	--	--	1.60E+03	--	1.60E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
TPHKEROSENE	Total petroleum hydrocarbons - kerosene range	SVOC	µg/L	--	--	--	5.00E+02	5.00E+02	WAC 173-340-900, Table 720-1
126-73-8	Tributyl phosphate	SVOC	µg/L	--	--	9.51E+00	--	9.51E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)
115-96-8	Tris-2-chloroethyl phosphate	SVOC	µg/L	--	--	4.38E+00	--	4.38E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)
TPHDIESEL	Total petroleum hydrocarbons - diesel range	TPH	µg/L	--	--	--	5.00E+02	5.00E+02	WAC 173-340-900, Table 720-1
TPHGASOLINE	Total petroleum hydrocarbons - gasoline range	TPH	µg/L	--	--	--	1.00E+03	1.00E+03	WAC 173-340-900, Table 720-1

Table 6-1. Action Levels for the 200-UP-1 OU

CAS No.	Contaminant Name	Contaminant Class	Units	Federal MCL or MCL Goal	WAC 246-290-310 MCL or Maximum Residual Disinfectant Level (MRDL)	WAC 173-340-720 Method B Groundwater Cleanup Levels	WAC 173-340-900 Method A	Action Level	Action Level Basis
179601-23-1	(m+p)-Xylene	VOC	µg/L	1.00E+04	--	1.60E+03	--	1.60E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
630-20-6	1,1,1,2-Tetrachloroethane	VOC	µg/L	--	--	1.68E+00	--	1.68E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)
71-55-6	1,1,1-Trichloroethane	VOC	µg/L	2.00E+02	--	1.60E+04	--	2.00E+02	40 CFR 141.61
79-34-5	1,1,2,2-Tetrachloroethane	VOC	µg/L	--	--	2.19E-01	--	2.19E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
79-00-5	1,1,2-Trichloroethane	VOC	µg/L	5.00E+00	--	7.68E-01	--	7.68E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
75-34-3	1,1-Dichloroethane	VOC	µg/L	--	--	1.60E+03	--	1.60E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
75-35-4	1,1-Dichloroethene	VOC	µg/L	7.00E+00	--	4.00E+02	--	7.00E+00	40 CFR 141.61
96-18-4	1,2,3-Trichloropropane	VOC	µg/L	--	--	1.46E-03	--	1.46E-03	WAC 173-340-720(4)(b)(iii)(A) and (B)
96-12-8	1,2-Dibromo-3-chloropropane	VOC	µg/L	2.00E-01	--	5.47E-02	--	5.47E-02	WAC 173-340-720(4)(b)(iii)(A) and (B)
106-93-4	1,2-Dibromoethane	VOC	µg/L	5.00E-02	--	2.19E-02	--	2.19E-02	WAC 173-340-720(4)(b)(iii)(A) and (B)
95-50-1	1,2-Dichlorobenzene	VOC	µg/L	6.00E+02	--	7.20E+02	--	6.00E+02	40 CFR 141.61
107-06-2	1,2-Dichloroethane	VOC	µg/L	5.00E+00	--	4.81E-01	--	4.81E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
540-59-0	1,2-Dichloroethene (Total)	VOC	µg/L	--	--	7.20E+01	--	7.20E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
78-87-5	1,2-Dichloropropane	VOC	µg/L	5.00E+00	--	1.22E+00	--	1.22E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)
541-73-1	1,3-Dichlorobenzene	VOC	--	--	--	--	--	--	--
123-91-1	1,4-Dioxane	VOC	µg/L	--	--	3.98E+00	--	3.98E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)
71-36-3	1-Butanol	VOC	µg/L	--	--	8.00E+02	--	8.00E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
71-23-8	1-Propanol	VOC	--	--	--	--	--	--	--
78-93-3	2-Butanone	VOC	µg/L	--	--	4.80E+03	--	4.80E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
110-75-8	2-Chloroethyl vinyl ether	VOC	--	--	--	--	--	--	--
104-76-7	2-Ethyl-1-hexanol	VOC	--	--	--	--	--	--	--
591-78-6	2-Hexanone	VOC	µg/L	--	--	8.00E+01	--	8.00E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
107-87-9	2-Pentanone	VOC	--	--	--	--	--	--	--
108-10-1	2-Pentanone, 4-Methyl	VOC	µg/L	--	--	6.40E+02	--	6.40E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
109-06-8	2-Picoline	VOC	--	--	--	--	--	--	--
67-63-0	2-Propanol	VOC	--	--	--	--	--	--	--
67-64-1	Acetone	VOC	µg/L	--	--	7.20E+03	--	7.20E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
75-05-8	Acetonitrile	VOC	--	--	--	--	--	--	--

Table 6-1. Action Levels for the 200-UP-1 OU

CAS No.	Contaminant Name	Contaminant Class	Units	Federal MCL or MCL Goal	WAC 246-290-310 MCL or Maximum Residual Disinfectant Level (MRDL)	WAC 173-340-720 Method B Groundwater Cleanup Levels	WAC 173-340-900 Method A	Action Level	Action Level Basis
107-02-8	Acrolein	VOC	µg/L	--	--	4.00E+00	--	4.00E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)
107-05-1	Allyl chloride	VOC	µg/L	--	--	2.08E+00	--	2.08E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)
71-43-2	Benzene	VOC	µg/L	5.00E+00	--	7.95E-01	--	7.95E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
75-27-4	Bromodichloromethane	VOC	µg/L	--	--	7.06E-01	--	7.06E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
75-25-2	Bromoform	VOC	µg/L	--	--	5.54E+00	--	5.54E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)
74-83-9	Bromomethane	VOC	µg/L	--	--	1.12E+01	--	1.12E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
75-15-0	Carbon disulfide	VOC	µg/L	--	--	8.00E+02	--	8.00E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
56-23-5	Carbon tetrachloride	VOC	µg/L	5.00E+00	--	3.37E-01	--	3.37E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
108-90-7	Chlorobenzene	VOC	µg/L	1.00E+02	--	1.60E+02	--	1.00E+02	40 CFR 141.61
75-00-3	Chloroethane	VOC	--	--	--	--	--	--	--
67-66-3	Chloroform	VOC	µg/L	7.00E+01	--	1.41E+00	--	1.41E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)
74-87-3	Chloromethane	VOC	--	--	--	--	--	--	--
126-99-8	Chloroprene	VOC	µg/L	--	--	1.60E+02	--	1.60E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
156-59-2	cis-1,2-Dichloroethylene	VOC	µg/L	7.00E+01	--	8.00E+01	--	7.00E+01	40 CFR 141.61
10061-01-5	cis-1,3-Dichloropropene	VOC	µg/L	--	--	4.38E-01	--	4.38E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
110-82-7	Cyclohexane	VOC	--	--	--	--	--	--	--
124-48-1	Dibromochloromethane	VOC	µg/L	6.00E+01	--	5.21E-01	--	5.21E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
74-95-3	Dibromomethane	VOC	µg/L	--	--	8.00E+01	--	8.00E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
75-71-8	Dichlorodifluoromethane	VOC	µg/L	--	--	1.60E+03	--	1.60E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
60-29-7	Diethyl ether	VOC	µg/L	--	--	1.60E+03	--	1.60E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
64-17-5	Ethanol	VOC	--	--	--	--	--	--	--
141-78-6	Ethyl acetate	VOC	µg/L	--	--	7.20E+03	--	7.20E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
107-12-0	Ethyl cyanide	VOC	--	--	--	--	--	--	--
97-63-2	Ethyl methacrylate	VOC	µg/L	--	--	7.20E+02	--	7.20E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
100-41-4	Ethylbenzene	VOC	µg/L	7.00E+02	--	3.98E+00	--	3.98E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)
107-21-1	Ethylene glycol	VOC	µg/L	--	--	1.60E+04	--	1.60E+04	WAC 173-340-720(4)(b)(iii)(A) and (B)
110-54-3	Hexane	VOC	µg/L	--	--	4.80E+02	--	4.80E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
74-88-4	Iodomethane	VOC	--	--	--	--	--	--	--

Table 6-1. Action Levels for the 200-UP-1 OU

CAS No.	Contaminant Name	Contaminant Class	Units	Federal MCL or MCL Goal	WAC 246-290-310 MCL or Maximum Residual Disinfectant Level (MRDL)	WAC 173-340-720 Method B Groundwater Cleanup Levels	WAC 173-340-900 Method A	Action Level	Action Level Basis
78-83-1	Isobutyl alcohol	VOC	µg/L	--	--	2.40E+03	--	2.40E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
78-59-1	Isophorone	VOC	µg/L	--	--	4.61E+01	--	4.61E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)
126-98-7	Methacrylonitrile	VOC	µg/L	--	--	8.00E-01	--	8.00E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
74-82-8	Methane	VOC	--	--	--	--	--	--	--
67-56-1	Methanol	VOC	µg/L	--	--	4.00E+03	--	4.00E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
80-62-6	Methyl methacrylate	VOC	µg/L	--	--	1.12E+04	--	1.12E+04	WAC 173-340-720(4)(b)(iii)(A) and (B)
75-09-2	Methylene chloride	VOC	µg/L	5.00E+00	--	5.83E+00	--	5.00E+00	40 CFR 141.61
108-38-3	m-Xylene	VOC	µg/L	--	--	1.60E+03	--	1.60E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
104-51-8	n-Butylbenzene	VOC	--	--	--	--	--	--	--
95-47-6	o-Xylene	VOC	µg/L	--	--	1.60E+03	--	1.60E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
100-42-5	Styrene	VOC	µg/L	1.00E+02	--	1.60E+03	--	1.00E+02	40 CFR 141.61
127-18-4	Tetrachloroethene	VOC	µg/L	5.00E+00	--	8.10E-02	--	8.10E-02	WAC 173-340-720(4)(b)(iii)(A) and (B)
109-99-9	Tetrahydrofuran	VOC	--	--	--	--	--	--	--
108-88-3	Toluene	VOC	µg/L	1.00E+03	--	6.40E+02	--	6.40E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
156-60-5	trans-1,2-Dichloroethylene	VOC	µg/L	1.00E+02	--	1.60E+02	--	1.00E+02	40 CFR 141.61
10061-02-6	trans-1,3-Dichloropropene	VOC	µg/L	--	--	4.38E-01	--	4.38E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
110-57-6	trans-1,4-Dichloro-2-butene	VOC	--	--	--	--	--	--	--
79-01-6	Trichloroethene	VOC	µg/L	5.00E+00	--	4.92E-01	--	4.92E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)
75-69-4	Trichloromonofluoromethane	VOC	µg/L	--	--	2.40E+03	--	2.40E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
108-05-4	Vinyl acetate	VOC	µg/L	--	--	8.00E+03	--	8.00E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
75-01-4	Vinyl chloride	VOC	µg/L	2.00E+00	--	6.08E-02	--	6.08E-02	WAC 173-340-720(4)(b)(iii)(A) and (B)
1330-20-7	Xylenes (total)	VOC	µg/L	1.00E+04	--	1.60E+03	--	1.60E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)
ALKALINITY	Alkalinity	Water Quality	--	--	--	--	--	--	--
7664-41-7	Ammonia	Water Quality	--	--	--	--	--	--	--
24959-67-9	Bromide	Water Quality	--	--	--	--	--	--	--
DO	Dissolved oxygen	Water Quality	--	--	--	--	--	--	--
EH	Oxidation Reduction Potential	Water Quality	--	--	--	--	--	--	--
PH	pH Measurement	Water Quality	--	--	--	--	--	--	--

Table 6-1. Action Levels for the 200-UP-1 OU

CAS No.	Contaminant Name	Contaminant Class	Units	Federal MCL or MCL Goal	WAC 246-290-310 MCL or Maximum Residual Disinfectant Level (MRDL)	WAC 173-340-720 Method B Groundwater Cleanup Levels	WAC 173-340-900 Method A	Action Level	Action Level Basis
CONDUCT	Specific Conductance	Water Quality	--	--	--	--	--	--	--
TEMPERATURE	Temperature	Water Quality	--	--	--	--	--	--	--
TDS	Total dissolved solids	Water Quality	--	--	--	--	--	--	--
TOC	Total organic carbon	Water Quality	--	--	--	--	--	--	--
59473-04-0	Total organic halides	Water Quality	--	--	--	--	--	--	--
TURBIDITY	Turbidity	Water Quality	--	--	--	--	--	--	--
14798-03-9	Ammonium ion	WET CHEM	--	--	--	--	--	--	--
16887-00-6	Chloride	WET CHEM	µg/L	2.50E+05	2.50E+05	--	--	2.50E+05	40 CFR 143.3
57-12-5	Cyanide	WET CHEM	µg/L	2.00E+02	2.00E+02	3.20E+02	--	2.00E+02	40 CFR 141.62
16984-48-8	Fluoride	WET CHEM	µg/L	4.00E+03	4.00E+03	9.60E+02	--	9.60E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)
FE(II)	Iron-II Ion	WET CHEM	--	--	--	--	--	--	--
14797-55-8	Nitrate*	WET CHEM	µg/L	4.50E+04	4.50E+04	1.14E+05	--	4.50E+04	40 CFR 141.62
14797-65-0	Nitrite	WET CHEM	µg/L	3.30E+03	3.30E+03	5.28E+03	--	3.30E+03	40 CFR 141.62
NO_2+NO_3-N	Nitrogen in Nitrite and Nitrate	WET CHEM	µg/L	1.00E+04	--	--	--	1.00E+04	40 CFR 141.62
14265-44-2	Phosphate	WET CHEM	--	--	--	--	--	--	--
14808-79-8	Sulfate	WET CHEM	µg/L	2.50E+05	2.50E+05	--	--	2.50E+05	40 CFR 143.3
18496-25-8	Sulfide	WET CHEM	--	--	--	--	--	--	--

* The listed action level for nitrate is based on the federal MCL for NO_3-N (10 mg/L). A conversion factor is used to derive the concentration in NO_3 to obtain 45,000 µg/L.

RAD = radionuclide

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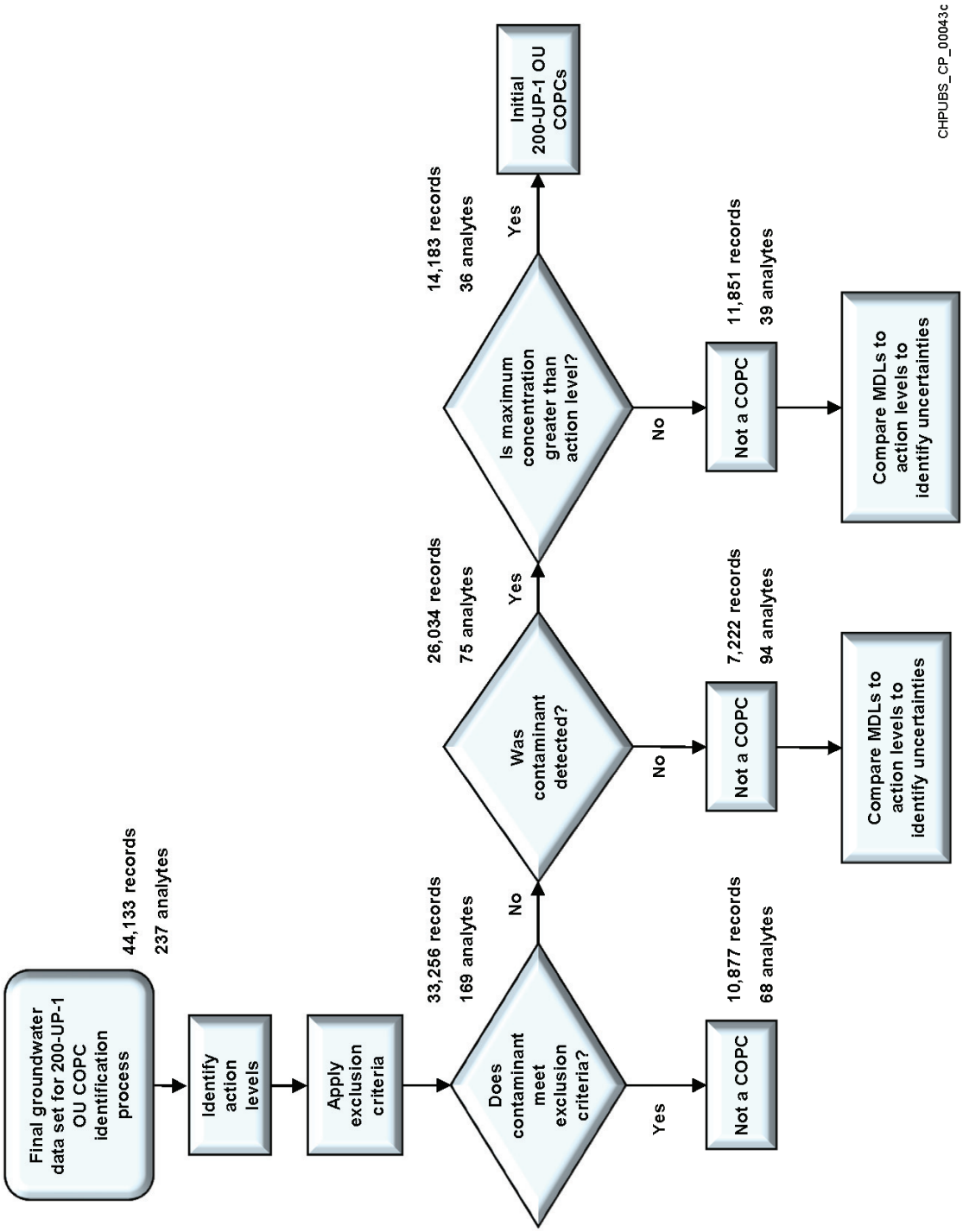

Figure 6-3. Initial COPC Identification—A Multi-step Process

6.1.3.4 Identify Contaminants with Maximum Detected Concentrations Less than Action Levels

In this initial screening, the measured concentrations of each contaminant detected were compared to its action level in order to identify any potential risk-contributing contaminants. If no measured concentrations were detected above the action level, the contaminant was eliminated as an initial COPC, unless the uncertainty analysis indicated it should be retained.

In total, 39 contaminants were detected at least once and had all detected concentrations less than their action levels. A list of these contaminants is presented in Table 6-5 and a summary is provided in Table 6-7. Each contaminant has sampling dates, minimum and maximum method detection limits, minimum and maximum detected concentrations, action levels, the basis for each action level, and the level of exceedance (that is, maximum concentration divided by the action level).

Uncertainty Analysis. An additional evaluation was performed on those contaminants that were detected at concentrations that were near, but did not exceed, their respective action level (that is, the maximum detected concentration was at least greater than one-tenth the action level, or one order of magnitude). The purpose of this evaluation is to determine whether there is a potential for underestimating cumulative effects when the concentrations of contaminants are only slightly less than their action levels. Additionally, method detection limits associated with these contaminants were evaluated to determine whether the limits are adequate for confirming presence or absence of the contaminants near their respective action levels.

The contaminants detected at concentrations that are near, but do not exceed, their respective action levels (that is, with maximum detected concentrations greater than one-tenth of their respective action level, or one order of magnitude) are bromomethane, cyanide, fluoride, lithium, selenium, silver, vanadium, sulfate, tributylphosphate, zinc, and trans-1,3-dichloropropene. The results of the uncertainty analysis indicate that concentrations of these contaminants are consistently below the action level. Elimination would be appropriate and would not lead to underestimating the cumulative risk. This conclusion is also verified using the EPA tap water scenario analysis (Section 6.5).

6.1.3.5 Identify Contaminants with Maximum Detected Concentrations Greater than Action Levels

This step involves identifying contaminants with measured concentrations greater than their respective action levels. Such contaminants have the potential to contribute to overall risk. If any detected concentration of a contaminant is greater than its action level, the contaminant is identified as an initial COPC.

In total, 36 contaminants were detected at least once, with detected concentrations greater than their action levels. A list of each contaminant is presented in Table 6-6 with sampling dates, minimum and maximum method detection limits, minimum and maximum detected concentrations, the action level, and the basis of the action level.

6.1.4 Final Contaminants of Potential Concern Identification Process

Contaminants with detected concentrations greater than the action level were carried forward to the final COPC selection process. Final COPCs are identified by comparing EPCs to their respective action levels, followed with an evaluation of the nature of contamination to identify localized plumes and potential uncertainties. Final COPCs with an EPC value greater than the action level are generally distributed throughout large portions of 200-UP-1 OU. However, a final COPC can also be defined as a smaller area or contaminant “hot spot” that has localized well measurements above the action level and not expressed as an EPC value. Additional detail is provided in this section for those final COPCs identified based on localized well-specific or area-specific measurements.

Table 6-2. Summary of Groundwater Contaminants that meet Exclusion Criteria and were Eliminated from the 200-UP-1 OU Dataset

Contaminant Name	Contaminant Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detects	Units	Min Detection Limit	Max Detection Limit	Min Detected Result	Max Detected Result	Basis for Exclusion
Calcium	Metal	9/9/2004	3/12/2009	272	272	100%	µg/L	--	--	18,000	120,000	Essential Nutrient
Magnesium	Metal	9/9/2004	3/12/2009	272	272	100%	µg/L	--	--	5,750	36,900	Essential Nutrient
Potassium	Metal	9/9/2004	3/12/2009	272	272	100%	µg/L	--	--	2,400	9,610	Essential Nutrient
Sodium	Metal	9/9/2004	3/12/2009	272	272	100%	µg/L	--	--	11,600	39,100	Essential Nutrient
Antimony-125	RAD	2/11/2004	4/1/2009	134	0	0%	pCi/L	-4.65E+00	50	--	--	Half-Life less than 3 years
Beryllium-7	RAD	2/11/2004	4/1/2009	134	0	0%	pCi/L	-3.80E+01	2,230	--	--	Half-Life less than 3 years
Cesium-134	RAD	2/11/2004	4/1/2009	134	0	0%	pCi/L	-1.03E+01	2.9	--	--	Half-Life less than 3 years
Potassium-40	RAD	2/11/2004	4/1/2009	134	0	0%	pCi/L	-6.81E+02	70	--	--	Background Radiation
Ruthenium-106	RAD	2/11/2004	4/1/2009	134	0	0%	pCi/L	-3.80E+01	18	--	--	Half-Life less than 3 years

Table 6-3. Groundwater Contaminants and Water Quality Measurements with No Action Level in the 200-UP-1 OU Dataset

Contaminant Name	Contaminant Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detects	Units	Min Detection Limit	Max Detection Limit	Min Detected Result	Max Detected Result	Note
Bismuth	Metal	3/29/2007	9/30/2008	18	2	11%	µg/L	3.0	6.0	5.0	7.3	No Action Level
Phosphorus	Metal	9/9/2004	9/30/2008	25	13	52%	µg/L	25	50	18	62	No Action Level
Silicon	Metal	9/9/2004	9/30/2008	25	25	100%	µg/L	--	--	4,670	22,800	No Action Level
Oil and grease	Oil/Grease	12/18/2008	12/18/2008	1	1	100%	µg/L	--	--	1,500	1,500	No Action Level
Gross beta	RAD	1/15/2004	2/24/2009	140	140	100%	pCi/L	--	--	3.3	71,800	No Action Level
Selenium-79	RAD	2/18/2004	4/1/2009	128	25	20%	pCi/L	-5.14E+01	30	8.0	2,080	No Action Level
Total alpha energy emitted from Radium	RAD	9/15/2004	9/30/2008	38	0	0%	pCi/L	-3.99E-01	0.17	--	--	No Action Level
Uranium-234	RAD	3/28/2006	3/25/2009	38	38	100%	pCi/L	--	--	0.29	166	No Action Level
Uranium-235	RAD	3/28/2006	3/25/2009	38	7	18%	pCi/L	-1.80E-02	0.11	0.25	7.1	No Action Level
Uranium-238	RAD	8/18/2004	3/25/2009	100	97	97%	pCi/L	0.080	0.22	0.022	170	No Action Level
1-Methyl-2-pyrrolidinone	SVOC	10/12/2004	12/14/2004	4	4	100%	µg/L	--	--	13	38	No Action Level
2,6-Dichlorophenol	SVOC	1/15/2004	3/26/2009	43	0	0%	µg/L	2.1	3.3	--	--	No Action Level
2-Nitrophenol	SVOC	1/15/2004	3/26/2009	109	0	0%	µg/L	0.47	3.3	--	--	No Action Level
3,5-Di-tert-butyl-4-hydroxybenzaldehyde	SVOC	10/12/2004	10/12/2004	1	1	100%	µg/L	--	--	8.4	8.4	No Action Level
3,4 Methylphenol (cresol, m+p)	SVOC	1/15/2004	3/26/2009	92	0	0%	µg/L	0.31	3.3	--	--	No Action Level
4-Bromophenylphenyl ether	SVOC	9/9/2004	2/14/2005	8	0	0%	µg/L	1.0	2.0	--	--	No Action Level
4-Chlorophenylphenyl ether	SVOC	9/9/2004	2/14/2005	8	0	0%	µg/L	1.1	2.3	--	--	No Action Level
Acenaphthylene	SVOC	9/9/2004	2/14/2005	8	0	0%	µg/L	0.99	2.4	--	--	No Action Level
Benzo(ghi)perylene	SVOC	9/9/2004	2/14/2005	8	0	0%	µg/L	2.3	3.1	--	--	No Action Level
Benzothiazole	SVOC	2/18/2004	3/12/2009	68	0	0%	µg/L	0.40	1.0	--	--	No Action Level
Dimethyl phthalate	SVOC	9/9/2004	2/14/2005	8	0	0%	µg/L	2.0	2.2	--	--	No Action Level
Di-n-octylphthalate	SVOC	9/9/2004	2/14/2005	8	0	0%	µg/L	2.2	2.6	--	--	No Action Level
Phenanthrene	SVOC	9/9/2004	2/14/2005	8	0	0%	µg/L	1.4	2.3	--	--	No Action Level
Phenols	SVOC	2/18/2004	3/25/2009	61	6	10%	µg/L	12	34	16	16	No Action Level
1,3-Dichlorobenzene	VOC	9/9/2004	2/14/2005	9	0	0%	µg/L	0.040	5.4	--	--	No Action Level
1-Propanol	VOC	12/28/2007	1/4/2008	2	0	0%	µg/L	5,000	5,000	--	--	No Action Level
2-Chloroethyl vinyl ether	VOC	5/16/2008	5/16/2008	1	0	0%	µg/L	0.43	0.43	--	--	No Action Level

Table 6-3. Groundwater Contaminants and Water Quality Measurements with No Action Level in the 200-UP-1 OU Dataset

Contaminant Name	Contaminant Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detects	Units	Min Detection Limit	Max Detection Limit	Min Detected Result	Max Detected Result	Note
2-Ethyl-1-hexanol	VOC	10/12/2004	12/14/2004	2	2	100%	µg/L	--	--	13	16	No Action Level
2-Pentanone	VOC	9/22/2005	6/21/2006	4	0	0%	µg/L	1.0	1.0	--	--	No Action Level
2-Picoline	VOC	2/18/2004	3/12/2009	68	0	0%	µg/L	0.48	5.9	--	--	No Action Level
2-Propanol	VOC	1/22/2008	1/22/2008	1	1	100%	µg/L	--	--	0.99	0.99	No Action Level
Acetonitrile	VOC	3/17/2004	3/3/2009	126	1	1%	µg/L	0.21	5.3	4.1	4.1	No Action Level
Chloroethane	VOC	3/17/2004	3/3/2009	182	0	0%	µg/L	0.050	10	--	--	No action level
Chloromethane	VOC	3/17/2004	3/3/2009	182	24	13%	µg/L	0.036	10	0.11	1.3	No action level
Cyclohexane	VOC	9/22/2005	6/21/2006	4	0	0%	µg/L	1.0	1.0	--	--	No action level
Ethanol	VOC	12/28/2007	1/4/2008	2	0	0%	µg/L	5,000	5,000	--	--	No Action Level
Ethyl cyanide	VOC	1/15/2004	3/12/2009	508	0	0%	µg/L	0.68	8.8	--	--	No Action Level
Iodomethane	VOC	3/17/2004	3/3/2009	122	3	2%	µg/L	0.090	1.3	0.28	2.3	No Action Level
Methane	VOC	8/18/2004	12/14/2004	13	6	46%	µg/L	5.0	5.0	0.021	23	No Action Level
n-Butylbenzene	VOC	3/1/2004	6/21/2006	5	0	0%	µg/L	0.28	1.0	--	--	No Action Level
Tetrahydrofuran	VOC	1/15/2004	3/12/2009	451	3	1%	µg/L	1.2	12	3.0	480	No Action Level
trans-1,4-Dichloro-2-butene	VOC	3/17/2004	3/3/2009	122	0	0%	µg/L	0.20	2.6	--	--	No Action Level
Alkalinity	Water Quality	1/12/2004	3/12/2009	658	657	100%	µg/L	1,000	1,000	64,000	439,000	Water Quality
Ammonia	Water Quality	2/18/2004	9/26/2007	29	5	17%	µg/L	6.1	26	12	48	No Action Level
Bromide	Water Quality	2/5/2004	10/21/2008	159	44	28%	µg/L	20	1,250	46	320	No Action Level
Dissolved oxygen	Water Quality	11/24/2004	3/26/2009	76	76	100%	µg/L	--	--	990	13,400	Water Quality
Oxidation Reduction Potential	Water Quality	12/14/2004	2/24/2009	17	17	100%	µg/L	--	--	-8.24E+02	485	Water Quality
pH Measurement	Water Quality	1/12/2004	4/28/2009	1224	1224	100%	µg/L	--	--	6.6	9.1	Water Quality
Specific Conductance	Water Quality	1/12/2004	4/28/2009	1218	1218	100%	µg/L	--	--	144	2,905	Water Quality
Temperature	Water Quality	1/12/2004	4/28/2009	1219	1219	100%	µg/L	--	--	9.5	28	Water Quality
Total dissolved solids	Water Quality	1/12/2004	9/30/2008	53	53	100%	µg/L	--	--	95,000	521,000	Water Quality

Table 6-3. Groundwater Contaminants and Water Quality Measurements with No Action Level in the 200-UP-1 OU Dataset

Contaminant Name	Contaminant Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detects	Units	Min Detection Limit	Max Detection Limit	Min Detected Result	Max Detected Result	Note
Total organic carbon	Water Quality	1/15/2004	3/12/2009	113	61	54%	µg/L	200	760	303	10,400	Water Quality
Total organic halides	Water Quality	1/15/2004	3/12/2009	148	114	77%	µg/L	2.2	5.2	2.6	189	Water Quality
Turbidity	Water Quality	1/12/2004	4/28/2009	1219	1219	100%	µg/L	--	--	0.10	1,000	Water Quality
Ammonium ion	WET CHEM	9/9/2004	3/12/2009	45	17	38%	µg/L	2.6	12	6.4	104	No Action Level
Iron-II Ion	WET CHEM	8/31/2004	9/14/2004	4	4	100%	µg/L	--	--	150	780	No Action Level
Phosphate	WET CHEM	3/18/2004	10/21/2008	60	0	0%	µg/L	100	2,500	--	--	No Action Level
Sulfide	WET CHEM	2/18/2004	3/25/2009	75	4	5%	µg/L	83	4,000	1,200	1,600	No Action Level
Total Inorganic Carbon	WET CHEM	8/18/2004	12/14/2004	13	13	100%	µg/L	--	--	17,600	68,200	Water Quality

Table 6-4. Groundwater Contaminants That Were Not Detected for the 200-UP-1 OU

Contaminant Name	Contaminant Class	Units	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detects	Units	Min Detection Limit	Max Detection Limit	Action Level	Action Level Basis	Level of Exceedance
Dinoseb(2-secButyl-4,6-dinitrophenol)	PEST	µg/L	1/15/2004	3/26/2009	43	0	0%	µg/L	2.4	4.2	7.00E+00	40 CFR 141.61	3.43E-01
Cesium-137	RAD	pCi/L	2/11/2004	4/1/2009	141	0	0%	pCi/L	-6.84	16.3	2.00E+02	40 CFR 141.66	-3.42E-02
Cobalt-60	RAD	pCi/L	2/11/2004	4/1/2009	141	0	0%	pCi/L	-3.81	31.6	1.00E+02	40 CFR 141.66	-3.81E-02
Europium-152	RAD	pCi/L	2/18/2004	4/1/2009	127	0	0%	pCi/L	-7.42	5.35	2.00E+02	40 CFR 141.66	-3.71E-02
Europium-154	RAD	pCi/L	2/11/2004	4/1/2009	134	0	0%	pCi/L	-105	8	6.00E+01	40 CFR 141.66	-1.75E+00
Europium-155	RAD	pCi/L	2/11/2004	4/1/2009	134	0	0%	pCi/L	-38.1	4.6	6.00E+02	40 CFR 141.66	-6.35E-02
Radium-226	RAD	pCi/L	3/18/2004	3/31/2004	4	0	0%	pCi/L	0.232	0.611	5.00E+00	40 CFR 141.66	4.64E-02
1,2,4-Trichlorobenzene	SVOC	µg/L	9/9/2004	3/3/2009	38	0	0%	µg/L	0.48	3.1	1.51E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.18E-01
2,4,5-Trichlorophenol	SVOC	µg/L	1/15/2004	3/26/2009	50	0	0%	µg/L	1.8	4.6	8.00E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.25E-03
2,4,6-Trichlorophenol	SVOC	µg/L	1/15/2004	3/26/2009	50	0	0%	µg/L	2.2	4.1	3.98E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)	5.53E-01
2,4-Dichlorophenol	SVOC	µg/L	1/15/2004	3/26/2009	109	0	0%	µg/L	0.27	3.1	2.40E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.13E-02
2,4-Dimethylphenol	SVOC	µg/L	1/15/2004	3/26/2009	50	0	0%	µg/L	1	4.4	1.60E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)	6.25E-03
2,4-Dinitrophenol	SVOC	µg/L	1/15/2004	3/26/2009	50	0	0%	µg/L	2.4	6.7	3.20E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)	7.50E-02
2,4-Dinitrotoluene	SVOC	µg/L	9/9/2004	3/3/2009	38	0	0%	µg/L	0.47	4	2.82E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.67E+00
2,6-Dinitrotoluene	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	2.1	3	1.60E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.31E-01
2-Chloronaphthalene	SVOC	µg/L	9/9/2004	12/16/2004	7	0	0%	µg/L	2.1	2.4	6.40E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.28E-03
2-Chlorophenol	SVOC	µg/L	1/15/2004	3/26/2009	79	0	0%	µg/L	0.47	3.2	4.00E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.18E-02
2-Methylnaphthalene	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	1.1	2	3.20E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.44E-02
2-Methylphenol (cresol, o-)	SVOC	µg/L	1/15/2004	3/26/2009	109	0	0%	µg/L	0.24	4	4.00E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)	6.00E-04
2-Nitroaniline	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	0.71	2.2	1.60E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)	4.44E-03
3,3'-Dichlorobenzidine	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	2.6	4.2	1.94E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.34E+01
3-Nitroaniline	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	0.85	4.6	4.17E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.04E-01
4,6-Dinitro-2-methylphenol	SVOC	µg/L	1/15/2004	3/26/2009	50	0	0%	µg/L	1.6	4	1.60E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.00E+00
4-Chloro-3-methylphenol	SVOC	µg/L	1/15/2004	3/26/2009	79	0	0%	µg/L	0.47	3.2	1.60E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.94E-04
4-Chloroaniline	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	1.3	7.4	2.19E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)	5.94E+00
4-Methylphenol (cresol, p-)	SVOC	µg/L	2/18/2004	10/20/2005	11	0	0%	µg/L	1.5	7.1	4.00E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.75E-02
4-Nitroaniline	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	0.84	3	4.38E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.92E-01
Acenaphthene	SVOC	µg/L	9/9/2004	3/3/2009	38	0	0%	µg/L	0.48	3.1	9.60E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)	5.00E-04

Table 6-4. Groundwater Contaminants That Were Not Detected for the 200-UP-1 OU

Contaminant Name	Contaminant Class	Units	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detects	Units	Min Detection Limit	Max Detection Limit	Action Level	Action Level Basis	Level of Exceedance
Anthracene	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	1.2	2.1	4.80E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.50E-04
Benzo(a)anthracene	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	1.7	2.2	1.20E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.42E+01
Benzo(a)pyrene	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	2	4	1.20E-02	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.67E+02
Benzo(b)fluoranthene	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	1.6	4.3	1.20E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.33E+01
Benzo(k)fluoranthene	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	2.6	4.8	1.20E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.17E+01
Bis(2-chloro-1-methylethyl)ether	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	1.1	2.2	6.25E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.76E+00
Bis(2-Chloroethoxy)methane	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	1.2	2.1	4.80E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.50E-02
Bis(2-chloroethyl) ether	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	1.1	3.5	3.98E-02	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.77E+01
Butylbenzylphthalate	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	1.8	2.1	4.61E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.91E-02
Carbazole	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	1.3	1.5	4.38E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.97E-01
Chrysene	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	2	2.4	1.20E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.67E+00
Dibenz[a,h]anthracene	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	1.4	2.7	1.20E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.17E+01
Dibenzofuran	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	1.2	2	1.60E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)	7.50E-02
Diethylphthalate	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	3.6	6.5	1.28E+04	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.81E-04
Di-n-butylphthalate	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	1.7	2.2	1.60E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.06E-03
Fluoranthene	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	1.5	2.2	6.40E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.34E-03
Fluorene	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	1.2	2.1	6.40E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.88E-03
Hexachlorobenzene	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	1.2	2.2	5.47E-02	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.19E+01
Hexachlorobutadiene	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	0.91	3.7	5.61E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.62E+00
Hexachlorocyclopentadiene	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	2.5	8	4.80E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)	5.21E-02
Hexachloroethane	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	0.8	5.7	3.13E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.56E-01
Indeno(1,2,3-cd)pyrene	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	2.4	2.7	1.20E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.00E+01
Naphthalene	SVOC	µg/L	2/18/2004	3/12/2009	75	0	0%	µg/L	0.3	2.5	1.60E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.88E-03
Nitrobenzene	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	0.86	2.1	1.60E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)	5.38E-02
n-Nitrosodi-n-dipropylamine	SVOC	µg/L	9/9/2004	3/3/2009	38	0	0%	µg/L	0.48	2.4	1.25E-02	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.84E+01
n-Nitrosodiphenylamine	SVOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	1.2	2.4	1.79E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)	6.72E-02
Pentachlorophenol	SVOC	µg/L	1/15/2004	3/26/2009	108	0	0%	µg/L	0.48	4.3	7.29E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)	6.58E-01
Pyrene	SVOC	µg/L	9/9/2004	3/3/2009	38	0	0%	µg/L	0.47	2.2	4.80E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)	9.79E-04
Total cresols	SVOC	µg/L	11/29/2006	3/12/2009	46	0	0%	µg/L	0.48	3.2	1.60E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.00E-04

Table 6-4. Groundwater Contaminants That Were Not Detected for the 200-UP-1 OU

Contaminant Name	Contaminant Class	Units	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detects	Units	Min Detection Limit	Max Detection Limit	Action Level	Action Level Basis	Level of Exceedance
Total petroleum hydrocarbons - kerosene range	SVOC	µg/L	2/18/2004	3/12/2009	71	0	0%	µg/L	36	500	5.00E+02	WAC 173-340-900, Table 720-1	7.20E-02
Tris-2-chloroethyl phosphate	SVOC	µg/L	2/18/2004	3/12/2009	68	0	0%	µg/L	0.24	1.2	4.38E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)	5.49E-02
Total petroleum hydrocarbons - diesel range	TPH	µg/L	8/11/2004	3/12/2009	69	0	0%	µg/L	33	78	5.00E+02	WAC 173-340-900, Table 720-1	6.60E-02
Total petroleum hydrocarbons - gasoline range	TPH	µg/L	2/26/2004	3/12/2009	64	0	0%	µg/L	7.9	250	1.00E+03	WAC 173-340-900, Table 720-1	7.90E-03
(m+p)-Xylene	VOC	µg/L	2/14/2005	2/14/2005	2	0	0%	µg/L	0.09	0.09	1.60E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)	5.63E-05
1,1,1,2-Tetrachloroethane	VOC	µg/L	3/17/2004	3/3/2009	122	0	0%	µg/L	0.04	0.9	1.68E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.38E-02
1,1,1-Trichloroethane	VOC	µg/L	1/15/2004	3/12/2009	563	0	0%	µg/L	0.035	5	2.00E+02	40 CFR 141.61	1.75E-04
1,1,2,2-Tetrachloroethane	VOC	µg/L	3/17/2004	3/3/2009	182	0	0%	µg/L	0.08	5	2.19E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.66E-01
1,2,3-Trichloropropane	VOC	µg/L	3/17/2004	3/3/2009	122	0	0%	µg/L	0.15	1.5	1.46E-03	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.03E+02
1,2-Dibromo-3-chloropropane	VOC	µg/L	3/17/2004	3/3/2009	122	0	0%	µg/L	0.18	2.7	5.47E-02	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.29E+00
1,2-Dibromoethane	VOC	µg/L	3/17/2004	3/3/2009	122	0	0%	µg/L	0.06	0.7	2.19E-02	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.74E+00
1,2-Dichlorobenzene	VOC	µg/L	9/9/2004	2/14/2005	9	0	0%	µg/L	0.09	4.3	6.00E+02	40 CFR 141.61	1.50E-04
1,2-Dichloroethene (Total)	VOC	µg/L	3/17/2004	3/3/2009	182	0	0%	µg/L	0.056	5	7.20E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)	7.78E-04
1,2-Dichloropropane	VOC	µg/L	3/17/2004	3/3/2009	182	0	0%	µg/L	0.054	5	1.22E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)	4.44E-02
1-Butanol	VOC	µg/L	1/15/2004	3/12/2009	455	0	0%	µg/L	1.1	100	8.00E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.38E-03
2-Hexanone	VOC	µg/L	3/17/2004	3/3/2009	182	0	0%	µg/L	0.08	10	8.00E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.00E-03
Allyl chloride	VOC	µg/L	3/17/2004	3/3/2009	122	0	0%	µg/L	0.047	0.8	2.08E+00	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.26E-02
Chloroprene	VOC	µg/L	3/17/2004	3/3/2009	122	0	0%	µg/L	0.046	0.9	1.60E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.88E-04
cis-1,3-Dichloropropene	VOC	µg/L	3/17/2004	3/3/2009	182	0	0%	µg/L	0.05	5	4.38E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.14E-01
Dibromochloromethane	VOC	µg/L	3/17/2004	3/3/2009	182	0	0%	µg/L	0.07	5	5.21E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.34E-01
Dibromomethane	VOC	µg/L	3/17/2004	3/3/2009	122	0	0%	µg/L	0.095	1.4	8.00E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.19E-03
Dichlorodifluoromethane	VOC	µg/L	3/17/2004	3/3/2009	122	0	0%	µg/L	0.045	1.4	1.60E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.81E-05
Diethyl ether	VOC	µg/L	12/28/2007	1/4/2008	2	0	0%	µg/L	5000	5000	1.60E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.13E+00
Ethyl acetate	VOC	µg/L	2/18/2004	3/3/2009	69	0	0%	µg/L	0.23	5000	7.20E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.19E-05
Ethyl methacrylate	VOC	µg/L	3/17/2004	3/3/2009	122	0	0%	µg/L	0.07	0.74	7.20E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)	9.72E-05
Ethylene glycol	VOC	µg/L	12/28/2007	1/4/2008	2	0	0%	µg/L	5000	5000	1.60E+04	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.13E-01
Hexane	VOC	µg/L	9/22/2005	3/3/2008	6	0	0%	µg/L	0.1	1	4.80E+02	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.08E-04

Table 6-4. Groundwater Contaminants That Were Not Detected for the 200-UP-1 OU

Contaminant Name	Contaminant Class	Units	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detects	Units	Min Detection Limit	Max Detection Limit	Action Level	Action Level Basis	Level of Exceedance
Isophorone	VOC	µg/L	9/9/2004	2/14/2005	8	0	0%	µg/L	1.1	2	4.61E+01	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.39E-02
Methacrylonitrile	VOC	µg/L	3/17/2004	3/3/2009	122	0	0%	µg/L	0.3	5.2	8.00E-01	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.75E-01
Methanol	VOC	µg/L	12/28/2007	1/4/2008	2	0	0%	µg/L	5000	5000	4.00E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.25E+00
Methyl methacrylate	VOC	µg/L	3/17/2004	3/3/2009	122	0	0%	µg/L	0.13	1.3	1.12E+04	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.16E-05
m-Xylene	VOC	µg/L	9/22/2005	10/13/2005	4	0	0%	µg/L	5	5	1.60E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.13E-03
o-Xylene	VOC	µg/L	2/14/2005	10/13/2005	6	0	0%	µg/L	0.05	5	1.60E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.13E-05
trans-1,2-Dichloroethylene	VOC	µg/L	1/15/2004	3/12/2009	542	0	0%	µg/L	0.016	5	1.00E+02	40 CFR 141.61	1.60E-04
Trichloromonofluoromethane	VOC	µg/L	3/17/2004	3/3/2009	126	0	0%	µg/L	0.032	1	2.40E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.33E-05
Vinyl acetate	VOC	µg/L	3/17/2004	3/3/2009	122	0	0%	µg/L	0.18	2	8.00E+03	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.25E-05
Vinyl chloride	VOC	µg/L	1/15/2004	3/12/2009	563	0	0%	µg/L	0.044	10	6.08E-02	WAC 173-340-720(4)(b)(iii)(A) and (B)	7.24E-01

Table 6-5. Groundwater Contaminants That Do Not Exceed an Action Level for the 200-UP-1 OU

Contaminant Name	Contaminant Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detects	Units	Min Detection Limit	Max Detection Limit	Min Detected Result	Max Detected Result	Action Level	Action Level Basis	Level of Exceedance
Barium	Metal	3/18/2004	3/12/2009	280	280	100%	µg/L	--	--	16	122	2,000	40 CFR 141.62	6.10E-02
Boron	Metal	9/9/2004	9/30/2008	25	20	80%	µg/L	26	26	14	61	3,200	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.91E-02
Copper	Metal	9/9/2004	3/12/2009	272	49	18%	µg/L	0.80	6.0	1.0	32	640	WAC 173-340-720(4)(b)(iii)(A) and (B)	5.05E-02
Lithium	Metal	9/9/2004	3/12/2009	62	48	77%	µg/L	4.0	9.6	4.1	18	32	WAC 173-340-720(4)(b)(iii)(A) and (B)	5.72E-01
Mercury	Metal	9/9/2004	3/12/2009	56	3	5%	µg/L	0.050	0.10	0.050	0.080	2.0	40 CFR 141.62	4.00E-02
Selenium	Metal	3/18/2004	9/30/2008	45	29	64%	µg/L	0.40	49	1.2	10	50	40 CFR 141.62	2.02E-01
Silver	Metal	9/9/2004	3/12/2009	272	33	12%	µg/L	0.10	6.0	0.21	19	80	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.43E-01
Strontium	Metal	9/9/2004	3/12/2009	256	256	100%	µg/L	--	--	63	534	9,600	WAC 173-340-720(4)(b)(iii)(A) and (B)	5.56E-02
Tin	Metal	3/18/2004	9/30/2008	38	5	13%	µg/L	0.80	6.3	3.4	7.0	9,600	WAC 173-340-720(4)(b)(iii)(A) and (B)	7.29E-04
Vanadium	Metal	3/18/2004	3/12/2009	280	279	100%	µg/L	12	12	0.53	56	80	WAC 173-340-720(4)(b)(iii)(A) and (B)	6.95E-01
Zinc	Metal	3/18/2004	3/12/2009	280	142	51%	µg/L	1.5	9.0	2.2	571	4,800	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.19E-01
Carbon-14	RAD	2/18/2004	3/26/2009	129	17	13%	pCi/L	-2.26E+01	45	7.9	33	2,000	40 CFR 141.66	1.65E-02
Neptunium-237	RAD	2/18/2004	3/26/2009	81	4	5%	pCi/L	-6.02E-02	0.27	0.028	0.20	15	40 CFR 141.66	1.33E-02
Protactinium-231	RAD	8/18/2004	3/12/2009	58	1	2%	pCi/L	-4.47E-01	0.72	1.1	1.1	15	40 CFR 141.66	7.33E-02
1,4-Dichlorobenzene	SVOC	1/15/2004	3/12/2009	457	4	1%	µg/L	0.047	5.2	0.12	0.25	8.1	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.09E-02
2,3,4,6-Tetrachlorophenol	SVOC	1/15/2004	3/26/2009	43	2	5%	µg/L	2.0	4.8	7.5	7.6	480	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.58E-02
2-Butoxyethanol	SVOC	10/12/2004	10/12/2004	1	1	100%	µg/L	--	--	66	66	4,000	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.65E-02
4-Nitrophenol	SVOC	1/15/2004	3/26/2009	79	1	1%	µg/L	0.48	3.2	3.7	3.7	128	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.89E-02
Phenol	SVOC	1/15/2004	3/26/2009	108	1	1%	µg/L	0.26	4.0	9.8	9.8	2,400	WAC 173-340-720(4)(b)(iii)(A) and (B)	4.08E-03
Tributyl phosphate	SVOC	2/18/2004	3/12/2009	68	1	1%	µg/L	0.22	1.5	1.6	1.6	9.5	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.68E-01
1,1-Dichloroethane	VOC	1/15/2004	3/12/2009	563	1	0%	µg/L	0.046	5.0	0.21	0.21	1,600	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.31E-04
1,1-Dichloroethene	VOC	3/17/2004	3/12/2009	547	1	0%	µg/L	0.040	5.0	0.11	0.11	7.0	40 CFR 141.61	1.57E-02
2-Butanone	VOC	1/15/2004	3/12/2009	564	5	1%	µg/L	0.10	10	0.41	120	4,800	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.50E-02
2-Pentanone, 4-Methyl	VOC	1/15/2004	3/12/2009	563	1	0%	µg/L	0.10	10	4.3	4.3	640	WAC 173-340-720(4)(b)(iii)(A) and (B)	6.72E-03
Acetone	VOC	1/15/2004	3/12/2009	567	62	11%	µg/L	0.21	10	0.66	120	7,200	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.67E-02
Bromoform	VOC	3/17/2004	3/3/2009	182	1	1%	µg/L	0.12	5.0	0.40	0.40	5.5	WAC 173-340-720(4)(b)(iii)(A) and (B)	7.22E-02
Bromomethane	VOC	3/17/2004	3/3/2009	181	10	6%	µg/L	0.085	10	0.30	3.7	11	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.30E-01
Carbon disulfide	VOC	1/15/2004	3/12/2009	563	20	4%	µg/L	0.029	5.0	0.13	25	800	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.13E-02

Table 6-5. Groundwater Contaminants That Do Not Exceed an Action Level for the 200-UP-1 OU

Contaminant Name	Contaminant Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detects	Units	Min Detection Limit	Max Detection Limit	Min Detected Result	Max Detected Result	Action Level	Action Level Basis	Level of Exceedance
Chlorobenzene	VOC	3/17/2004	3/12/2009	389	3	1%	µg/L	0.027	5.0	0.092	1.2	100	40 CFR 141.61	1.20E-02
cis-1,2-Dichloroethylene	VOC	1/15/2004	3/12/2009	542	3	1%	µg/L	0.048	5.0	0.28	1.1	70	40 CFR 141.61	1.57E-02
Ethylbenzene	VOC	1/15/2004	3/12/2009	522	1	0%	µg/L	0.061	5.0	0.16	0.16	4.0	WAC 173-340-720(4)(b)(iii)(A) and (B)	4.02E-02
Isobutyl alcohol	VOC	3/17/2004	3/3/2009	122	1	1%	µg/L	5.7	94	52	52	2,400	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.17E-02
Styrene	VOC	3/17/2004	3/3/2009	182	2	1%	µg/L	0.042	5.0	0.16	0.23	100	40 CFR 141.61	2.30E-03
Toluene	VOC	1/15/2004	3/12/2009	592	20	3%	µg/L	0.025	5.0	1.1	28	640	WAC 173-340-720(4)(b)(iii)(A) and (B)	4.38E-02
trans-1,3-Dichloropropene	VOC	3/17/2004	3/3/2009	182	1	1%	µg/L	0.050	5.0	0.10	0.10	0.44	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.29E-01
Xylenes (total)	VOC	1/15/2004	3/12/2009	563	4	1%	µg/L	0.13	5.0	0.33	0.45	1,600	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.81E-04
Cyanide	WET CHEM	2/18/2004	3/12/2009	72	3	4%	µg/L	2.0	4.7	4.1	25	200	40 CFR 141.62	1.26E-01
Fluoride	WET CHEM	1/12/2004	3/12/2009	1,028	1,015	99%	µg/L	63	2,500	49	790	960	WAC 173-340-720(4)(b)(iii)(A) and (B)	8.23E-01
Sulfate	WET CHEM	1/12/2004	3/12/2009	1,037	1,037	100%	µg/L	--	--	170	241,000	250,000	40 CFR 143.3	9.64E-01

Table 6-6. Groundwater Contaminants That Exceed an Action Level for the 200-UP-1 OU

Contaminant Name	Contaminant Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detects	Units	Min Detection Limit	Max Detection Limit	Min Detected Result	Max Detected Result	Action Level	Action Level Basis	Level of Exceedance*
Aluminum	Metal	9/9/2004	12/18/2008	68	40	59%	µg/L	17	80	8.5	311	50	40 CFR 143.3	6.22E+00
Antimony	Metal	9/9/2004	3/12/2009	272	15	6%	µg/L	0.50	60	1.8	74	6.0	40 CFR 141.62	1.24E+01
Arsenic	Metal	3/18/2004	3/12/2009	99	67	68%	µg/L	0.30	34	0.93	6.9	0.058	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.18E+02
Beryllium	Metal	9/9/2004	3/12/2009	272	3	1%	µg/L	0.10	4.0	0.23	5.5	4.0	40 CFR 141.62	1.38E+00
Cadmium	Metal	9/9/2004	3/12/2009	273	1	0%	µg/L	0.10	4.2	9.7	9.7	5.0	40 CFR 141.62	1.94E+00
Chromium	Metal	3/18/2004	3/12/2009	280	191	68%	µg/L	3.1	13	1.3	846	100	40 CFR 141.62	8.46E+00
Cobalt	Metal	9/9/2004	3/12/2009	272	31	11%	µg/L	0.10	6.4	0.15	16	4.8	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.23E+00
Hexavalent Chromium	Metal	6/16/2004	3/26/2009	74	42	57%	µg/L	2.0	5.0	2.0	236	48	WAC 173-340-720(4)(b)(iii)(A) and (B)	4.92E+00
Iron	Metal	9/9/2004	3/12/2009	272	223	82%	µg/L	9.0	45	9.6	3,780	300	40 CFR 143.3	1.26E+01
Lead	Metal	3/18/2004	3/12/2009	84	6	7%	µg/L	0.10	32	0.18	38	15	40 CFR 141.62	2.51E+00
Manganese	Metal	9/9/2004	3/12/2009	273	117	43%	µg/L	0.96	5.4	1.0	580	50	40 CFR 143.3	1.16E+01
Molybdenum	Metal	9/9/2004	9/30/2008	25	25	100%	µg/L	--	--	3.6	87	80	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.08E+00
Nickel	Metal	9/9/2004	3/12/2009	272	104	38%	µg/L	1.0	18	0.90	206	100	WAC 246-290-310	2.06E+00
Thallium	Metal	9/9/2004	9/30/2008	25	5	20%	µg/L	0.10	8.0	0.12	6.0	2.0	40 CFR 141.62	3.00E+00
Uranium	Metal	1/15/2004	3/12/2009	743	736	99%	µg/L	0.050	10	0.097	613	30	40 CFR 141.62	2.04E+01
Gross alpha	RAD	1/15/2004	2/24/2009	148	42	28%	pCi/L	-7.72E+00	17	1.2	17	15	40 CFR 141.66	1.11E+00
Iodine-129	RAD	1/12/2004	4/6/2009	452	79	17%	pCi/L	-3.75E+00	5.1	0.58	39	1.0	40 CFR 141.66	3.87E+01
Strontium-90	RAD	2/9/2004	3/12/2009	134	12	9%	pCi/L	-4.90E+00	2.1	0.60	32	8.0	40 CFR 141.66	4.00E+00
Technetium-99	RAD	1/12/2004	3/12/2009	1094	952	87%	pCi/L	-3.20E+01	855	5.0	137,000	900	40 CFR 141.66	1.52E+02
Tritium	RAD	1/12/2004	3/12/2009	451	348	77%	pCi/L	-2.09E+02	324	220	1.02E+06	20,000	40 CFR 141.66	5.10E+01
Bis(2-ethylhexyl) phthalate	SVOC	2/18/2004	3/12/2009	75	4	5%	µg/L	0.48	3.6	0.90	7.4	6.0	40 CFR 141.61	1.23E+00
1,1,2-Trichloroethane	VOC	1/15/2004	3/12/2009	563	1	0%	µg/L	0.050	5.0	1.0	1.0	0.77	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.30E+00
1,2-Dichloroethane	VOC	1/15/2004	3/12/2009	563	2	0%	µg/L	0.050	5.0	0.66	1.2	0.48	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.50E+00
1,4-Dioxane	VOC	2/9/2004	3/11/2009	340	1	0%	µg/L	2.0	45	120	120	4.0	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.02E+01
Acrolein	VOC	3/17/2004	3/3/2009	122	1	1%	µg/L	0.44	28	11	11	4.0	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.75E+00
Benzene	VOC	1/15/2004	3/12/2009	592	5	1%	µg/L	0.032	5.0	0.085	2.6	0.80	WAC 173-340-720(4)(b)(iii)(A) and (B)	3.27E+00
Bromodichloromethane	VOC	3/17/2004	3/3/2009	182	31	17%	µg/L	0.064	5.0	0.11	1.1	0.71	WAC 173-340-720(4)(b)(iii)(A) and (B)	1.56E+00

Table 6-6. Groundwater Contaminants That Exceed an Action Level for the 200-UP-1 OU

Contaminant Name	Contaminant Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detects	Units	Min Detection Limit	Max Detection Limit	Min Detected Result	Max Detected Result	Action Level	Action Level Basis	Level of Exceedance*
Carbon tetrachloride	VOC	1/15/2004	3/12/2009	628	564	90%	µg/L	0.039	5.0	0.061	1,600	0.34	WAC 173-340-720(4)(b)(iii)(A) and (B)	4.75E+03
Chloroform	VOC	1/15/2004	3/12/2009	614	506	82%	µg/L	0.070	5.0	0.081	35	1.4	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.48E+01
Methylene chloride	VOC	1/15/2004	3/12/2009	565	61	11%	µg/L	0.091	5.0	0.15	71	5.0	40 CFR 141.61	1.42E+01
Tetrachloroethene	VOC	1/15/2004	3/12/2009	605	47	8%	µg/L	0.065	5.0	0.077	3.8	0.081	WAC 173-340-720(4)(b)(iii)(A) and (B)	4.69E+01
Trichloroethene	VOC	1/15/2004	3/12/2009	631	244	39%	µg/L	0.037	5.0	0.16	13	0.49	WAC 173-340-720(4)(b)(iii)(A) and (B)	2.64E+01
Chloride	WET CHEM	1/12/2004	3/12/2009	1034	1034	100%	µg/L	--	--	1,700	386,000	250,000	40 CFR 143.3	1.54E+00
Nitrate	WET CHEM	1/12/2004	3/12/2009	1044	1043	100%	µg/L	58	58	753	1.74E+06	45,000	40 CFR 141.62	3.87E+01
Nitrite	WET CHEM	1/12/2004	3/12/2009	987	66	7%	µg/L	6.6	2,500	33	7,230	3,300	40 CFR 141.62	2.19E+00
Nitrogen in Nitrite and Nitrate	WET CHEM	3/18/2004	9/30/2008	55	53	96%	µg/L	20.0	20.0	2,000	79,300	10,000	40 CFR 141.62	7.93E+00

* Maximum detected value divided by action level.

Table 6-7. Initial COPCs for the 200-UP-1 OU

Metals	Volatile Organic Compounds	Radionuclides
Aluminum Antimony Arsenic Beryllium Cadmium Chromium Cobalt Hexavalent Chromium Iron Lead Manganese Molybdenum Nickel Thallium Uranium	1,1,2-Trichloroethane 1,2-Dichloroethane 1,4-Dioxane Acrolein Benzene Bromodichloromethane Carbon Tetrachloride Chloroform Methylene Chloride Tetrachloroethene Trichloroethene	Gross Alpha Iodine-129 Strontium-90 Technetium-99 Tritium
	Semivolatile Organic Compounds	**Anions**
	Bis(2-ethylhexyl) phthalate	Chloride Fluoride Nitrate Nitrite Nitrogen in Nitrite and Nitrate

Figure 6-4 depicts the final COPC identification process and the number of contaminants associated with each step. The sequence is described in the following subsections.

6.1.4.1 Calculate EPCs for Initial COPCs

EPA Superfund guidance (OSWER 9285.6-10, *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites*) recommends using the 95 percent upper confidence limit (UCL) on the mean concentration for estimating EPCs. However, experience at the Hanford Site indicates that averages and UCLs can sometimes be unreliable for groundwater datasets. The groundwater at 200-UP-1 OU exhibits an aquifer setting where multiple contaminants are present in overlapping plumes (S-SX area, U Plant area, and technetium-99, nitrate, and iodine-129 area), and the highest concentrations have different locations within the plumes.

Because of this overlapping plume condition, the EPC for detected contaminants were estimated by calculating the 90th percentile value. The 90th percentile exposure value methodology is identified by EPA as an accepted means of expressing and characterizing health risks, and it produces risk estimates that correspond to the reasonable maximum exposure. A description of the methodology used to calculate the 90th percentile values and the values themselves are provided below and in Appendix D (ECF-200UP1-10-0229, *Calculation of Exposure Point Concentrations for the 200-UP-1 Groundwater Operable Unit*). The method detection limit was used as the concentration for nondetect results in the 90th percentile calculations. According to EPA (EPA/100/B-04/001, *An Examination of EPA Risk Assessment Principles and Practices*), the reasonable maximum exposure is an appropriate exposure scenario for risk calculations, within the realistic range of exposure, because the goal of the Superfund program is to protect against high end, not average, exposures. The high end is defined as that part of the exposure distribution that is above the 90th percentile but below the 99.9th percentile. Groundwater concentrations directly reflect potential exposures and risks, so a 90th percentile concentration reflects a reasonable maximum exposure scenario.

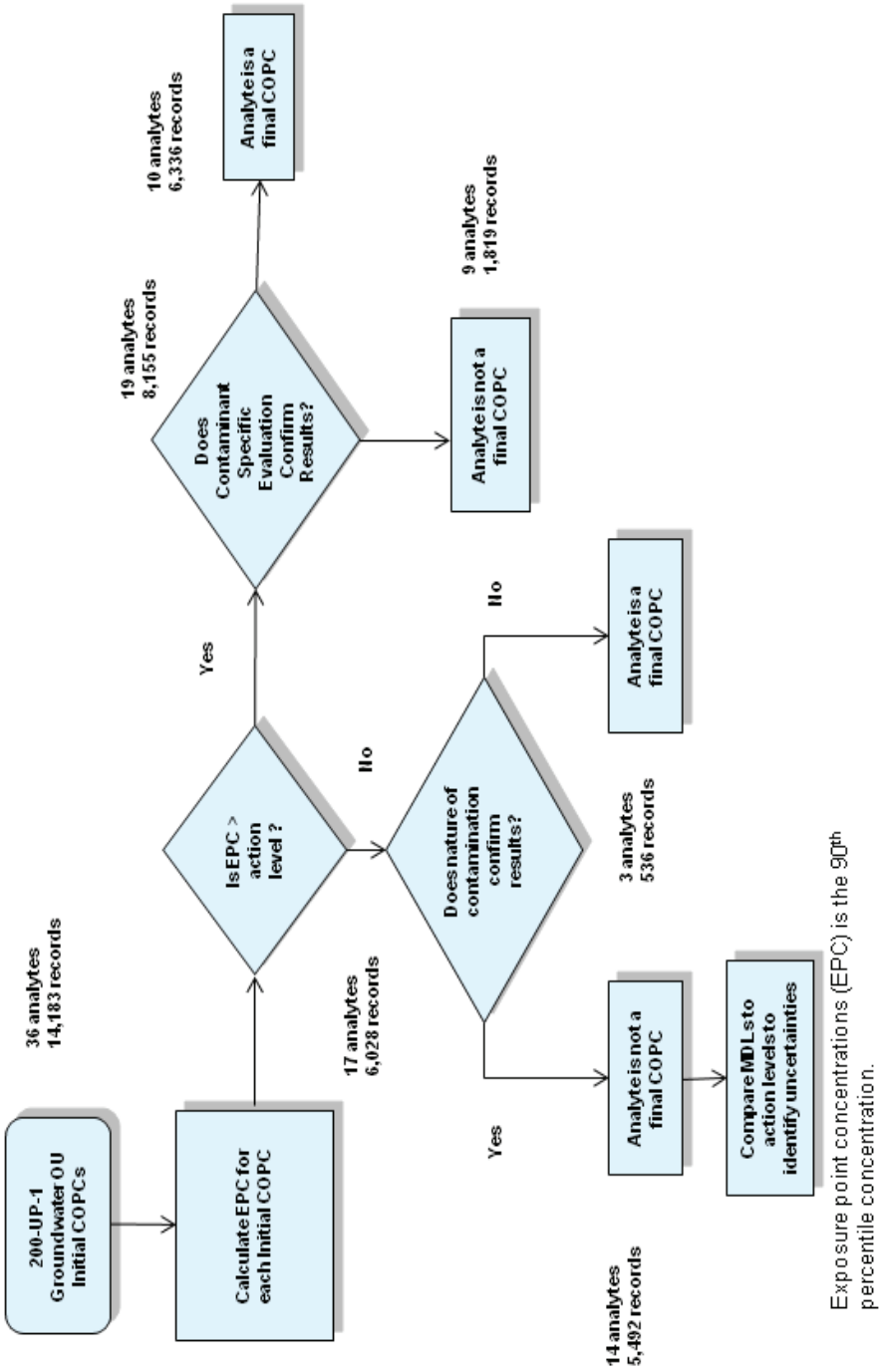

Figure 6-4. Final COPC Identification—A Multi-step Process

Groundwater datasets at Hanford are also skewed because of a large proportion of below method detection limit values. The EPA (EPA/240/B-06/003, *Data Quality Assessment: Statistical Methods for Practitioners*) provides guidance for estimating statistical parameters (whether means or upper percentiles) depending on the variability in the dataset. The variability of the dataset is assessed in terms of the coefficient of variation and the proportion of observations that are below detection limits. For datasets with coefficients of variation greater than 0.5 and 50 percent, or more observations that are below the method detection limit, EPA recommends using upper percentiles as opposed to means to develop summary statistics. Results of the evaluation indicate that, for the majority of COPCs, a reliable and meaningful 95 percent UCL estimate cannot be calculated because of an insufficient number of detects or a high coefficient of variation.

The mean in Table 6-8 was calculated using a simple substitution of concentration values for nondetected values with the method detection limit. For the 95 percent UCL, the nondetects were used to infer probabilities of exceedance values for those samples, and probability density functions were fitted to the datasets to enable the calculation of the 95 percent UCL. For highly skewed and highly censored datasets, these approaches can lead to large differences between the two calculated values. This is especially true when the frequency of nondetects exceeds 80 percent. For example, the calculated mean concentration value for antimony is 31.45 µg/L. This mean value is based on 15 detected values and 257 nondetect values (detection frequency of about 6 percent), for which the method detection limit is used as the observed concentration. When pro UCL used its algorithms to calculate the 95 percent UCL, the recommended calculated value was 5.073 µg/L. This value only highlights the limits of the 95 percent UCL calculations and the need to use judgment in the establishment of the final EPCs. Table 6-8 presents other examples of this.

Results of the EPC calculation. With the exception of 1,2-dichloroethane, beryllium, bis(2-ethylhexyl)phthalate, methylene chloride, and strontium-90, the 90th percentile concentration is greater than the 95 percent UCL value. That is, the 90th percentile (with few exceptions) is a higher concentration than the 95 percent UCL. Although the 95 percent UCL value is greater than the 90th percentile value for these five contaminants, the decision to identify or exclude these contaminant as final COPCs does not change if the 90th percentile or the 95 percent UCL is used to estimate their EPCs.

For beryllium, the 95 percent UCL of 5.5 µg/L is greater than the action level of 4 µg/L, whereas the 90th percentile value is less than the action level. However, beryllium is only detected in 3 of 272 samples, with one of these detections being greater than the action level. Beryllium is not considered a final COPC based on either concentration calculated because these few detections are not associated with a local trend or a localized hot spot.

For 1,2-dichloroethane, the 95 percent UCL of 1.2 µg/L and the 90th percentile value of 0.5 µg/L are greater than the action level of 0.48 µg/L. However, 1,2-dichloroethane is only detected in 2 of 563 samples, with both detections being greater than the action level. Although both statistics are greater than the action level, 1,2-dichloroethane is not a final COPC because the few detections are not associated with a local trend or a localized hot spot.

For methylene chloride, the 95 percent UCL value and the 90th percentile value are equal (1.1 µg/L). Both concentrations are less than the action level of 5 µg/L.

For bis(2-ethylhexyl)phthalate, the 95 percent UCL value (3.9 µg/L) and the 90th percentile value (1.8 µg/L) are less than the action level of 6 µg/L.

Table 6-8. Percentile Concentrations and Summary Statistics for the 200-UP-1 OU Dataset

COPC	Units	Number of Measurements	Number of Detections	90th Percentile	Maximum	Mean	95% UCL	Is 90th Percentile > 95% UCL
Aluminum	µg/L	68	40	96.25	311	69.73	59	Yes
Antimony	µg/L	272	15	28	74.2	31.45	5.073	Yes
Arsenic	µg/L	99	67	6.6	6.9	3.51	3.155	Yes
Beryllium	µg/L	272	3	2	5.5	2.027	5.5	No
Cadmium	µg/L	273	1	2	9.7	9.7	Not Calculated	--
Chromium	µg/L	280	191	99	846	80.19	91.82	Yes
Cobalt	µg/L	272	31	2.8	15.5	6.9	1.681	Yes
Hexavalent Chromium	µg/L	74	42	52	236	25.28	31.61	Yes
Iron	µg/L	272	223	406	3,780	234.2	310.2	Yes
Lead	µg/L	84	6	3.7	37.7	7.866	1.554	Yes
Manganese	µg/L	273	117	18	580	25.35	17.11	Yes
Molybdenum	µg/L	25	25	60	86.6	15.59	35.16	Yes
Nickel	µg/L	272	104	18	206	16.6	8.998	Yes
Thallium	µg/L	25	5	5	6	2.482	1.21	Yes
Uranium	µg/L	743	736	206	613	56.29	80.53	Yes
Gross alpha	pCi/L	148	42	4.1	16.6	3.961	3.171	Yes
Iodine-129	pCi/L	452	79	3.5	38.7	7.273	2.951	Yes
Strontium-90	pCi/L	134	12	0.66	32	7.753	3.485	No
Technetium-99	pCi/L	1,094	952	4,150	137,000	2,730	4,110	Yes
Tritium	µg/L	451	348	51,150	1,020,000	30,661	43,718	Yes

Table 6-8. Percentile Concentrations and Summary Statistics for the 200-UP-1 OU Dataset

COPC	Units	Number of Measurements	Number of Detections	90th Percentile	Maximum	Mean	95% UCL	Is 90th Percentile > 95% UCL
Bis(2-ethylhexyl) phthalate	µg/L	75	4	1.8	7.4	3.6	3.944	No
1,1,2-Trichloroethane	µg/L	563	1	0.5	1	1	Not Calculated	--
1,2-Dichloroethane	µg/L	563	2	0.5	1.2	0.93	1.2	No
1,4-Dioxane	µg/L	340	1	6	120	120	Not Calculated	--
Acrolein	µg/L	122	1	1.4	11	11	Not Calculated	--
Benzene	µg/L	592	5	0.5	2.6	0.853	0.389	Yes
Bromodichloromethane	µg/L	182	31	2.5	1.1	0.289	0.179	Yes
Carbon tetrachloride	µg/L	628	564	189	1,600	95.38	126.6	Yes
Chloroform	µg/L	614	506	7.2	35	3.682	3.359	Yes
Methylene chloride	µg/L	565	61	1.118	71	5.19	1.118	No
Tetrachloroethene	µg/L	605	47	1	3.8	0.775	0.245	Yes
Trichloroethene	µg/L	631	244	3.3	13	2.326	1.163	Yes
Chloride	µg/L	1,034	1,034	30,600	386,000	14,193	16,299	Yes
Fluoride	µg/L	1,028	1,015	470	790	361.8	364.6	Yes
Nitrate	µg/L	1,044	1,043	133,000	1,740,000	76,922	98,692	Yes
Nitrite	µg/L	987	66	105	7,230	463.6	89.75	Yes
Nitrogen in Nitrate and Nitrite	µg/L	55	53	30,650	79,300	14,793	22,109	Yes

For strontium-90, the 95 percent UCL value (3.5 pCi/L) and the 90th percentile value (0.66 µg/L) are less than the action level of 8 pCi/L.

For PCE, the 90th percentile value is considered an elevated concentration because the value is based on a method detection limit that cannot attain the groundwater cleanup standard of 0.081 µg/L. The majority of method detection limits reported for PCE could not confirm the presence of PCE down to a concentration of 0.081 µg/L. Only 36 of 558 (see Table 6-8) nondetected results were reported with a method detection limit less than or equal to 0.081 µg/L. The remaining method detection limits ranged between 0.1 µg/L and 5 µg/L. Therefore, the 90th percentile value for PCE is most likely an overestimation of the reasonable maximum exposure. Additional discussion of the uncertainties associated with the use of the 90th percentile groundwater concentration as an estimate of the EPC is provided in the uncertainty analysis in Section 6.8.

6.1.4.2 Identify COPCs with 90th Percentile Values Less Than Action Levels

The 90th percentile values are compared to the action levels, and the results are provided in Table 6-9.

Contaminant-specific Evaluation. A contaminant-specific evaluation was conducted when the 90th percentile for an initial COPC was less than its action level, but one or more individual sample results were greater than the action level. A flowchart depicting this contaminant-specific evaluation is provided on Figure 6-5. This evaluation is performed to confirm that the initial COPC has not been inappropriately eliminated as a final COPC, and takes into consideration the following specific attributes:

- Is the initial COPC collocated with one or more final COPCs, with some sample concentrations above its action level?
- Is the initial COPC associated with a significant local trend (increasing or persistent concentrations)?
- Is the initial COPC associated with a discrete local exposure point with some concentrations above its action level?

Of 36 initial COPCs, 17 were detected at least once and have 90th percentile values less than their action levels (Table 6-9). Of these 17 initial COPCs, chromium, 1,4-dioxane, and strontium-90 were retained as final COPCs. Acrolein and molybdenum were reported infrequently above their action level and are not retained as final COPCs.

The 90th percentile concentration for total chromium is 99 µg/L, which is approximately equal to the federal MCL of 100 µg/L. If total chromium is assumed to be in hexavalent form, the calculated concentration value would be higher than the State MTCA B Cleanup Level of 48 µg/L. Chromium is identified as a final COPC because there are known sources of chromium in the OU and it occurs in two distinct plume areas (S-SX WMAs and southeastern plume area). Chromium is consistently measured at concentrations above the action level in four wells: Wells 299-W22-44, 299-W22-47, 299-W22-83, and 299-W23-19. Chromium was detected at concentrations ranging between 352 and 686 µg/L in Well 299-W22-44, between 250 and 287µg/L in Well 299-W22-47, between 189 and 234 µg/L in Well 299-W22-83, and between 657 and 846 µg/L in Well 299-W23-19. Chromium was detected at a concentration of 101 µg/L at Well 299-W18-30, but five other sample results were below the federal MCL. Similar conclusions will be made if it is assumed that all total chromium measurements are in hexavalent form.

Table 6-9. Contaminant of Potential Concern Exposure Point Concentration Summary for the 200-UP-1 OU

Contaminant Name	Contaminant Class	Total Samples	Total Detects	Frequency of Detects	Units	Min Detection Limit	Max Detection Limit	Min Detected Result	Max Detected Result	90th Percentile Value	Action Level	Action Level Basis	90th Percentile > Action Level?	Level of Exceedance
Aluminum	Metal	68	40	59%	µg/L	17	80	8.5	311	96	50	40 CFR 143.3	Yes	1.93E+00
Antimony	Metal	272	15	6%	µg/L	0.50	60	1.8	74	28	6.0	40 CFR 141.62	Yes	4.67E+00
Arsenic	Metal	99	67	68%	µg/L	0.30	34	0.93	6.9	7	0.058	WAC 173-340-720(4)(b)(iii)(A) and (B)	Yes	1.13E+02
Beryllium	Metal	272	3	1%	µg/L	0.10	4.0	0.23	5.5	2	4.0	40 CFR 141.62	No	5.00E-01
Cadmium	Metal	273	1	0%	µg/L	0.10	4.2	9.7	9.7	2	5.0	40 CFR 141.62	No	4.00E-01
Chromium	Metal	280	191	68%	µg/L	3.1	13	1.3	846	99	100	40 CFR 141.62	No	9.90E-01
Cobalt	Metal	272	31	11%	µg/L	0.10	6.4	0.15	16	3	4.8	WAC 173-340-720(4)(b)(iii)(A) and (B)	No	5.83E-01
Hexavalent Chromium	Metal	74	42	57%	µg/L	2.0	5.0	2.0	236	52	48	WAC 173-340-720(4)(b)(iii)(A) and (B)	Yes	1.08E+00
Iron	Metal	272	223	82%	µg/L	9.0	45	9.6	3,780	406	300	40 CFR 143.3	Yes	1.35E+00
Lead	Metal	84	6	7%	µg/L	0.10	32	0.18	38	4	15	40 CFR 141.62	No	2.47E-01
Manganese	Metal	273	117	43%	µg/L	0.96	5.4	1.0	580	18	50	40 CFR 143.3	No	3.60E-01
Molybdenum	Metal	25	25	100%	µg/L	--	--	3.6	87	60	80	WAC 173-340-720(4)(b)(iii)(A) and (B)	No	7.50E-01
Nickel	Metal	272	104	38%	µg/L	1.0	18	0.90	206	18	100	WAC 246-290-310	No	1.80E-01
Thallium	Metal	25	5	20%	µg/L	0.10	8.0	0.12	6.0	5	2.0	40 CFR 141.62	Yes	2.50E+00
Uranium	Metal	743	736	99%	µg/L	0.050	10	0.097	613	206	30	40 CFR 141.62	Yes	6.87E+00
Gross alpha	RAD	148	42	28%	pCi/L	-7.72E+00	17	1.2	17	4	15	40 CFR 141.66	No	2.73E-01
Iodine-129	RAD	452	79	17%	pCi/L	-3.75E+00	5.1	0.58	39	4	1.0	40 CFR 141.66	Yes	3.50E+00
Strontium-90	RAD	134	12	9%	pCi/L	-4.90E+00	2.1	0.66	32	1	8.0	40 CFR 141.66	No	8.25E-02
Technetium-99	RAD	1094	952	87%	pCi/L	-3.20E+01	855	5.0	137,000	4150	900	40 CFR 141.66	Yes	4.61E+00
Tritium	RAD	451	348	77%	pCi/L	-2.09E+02	324	220	1.02E+06	51150	20,000	40 CFR 141.66	Yes	2.56E+00
Bis(2-ethylhexyl) phthalate	SVOC	75	4	5%	µg/L	0.48	3.6	0.90	7.4	2	6.0	40 CFR 141.61	No	3.00E-01
1,1,2-Trichloroethane	VOC	563	1	0%	µg/L	0.050	5.0	1.0	1.0	0.5	0.77	WAC 173-340-720(4)(b)(iii)(A) and (B)	No	6.51E-01
1,2-Dichloroethane	VOC	563	2	0%	µg/L	0.050	5.0	0.66	1.2	0.66	0.48	WAC 173-340-720(4)(b)(iii)(A) and (B)	Yes	1.04E+00
1,4-Dioxane	VOC	340	1	0%	µg/L	2.0	45	120	120	6	4.0	WAC 173-340-720(4)(b)(iii)(A) and (B)	Yes	1.51E+00
Acrolein	VOC	122	1	1%	µg/L	0.44	28	11	11	1.4	4.0	WAC 173-340-720(4)(b)(iii)(A) and (B)	No	3.50E-01
Benzene	VOC	592	5	1%	µg/L	0.032	5.0	0.085	2.6	0.5	0.80	WAC 173-340-720(4)(b)(iii)(A) and (B)	No	6.29E-01
Bromodichloromethane	VOC	182	31	17%	µg/L	0.064	5.0	0.11	1.1	3	0.71	WAC 173-340-720(4)(b)(iii)(A) and (B)	Yes	3.54E+00
Carbon tetrachloride	VOC	628	564	90%	µg/L	0.039	5.0	0.061	1,600	189	0.34	WAC 173-340-720(4)(b)(iii)(A) and (B)	Yes	5.62E+02

Table 6-9. Contaminant of Potential Concern Exposure Point Concentration Summary for the 200-UP-1 OU

Contaminant Name	Contaminant Class	Total Samples	Total Detects	Frequency of Detects	Units	Min Detection Limit	Max Detection Limit	Min Detected Result	Max Detected Result	90th Percentile Value	Action Level	Action Level Basis	90th Percentile > Action Level?	Level of Exceedance
Chloroform	VOC	614	506	82%	µg/L	0.070	5.0	0.081	35	7	1.4	WAC 173-340-720(4)(b)(iii)(A) and (B)	Yes	5.10E+00
Methylene chloride	VOC	565	61	11%	µg/L	0.091	5.0	0.15	71	1	5.0	40 CFR 141.61	No	2.24E-01
Tetrachloroethene	VOC	605	47	8%	µg/L	0.065	5.0	0.077	3.8	1	0.081	WAC 173-340-720(4)(b)(iii)(A) and (B)	Yes	1.23E+01
Trichloroethene	VOC	631	244	39%	µg/L	0.037	5.0	0.16	13	3	0.49	WAC 173-340-720(4)(b)(iii)(A) and (B)	Yes	6.71E+00
Chloride	WET CHEM	1034	1034	100%	µg/L	--	--	1,700	386,000	30600	250,000	40 CFR 143.3	No	1.22E-01
Nitrate	WET CHEM	1044	1043	100%	µg/L	58	58	753	1.74E+06	133000	45,000	40 CFR 143.62	Yes	2.96E+00
Nitrite	WET CHEM	987	66	7%	µg/L	6.6	2,500	33	7,230	105	3,300	40 CFR 143.62	No	3.18E-02
Nitrogen in Nitrate and Nitrite	WET CHEM	55	53	96%	µg/L	20.0	20.0	2,000	79,300	30,650	10,000	40 CFR 141.62	Yes	3.37E+00

RAD = radionuclide

SVOC = semivolatile organic compound

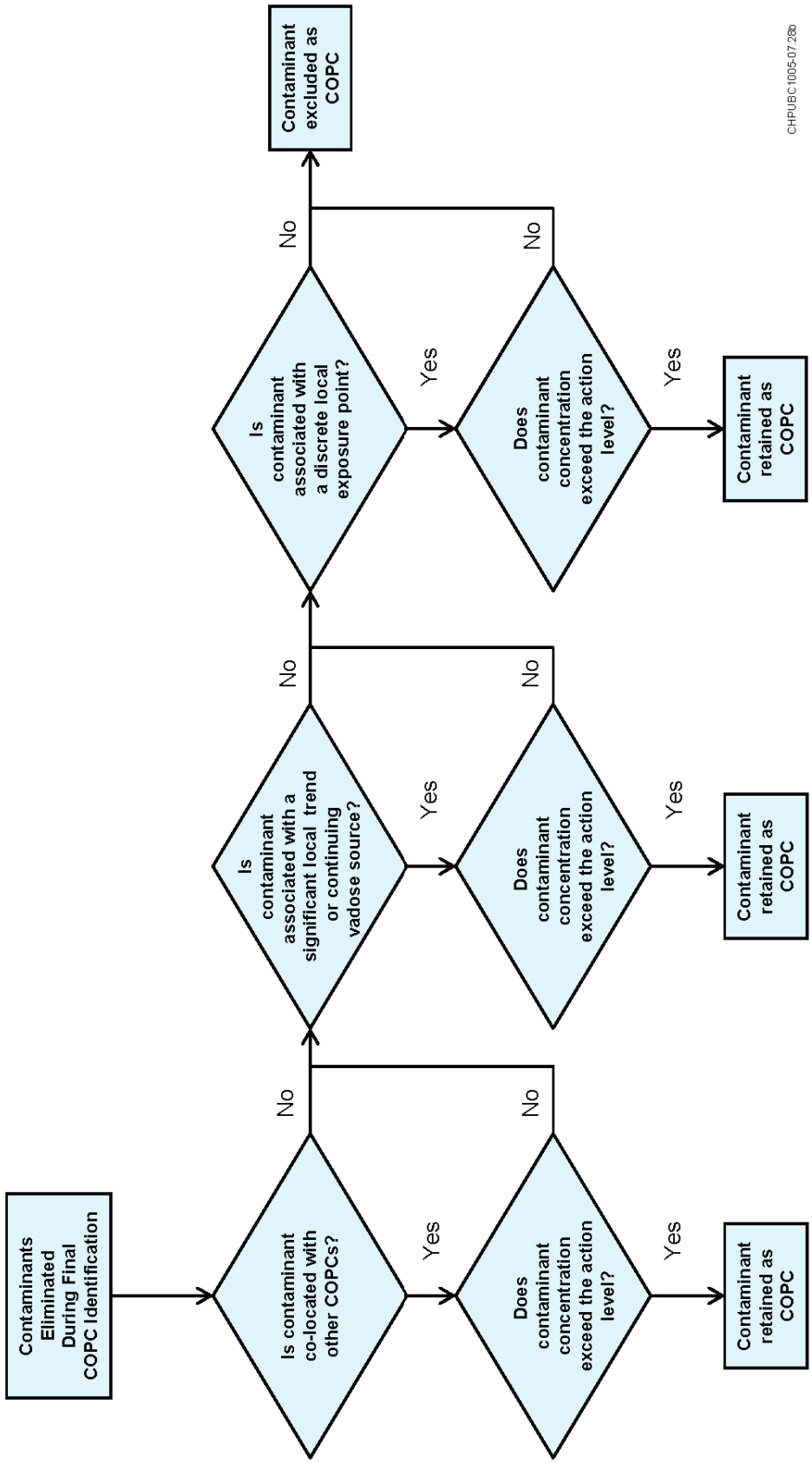

Figure 6-5. Contaminant-Specific Evaluation

One detection of 1,4-dioxane occurred in Well 299-W22-20, which is downgradient from the 216-S-20 Crib, at a concentration of 120 µg/L (The MTCA B cleanup level is about 4 µg/L). In addition, 1,4-dioxane was measured at Well 299-W22-20 between 2002 and 2003 at concentrations ranging between 110 µg/L and 160 µg/L but was not measured at any other location between 1999 and 2009. Nevertheless, 1,4-dioxane is identified as a final COPC.

Strontium-90 was detected at concentrations ranging between 0.66 and 32 pCi/L between 2000 and 2005 at Well 299-W22-10, which is downgradient from the 216-S-1 and 216-S-2 Cribs. No other samples were collected from this location after 2005. Strontium-90 was not detected above the action level of 8 pCi/L (federal MCL) at any other location between 1999 and 2009. Strontium-90 is identified as a final COPC.

The 90th percentile value for acrolein is 1.4 µg/L, which is below the action level of 4.0 µg/L. It was detected once in Well 699-36-70B (B1BNM3) at a concentration of 11 µg/L. Acrolein was analyzed 13 times at the same well between 2004 and 2008, with the single detection occurring in 2004 and the remaining reported method detection limits at less than the action level. As a result, acrolein is not considered to be associated with a trend or local exposure point and is not identified as a final COPC.

The 90th percentile value for molybdenum is 60 µg/L which is below the action level of 80 µg/L (MTCA B Cleanup Level). Molybdenum was detected in 25 of 25 water samples (9 locations) collected between 2004 and 2009. Two wells were reported with concentrations slightly above the action level (83.8 and 86.6 µg/L) at Wells 699-30-66 and 699-36-70B, respectively. One subsequent sample round from Well 699-30-66 reported molybdenum at a concentration less than the action level. No other samples were analyzed for molybdenum at Well 699-36-70B. Hanford Site background concentrations of molybdenum in filtered and unfiltered samples range between 1.8 and 12 µg/L. The results of this evaluation suggest that molybdenum concentrations are greater than Site background, and the majority of results are below the action level. Molybdenum is not associated with a trend or local exposure point and is not identified as a final COPC.

6.1.4.3 Identify COPCs with 90th Percentile Values Greater Than Action Levels

The 90th percentile values are compared to the action levels, and the results are provided in Table 6-9.

Contaminant-Specific Evaluation. A contaminant-specific evaluation was performed on initial COPCs with EPC values greater than their action levels. A flow chart depicting this contaminant-specific evaluation is provided on Figure 6-5. This step was performed to confirm that the EPC value has not inappropriately identified an initial COPC as a final COPC and takes into consideration the following effects that data quality, naturally occurring levels, and action level selection have on COPC identification:

- Is the initial COPC at or below background levels and thus a naturally occurring substance?
- Are there data quality issues associated with the analytical dataset?

Of the 36 initial COPCs, 19 have been detected at least once and have EPC values greater than their respective action levels (Table 6-9). Of these 19 initial COPCs, carbon tetrachloride, chloroform, hexavalent chromium, iodine-129, nitrate, PCE, TCE, technetium-99, tritium, and uranium are identified as final COPCs. The remaining contaminants were eliminated as final COPCs because they are considered naturally occurring, their action levels are secondary MCLs, or they have data quality issues. For example, antimony is not retained as a final COPC. For antimony, the analytical method used for the available measurements is not considered reliable because detected concentrations are reported to be false positives, and method detection limits are generally above the federal MCL. Arsenic and cobalt concentrations fall within naturally occurring values and are considered to be within background values.

Summary of Final Groundwater COPCs. The final COPCs selected are listed in Table 6-10. These final COPCs are the contaminants most likely to contribute to overall risk. The detailed evaluation and selection of the final COPCs are presented in Appendix D (ECF-200UP1-10-0231).

Table 6-10. Final Groundwater COPCs for the 200-UP-1 OU

Metals	Volatile Organic Compounds	Radionuclides	Anions
Chromium Hexavalent Chromium Uranium	1,4-Dioxane* Carbon Tetrachloride Chloroform Tetrachloroethene Trichloroethene	Iodine-129 Strontium-90* Technetium-99 Tritium	Nitrate

* EPC did not exceed action level, but was retained as a final COPC because of localized contamination.

With the exception of 1,4-dioxane and strontium-90, all final COPCs were identified because the EPC value exceeded the action level. Final COPCs 1,4-Dioxane and strontium-90 were identified because they are associated with localized areas having long-term trends (or hot spots). The 90th percentile value for 1,4-dioxane is 6 µg/L, which is greater than the action level of 4 µg/L. It was detected once at Well 299-W22-20, which is downgradient from the 216-S-20 Crib, at a concentration of 120 µg/L, based on 2004 to 2009 data. It was also measured at Well 299-W22-20 between 2002 and 2003 at concentrations ranging between 110 µg/L and 160 µg/L. Finally, 1,4-dioxane was not measured at any other locations between 1999 and 2009. Strontium-90 concentration values are discussed in Section 6.1.4.2.

Results of the COPC identification process were verified (Section 6.5) using the EPA tap water scenario to ensure that the COPC identification process did not screen out any significant risk drivers contributing more than 1 percent to overall risk or hazard. EPA/540/1-89/002 suggests that contaminants contributing less than 1 percent of the total risk or hazard can be eliminated as COPCs. The process used to identify COPCs for this OU that are carried into the risk characterization step is more conservative (that is, the process identifies more contaminants) than EPA recommends. As described in Section 6.1.2, the lowest available standard or cleanup level is selected as the action level for COPC identification.

6.2 Exposure Assessment

The exposure assessment component of the risk assessment identifies the populations that may be exposed, the routes of exposure, and the magnitude, frequency, and duration of the potential exposures.

This section also provides the conceptual exposure model for the 200-UP-1 OU. It identifies the means by which human or ecological receptors may contact contaminants in groundwater. The conceptual exposure model provides a current understanding of the sources of contamination, physical setting, current and reasonably anticipated future land use, and groundwater beneficial use. The model identifies potentially complete human and ecological exposure pathways. Site information from previous investigations and work plans has been incorporated into the conceptual exposure model to identify potential exposure scenarios.

6.2.1 Current and Reasonably Anticipated Future Land Use

Current land use on the Central Plateau is industrial, and public access to the site is restricted (PNNL-15892, *Hanford Site Environmental Report for Calendar Year 2005*). Land use in the 200 West

and 200 East Areas are anticipated to remain industrial for the foreseeable future and will be used for ongoing waste disposal operations and infrastructure services.

Anticipated Future Land Use

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*, 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 HCP EIS (DOE/EIS-0222-F) and associated HCP EIS ROD (64 FR 61615) in 1999. The HCP EIS analyzes the potential environmental impacts of alternative land-use plans for Hanford 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 exclusive use, defined as areas suitable and desirable for TSD of hazardous, dangerous, radioactive, and nonradioactive wastes, as well as related activities.

Subsequent to the HCP EIS, the HAB issued HAB Advice #132 ("Exposure Scenarios Task Force on the 200 Area" [HAB 132 2002.T]). The HAB acknowledged that some waste would remain in the core zone of the Central Plateau when cleanup is complete. The goal identified within HAB Advice #132 is that the core zone be as small as possible and not include contaminated areas outside the Central Plateau's fenced areas. HAB Advice #132 further stated that waste within the core zone should be stored and managed to make it inaccessible to inadvertent intruding humans and biota, and that the DOE should maximize the potential for any beneficial use of the accessible areas of the core zone. The HAB advised that risk scenarios for the waste management areas of the core zone should include a reasonable maximum exposure to a worker/day user and to an intruder.

In response to HAB Advice #132 ("Consensus Advice #132: Exposure Scenarios Task Force on the 200 Area" [Klein et al. 2002]), and for the purposes of the 200-ZP-1 OU remedial action, 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. Following that period, the area above the 200-ZP-1 OU area is 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 will be required.

6.2.2 Groundwater Beneficial Use

CERCLA and the NCP (40 CFR 300) establish separate requirements for a groundwater remedy. They are to be protective of human health and the environment, and to meet applicable or relevant and appropriate requirements (ARARs). This is a concept of central importance to the development of the groundwater remedy for the 200-UP-1 OU. These separate requirements are further clarified in a memorandum (Fields, 1997, "Clarification of the Role of Applicable, or Relevant and Appropriate Requirements in Establishing Preliminary Remediation Goals under CERCLA").

The requirement to achieve threshold protectiveness and ARAR-based requirements is established by the NCP (40 CFR 300). The NCP (40 CFR 300) also establishes the requirement to return useable groundwater to beneficial use within a reasonable time frame. EPA generally defers to state agency definitions of useable groundwater provided under state groundwater protection programs and a state's

determination of groundwater usability at CERCLA sites (EPA/540/G-88/003, *Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites, Interim Final*). The State of Washington defines groundwater as potable in WAC 173-340-720(2), unless the exclusion criteria in WAC 173-340-720(2)(a) through (c) can be demonstrated (insufficient yield, natural constituents that make it unsuitable as a drinking water source). The groundwater beneath the Central Plateau does not meet the exclusion criteria; therefore, it is classified as potable and must be restored to beneficial use wherever practicable, and within a reasonable time frame. The State of Washington has further determined that the highest beneficial use for potable groundwater, including the potable groundwater at the Hanford Site, is as a potential source of domestic drinking water (WAC 173-340-720(1)(a)).

Groundwater beneath the Central Plateau is currently contaminated, and withdrawal is prohibited as a result of institutional controls placed on it by DOE. Under current Site use conditions, there are no complete human or ecological exposure pathways. Further, regardless of land use designations for soils, groundwater within this OU is not anticipated to become a future source of drinking water until cleanup criteria are met and groundwater is restored to its highest beneficial use. However, groundwater in this risk analysis is evaluated for drinking water use to support the determination of the basis for action and to support the development of preliminary remediation goals (PRGs) for evaluating remedial alternatives in Chapters 7, 8, and 9.

6.2.3 200-UP-1 OU Exposure Area

The exposure area is defined by the boundaries of the 200-UP-1 OU and the associated groundwater plumes.

6.2.4 Conceptual Exposure Model for Human Health and the Environment

This section describes the potential exposure pathways resulting from Site contaminants, based on currently available information. Appendix A shows the locations of each monitoring well included in this BRA. The conceptual exposure model is formulated according to EPA guidance, and information on contaminant sources, release mechanisms, routes of migration, potential exposure points, potential routes of exposure, and potential receptor groups.

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

- A source
- A mechanism of chemical release
- An environmental transport mechanism
- An exposure point
- An exposure route
- A receptor or exposed population

In the absence of any one of these components, an exposure pathway is considered incomplete and, therefore, creates no risk or hazard. Figure 6-6 schematically presents the exposure pathway analysis in the form of a human and ecological conceptual exposure model. Figure 6-6 presents a complete conceptual exposure model, although not all pathways are applicable in the 200-UP-1 OU, as signified by use of gray process arrows instead of black (for example, the Columbia River pathway is shown as inactive, so fish consumption, for instance, is not applicable).

6.2.4.1 Contaminant Sources

The primary sources of contaminants that are known or suspected to have contributed to contamination include liquid chemical and radiological process wastes, process wastewater and sanitary sewer wastes generated during historical operations of S Plant, U Plant, S-SX WMA, and U WMA.

The observed groundwater contamination is believed to have resulted from historical discharge of large volumes of liquid wastes and wastewater to the ground. These wastes were discharged in volumes that exceeded the porosity of the soil beneath the waste sites and resulted in downward migration of associated contaminants into underlying groundwater. In some cases, the resulting groundwater contaminant concentrations in the immediate vicinity of the release point, and adjacent groundwater downgradient from the release point, substantially exceed cleanup target concentrations.

Continued contribution of contaminants to groundwater from downward migration of residual contaminants within the vadose zone soil column was not included in the BRA. As shown on Figure 5-62, assessment of the groundwater immediately beneath a source area and affected by the overlying waste sites is the responsibility of the source waste site. Solid waste materials disposed of into the ground (to dumps, pits, or burial grounds) are generally not considered to have affected groundwater at this time. Those waste materials were not disposed of, along with large volumes of water or wastewater, and are not expected to affect groundwater in the future.

6.2.4.2 Release Mechanisms and Environmental Transport Medium

The contaminants observed in groundwater all resulted from release of process liquid wastes and wastewater to the soil via discharge to engineered structures (cribs, trenches, ditches, ponds, leach fields, or injection wells) in the case of intentional releases. Unintentional or unplanned releases typically resulted from inadvertent releases of similar waste materials from tanks, pipelines, or other waste storage or conveyance components. Most of the liquid waste and wastewater that contributed to observed groundwater contamination entered the soil column directly and migrated downward through the soil column by gravity to reach the groundwater. In most instances, the vadose zone has drained its readily drainable waste, and continued contributions are no longer apparent. Model uncertainties include the possibility that some sites may continue to function as continuing sources. This uncertainty is addressed in Section 5.2.2.2.

Upon entering the groundwater at the water table, contaminants migrate in a downward direction away from the point of entry. Groundwater flow directions within the OU have varied substantially over the period of historical operations. During the first years of operation, groundwater flowed generally west to east. As discharge of large volumes of wastewater to surface infiltration ponds within the 200 West Area continued, substantial groundwater mounds developed. Groundwater then flowed radially away from these mounds in all directions. When these large volume discharges were stopped in the 1990s, the mounds began to dissipate and flow directions began to return to a more natural condition (generally west to east). The groundwater flow system has not yet returned to it fully natural state; however, there is little evidence of the historical radial flows associated with the groundwater mounds. Section 5.1 and Section 5.2 provide additional descriptions of the processes that affect contaminant migration within the affected aquifer.

6.2.4.3 Potentially Complete Exposure Pathways and Receptors

Except for monitoring purposes, groundwater is not currently withdrawn from the aquifer and there are no complete exposure pathways for receptor populations. In addition, ecological receptors are not exposed to the contaminated groundwater.

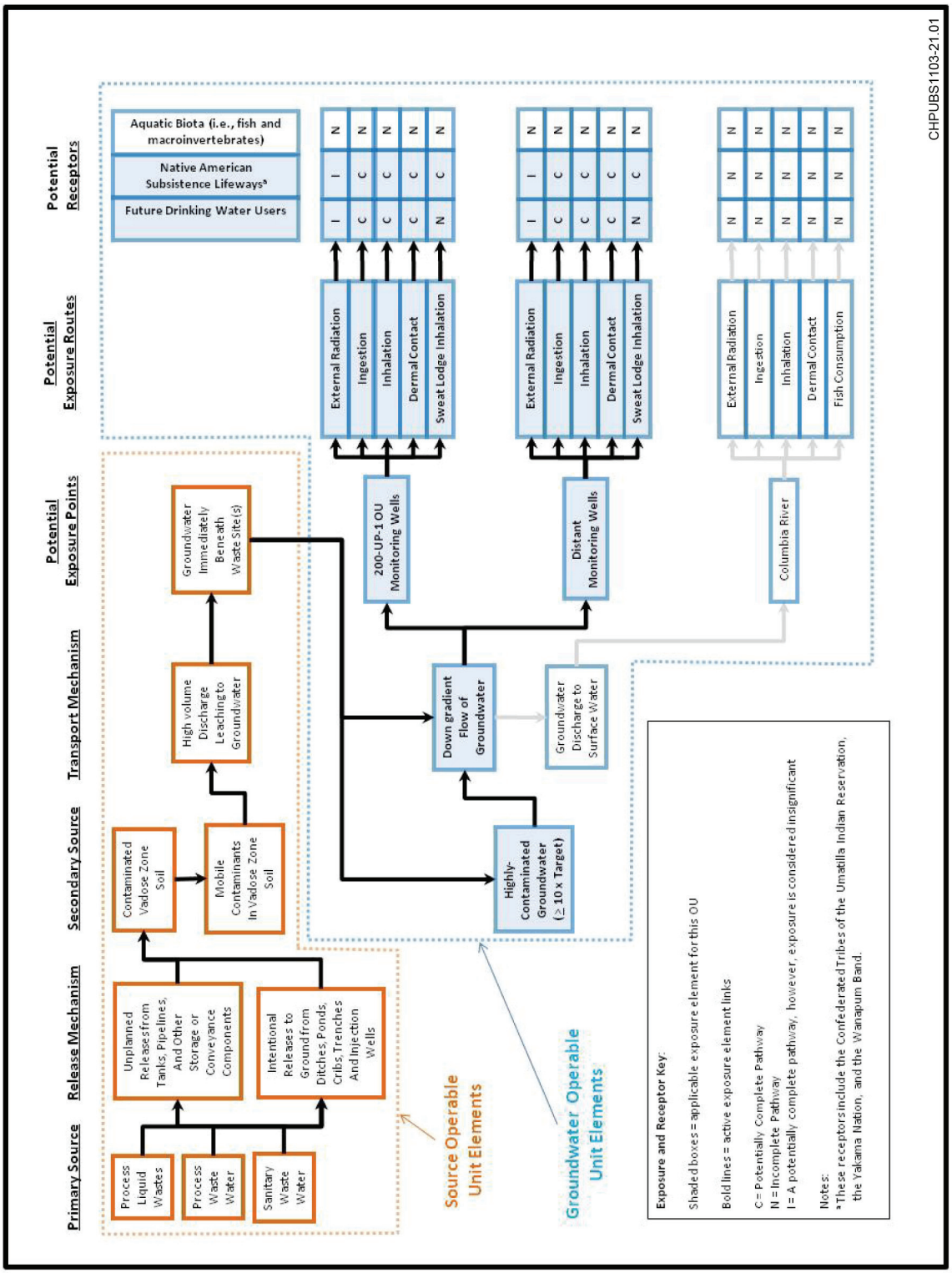
Primary Source
Release Mechanism
Secondary Source
Transport Mechanism
Potential Exposure Points
Potential Exposure Routes
Potential Receptors
Process Liquid Wastes
Process Waste Water
Sanitary Waste Water
Unplanned Releases from Tanks, Pipelines, And Other Storage or Conveyance Components
Intentional Releases to Ground from Ditches, Ponds, Cribs, Trenches And Injection Wells
Contaminated Vadose Zone Soil
Mobile Contaminants In Vadose Zone Soil
High volume Discharge Leaching to Groundwater
Groundwater Immediately Beneath Waste Site(s)
Highly-Contaminated Groundwater (≥ 10 x Target)
Down gradient Flow of Groundwater
Groundwater Discharge to Surface Water
200-UP-1 OU Monitoring Wells
Distant Monitoring Wells
Columbia River
External Radiation
Ingestion
Inhalation
Dermal Contact
Sweat Lodge Inhalation
Fish Consumption
Aquatic Biota (i.e., fish and macroinvertebrates)
Native American Subsistence Lifeways*
Future Drinking Water Users
Source Operable Unit Elements
Groundwater Operable Unit Elements
Exposure and Receptor Key:
Shaded boxes = applicable exposure element for this OU
Bold lines = active exposure element links
C = Potentially Complete Pathway
N = Incomplete Pathway
I = A potentially complete pathway, however, exposure is considered insignificant
Notes:
*These receptors include the Confederated Tribes of the Umatilla Indian Reservation, the Yakama Nation, and the Wanapum Band.
CHPUBS1103-21.01

Figure 6-6. Conceptual Exposure Model for Potential Human Health and Ecological Receptors It is anticipated that groundwater contamination in this exposure area will not disperse beyond the boundaries of the OU at levels that would present an unacceptable risk within 1,000 years.

No discharge of groundwater originating from the OU to surface water is anticipated; thus, only exposure to human receptors is considered in this BRA. Based on this understanding, hypothetical adult and child receptors could potentially use the groundwater within this exposure area for drinking water and other domestic purposes.

Potential routes of exposure to groundwater contaminants include the following:

- Ingestion of contaminated water by drinking or in food preparation
- Inhalation of contaminant vapors during showering or other household activities
- Dermal contact exposure to contaminants in groundwater
- External radiation exposure from radioactive contaminants in groundwater

Ingestion and inhalation of vapors were considered as the major potentially complete and significant pathways for exposure. The dermal contact pathway is considered a complete but insignificant pathway of exposure for the contaminants detected in groundwater at the 200-UP-1 OU and generally does not require quantitative evaluation but is discussed qualitatively as described in WAC 173-340-720(4)(iii)(A) and (B) and quantified for nonradionuclides within the EPA tap water scenario analysis as explained in Section 6.5.1. This approach is consistent with the State of Washington procedures, which assume that inhalation of VOC vapors is a complete and significant exposure pathway and do not include the dermal contact exposure route in the equations for calculation of potable groundwater cleanup levels. Omission of the dermal contact exposure route from the risk assessment may result in an underestimation of the cleanup level and uncertainties associated with exclusion of this exposure route are addressed in Section 6.8. External radiation exposure is also assumed to be an insignificant exposure pathway as a result of water's shielding effects. The exposure assessment component of the risk assessment identifies the receptors or populations that may be exposed, the routes by which these receptors may become exposed, and the magnitude, frequency, and duration of potential exposures.

The 200-UP-1 OU is evaluated as a single exposure area for quantifying and evaluating risk. The primary objective for evaluating it as a single exposure area is to provide information necessary to determine the need for remedial action. The remedial strategy presented in Chapter 8 divides the OU into plume areas for cleanup purposes and remedy selection. Evaluating the OU as a single exposure area captures the highest contaminant concentrations from the five primary sources of contamination (U Plant, S-SX Tank Farms, southeastern chrome, iodine-129 area, and northeastern nitrate area).

6.3 Toxicity Assessment

The toxicity assessment component evaluates the relationship between the magnitude of exposure to a contaminant and the likelihood of adverse health effects to potentially exposed populations. Similar to the exposure assessment, the comparison to the action levels takes into consideration the likelihood of an adverse health effect to occur to the potentially exposed population. For example, the risk-based concentrations, presented in WAC 173-340-720, are developed using toxicological information published at EPA's Integrated Risk Information System (IRIS) Web site and EPA's hierarchy of toxicity values described in Section 6.3.3. The assignment of action levels to the detected contaminants within the OU is described in Section 6.1.2.

6.3.1 State and Federal MCLs for Nonradionuclides

The MCL goal is the maximum level of a contaminant in drinking water at which no known or anticipated adverse health effects occur, allowing for an adequate margin of safety. The MCL is the maximum permissible level of a contaminant in water that is delivered (at the tap) to any user of a public water system. EPA establishes the MCL based on the MCL goal, but MCL goals are nonenforceable health goals. Before the 1996 Amendments to the *Safe Drinking Water Act of 1974*, the MCL was set as close to the MCL goal as was feasible. The 1996 *Safe Drinking Water Act* Amendments allow consideration of costs and benefits in establishing an MCL. MCLs are enforceable standards.

MCL goals are developed using an oral reference dose (RfD) for contaminants that exhibit a threshold toxic effect. The RfD is an estimate (with uncertainty spanning an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is unlikely to cause noncancer effects during a human lifetime. EPA assumes that the relative source contribution from drinking water is 20 percent of the RfD, unless other exposure data for the chemical are available. This percentage allows 80 percent of the total exposure to come from sources other than drinking water, such as exposure from food, inhalation, or dermal contact.

EPA has also used several systems for classifying carcinogenicity of the contaminants (EPA 822-R-03-008). For drinking water contaminants regulated before the 1996 *Safe Drinking Water Act* Amendments, the Office of Water followed a three-category, regulatory cancer classification system (Categories I, II, or III). EPA also used the six alphanumeric categories (A, B1, B2, C, D, and E) of the 1986 cancer guidelines in EPA/630/P-03/001F, *Guidelines for Carcinogen Risk Assessment*, for establishing the MCL goal. The six-group classification system is often equated to the three-category system in the National Primary Drinking Water Regulations Federal Register announcements. If a chemical is a known or a probable human carcinogen (Category I, generally Group A or B), the MCL goal is generally set at zero. If a chemical falls in Group C, an RfD approach, along with an additional safety factor, is used in deriving the MCL goal.

6.3.2 Federal MCLs for Radionuclides in Drinking Water

Current groundwater MCLs for radionuclides are set at a 4 mrem/yr dose basis for the sum of the doses from beta particle and photon emitters, 15 pCi/L for gross alpha emitter activity concentration (including Radium-226 but excluding uranium and radon), and 5 pCi/L combined activity concentration for Radium-226 and Radium-228. A mass concentration MCL has been established for uranium in groundwater as 30 μg/L. The current MCLs for beta emitters specify that MCLs are to be calculated based on an annual dose equivalent of 4 mrem to the total body or any internal organ. It is further specified that the calculation is performed on the basis of a 2 L/day (0.5 gal/day) drinking water intake, using the 168-hour data listed in NBS Handbook 69, *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air or Water for Occupational Exposure*.

6.3.3 Washington State Regulations

Toxicological parameter values are obtained from the "Cleanup Levels and Risk Calculations" (CLARC) (Ecology, 2009a) Web-based compendium of technical information related to the calculation of cleanup levels under the MTCA (WAC 173-340) cleanup procedures. The sources for the oral cancer potency values and oral RfDs are provided in the "Cleanup Levels and Risk Calculations" (CLARC) database (Ecology, 2009a). The sources for identifying RfDs and carcinogenic potency factors are defined in WAC 173-340-708(7) and WAC 173-340-708(8), respectively.

In general, the sources of toxicity values defined by WAC 173-340-708(7) and (8) differ from the recommended hierarchy for sources as described in OSWER Directive 9285.7-53 (Cook, 2003, "Human

Health Toxicity Values in Superfund Risk Assessments"). As a result of this difference, toxicity values were determined using the following recommended reference hierarchy (Cook, 2003):

- Tier 1—The EPA IRIS
- Tier 2—The EPA Provision Peer Reviewed Toxicity Values
- Tier 3—Other Toxicity Values

Tier 3 toxicity values include additional EPA and non-EPA sources of toxicity information, including: the California EPA Toxicity Criteria Database, the Agency for Toxic Substances and Disease Registry Minimal Risk Levels for Hazard Substances, and toxicity values in EPA/540/R-97-036, *Health Effects Assessment Summary Tables: FY 1997 Update*. Each of the Tier 3 toxicity values can be found in "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2009).

When Tier 1, Tier 2, or Tier 3 toxicity values were not available for a chemical, the toxicity values from the National Center for Environmental Assessment were used, which values can be found in the Oak Ridge National Laboratory Risk Assessment Information System (RAIS) database.

Toxic equivalency factors were used to calculate toxicity values for dioxins, furans, and carcinogenic polynuclear aromatic hydrocarbons, as described in WAC-173-340-708(8)(d)(iii)(A).

The toxicity value published in the CLARC database (Ecology, 2009a) was selected for final COPCs when Cook (2003) recommended a different source of information. The alternative toxicity values published by the States of New Jersey and California, described as follows, were not used for the purposes of calculating groundwater cleanup levels. The toxicity values currently have an uncertain status because the science is still emerging, and EPA's National Center for Environmental Assessment has not evaluated these values. Therefore, the values currently recommended in the CLARC database were selected for calculating groundwater cleanup levels. The differences in toxicity values for final COPCs are summarized as follows:

- The oral cancer potency factor of 0.089 $(mg/kg\text{-}day)^{-1}$ for TCE published by the Health Effects Assessment Summary Tables (HEAST) is the value published in the CLARC database (Ecology, 2009a) and is used to develop the WAC 173-340-720 groundwater cleanup level. HEAST has not been updated since 1997, so it does not reflect the most current source of information for the oral cancer potency factor. The source of this toxicity value is consistent with the hierarchy of toxicity values recommended in Cook (2003). However, the oral slope factor currently implemented by EPA for TCE in the "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2009) is established by the California Environmental Protection Agency (CalEPA) Office of Environmental Health Hazard Assessment (OEHHA). The oral slope factor derived by OEHHA is 0.0059 $(mg/kg\text{-}day)^{-1}$, as presented in OEHHA, 2009, *Public Health Goal for Trichloroethylene in Drinking Water*. If the CalEPA values were used to calculate the WAC 173-340-720 groundwater cleanup level, the groundwater concentration would increase from 0.49 µg/L to 7.4 µg/L. While the CalEPA toxicity value may be more current, the existing value published by Ecology provides a more conservative cleanup level for groundwater. Long-term exposure to high levels of TCE in drinking water can damage the liver, kidney, immune system, and the nervous system. TCE may also harm a developing fetus if the mother consumes water containing high levels of TCE.

- For consistency with previous Hanford analyses of carbon tetrachloride, the toxicity assessment uses an oral cancer slope factor of 0.13 $(mg/kg\text{-}day)^{-1}$, an oral RfD of 0.0007 (mg/kg-day), and an inhalation unit risk factor of 1.5E-05 $(\mu g/m^3)^{-1}$ previously published in IRIS, as well as the inhalation reference concentration of 0.19 (mg/m^3) published by the Agency for Toxic Substances and Disease Registry. These values do not reflect the most current toxicity values published for carbon

tetrachloride. The oral cancer slope factor of 0.07 $(mg/kg\text{-}day)^{-1}$, oral RfD of 0.004 (mg/kg-day), inhalation unit risk of 6E-06 $(\mu g/m^3)^{-1}$, and inhalation reference concentration of 0.1 (mg/m^3) for carbon tetrachloride are currently implemented in "Regional Screening Levels for Chemical Contaminants at Superfund Sites, (EPA, 2009) and are established by IRIS. Use of the previous IRIS values in this assessment has the potential to underestimate cancer risks and noncancer hazards. Long-term exposure to high levels of carbon tetrachloride in drinking water can damage the central nervous system, eyes, lungs, liver and kidneys.

- The RfD of 0.003 mg/kg-day that is published by IRIS is used to develop the WAC 173-340-720 groundwater cleanup level for hexavalent chromium. An oral carcinogenic potency factor has recently been published by the New Jersey Department of Environmental Protection (NJDEP). The oral carcinogenic potency factor derived by NJDEP is 0.5 $(mg/kg\text{-}day)^{-1}$ (NJDEP, 2009, *Derivation of an Ingestion-Based Soil Remediation Criterion for Cr^{+6} Based on the NTP Chronic Bioassay Data for Sodium Dichromate Dihydrate*). If the NJDEP value was used to calculate the WAC 173-340-720 groundwater cleanup level, the groundwater concentration would decrease from 48 µg/L to 0.18 µg/L. Long-term exposure to high levels of hexavalent chromium include lung cancer, nasal septum ulcerations and perforations, skin ulcerations, and allergic and irritant contact dermatitis.

- The RfD of 0.2 mg/kg-day that is published by the EPA Provision Peer Reviewed Toxicity Values is used to develop the WAC 173-340-720 groundwater cleanup level for 1,1-dichloroethane. An oral carcinogenic potency factor has recently been published by the CalEPA OEHHA. The oral carcinogenic potency factor derived by OEHHA is 0.0057 $(mg/kg\text{-}day)^{-1}$, as presented in OEHHA, 2003, *Public Health Goals for Chemicals in Drinking Water: 1,1,-Dichloroethane in Drinking Water*. If the value published by CalEPA was used to calculate the WAC 173-340-720 groundwater cleanup level, the groundwater concentration would decrease from 1,600 µg/L to 7.7 µg/L. Long-term exposure to high levels of 1,1-dichloroethane in drinking water can cause liver damage.

- A derived RfD for nitrate was calculated from the RfD reported in IRIS (1.6 mg/kg-day) for nitrate as nitrogen (N_{O3}--N) using the mass fraction of nitrogen in nitrate. The mass fraction of nitrogen in nitrate = mol wt N/mol wt N_{O3}- = (14 g/mol)/(62 g/mol) = 0.226. The derived RfD for nitrate = (1.6 mg N_{O3}--N/kg-day) × (1 mg N_{O3}-/0.226 mg N_{O3}--N) = 7.1 mg N_{O3}-/kg-day. Exposure to high levels of nitrate in drinking water in infants 6 months or younger can cause shortness of breath and blue baby syndrome.

- A derived RfD for nitrite was calculated from the RfD reported in IRIS (0.1 mg/kg-day) for nitrite as nitrogen (NO_2--N) using the mass fraction of nitrogen in nitrite. The mass fraction of nitrogen in nitrite = mol wt N/mol wt NO_2- = (14 g/mol)/(46 g/mol) = 0.304. The derived RfD for nitrite = (0.1 mg NO_2--N/kg-day) × (1 mg NO_2-/0.304 mg NO_2--N) = 0.3 mg NO_2-/kg-day.

The purpose of the toxicity assessment is to weigh the available and relevant evidence regarding the potential for contaminants to cause adverse health effects in exposed individuals and to provide a quantitative estimate of the relationship between the magnitude of exposure and the likelihood of adverse effects (EPA 540/1-89/002). The toxicity assessment resulted in factors that are used in the risk characterization Section 6.4.3.2).

6.4 Risk Characterization

Risk characterization is a summarizing step of a BRA and it is completed through integration of exposure and toxicity information to characterize potential risk. It is also used to determine whether current groundwater concentrations have the potential to exceed a hazard index (HI) greater than 1, or the upper

end of the NCP (40 CFR 300) risk range for cumulative carcinogenic site risk to an individual based on the reasonable maximum exposure for current and future land use.

6.4.1 Protectiveness Evaluation

Protectiveness of human health is determined by the comparison of calculated EPCs to existing federal or state MCLs or nonzero MCL goals as well as state cleanup levels (MTCA Method B).

6.4.2 Risk Evaluation

The risk evaluation step addresses multiple exposure pathways or the potential for exposure to multiple contaminants. This step also addresses the requirements of WAC 173-340-708(5)(a) and WAC 173-340-708(6)(b). These procedures require that cleanup levels be adjusted downward to take into account exposure to multiple hazardous substances or multiple pathways of exposure. This adjustment needs to be made only if, without this adjustment, the HI would exceed 1 or the total excess lifetime cancer risk (ELCR) would exceed 1 in 100,000 (1×10^{-5}).

The WAC 173-340-720 standard is used for the potential to exceed an HI greater than 1, or the upper end of the NCP (40 CFR 300) risk range for cumulative carcinogenic site risk to an individual based on the reasonable maximum exposure for current and future land use.

For the purposes of this evaluation, the potential for unacceptable human health risk is identified using the following risk thresholds based on Clay, 1991, "Role of Baseline Risk Assessment in Superfund Remedy Selection Decisions":

- ELCR values are compared to the point of departure range of 10^{-6} to 10^{-4} that is generally used by EPA. The WAC 173-340 states that cancer risks resulting from multiple hazardous substances should not exceed 1×10^{-5} for unrestricted land use. ELCR values within or exceeding this range require a risk management decision that includes evaluating site-specific characteristics and exposure scenario factors to assess whether remedial action is warranted.
- An HI (the ratio of chemical intake to the RfD for all constituents) greater than 1 indicates the potential for adverse noncancer health effects associated with exposure to the COPCs.

6.4.2.1 Cancer Risk Estimation Method

The potential for cancer effects is evaluated by estimating the ELCRs. This risk is an incremental increase in the probability of developing cancer during one's lifetime in addition to the background probability of developing cancer (if no exposure to site chemicals occurs). For example, a 2×10^{-6} ELCR means that, for every 1 million people exposed to the carcinogen throughout their lifetimes, the average incidence of cancer may increase by two cases of cancer. As previously mentioned, cancer slope factors developed by EPA represent upper bound estimates. Therefore, any cancer risks generated in this assessment should be regarded as an upper bound on the potential cancer risks rather than accurate representations of true cancer risk. The true cancer risk is likely to be less than that predicted (EPA/540/1-89/002).

Although synergistic or antagonistic interactions might occur between cancer causing chemicals and other chemicals, information is generally lacking in the toxicological literature to predict quantitatively the effects of these potential interactions. Therefore, in this assessment, cancer risks are treated as additive within an exposure route. This approach is consistent with the EPA guidelines on chemical mixtures (EPA/630/R-00/002, *Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures*). To estimate the cancer risks from exposure to an individual carcinogen from all exposure routes considered, the following equation is used:

$$Risk_I = \frac{EPC_{water}}{CUL_{carcinogen}} \times TR$$

Where:

$Risk_I$	=	Excess lifetime cancer risk for individual chemical
EPC_{water}	=	90th percentile concentration in groundwater (µg/L)
$CUL_{carcinogen}$	=	Groundwater cleanup level based on carcinogenic effect (µg/L)
TR	=	Target excess lifetime cancer risk for individual hazardous substance for unrestricted land use (10^{-6})

To estimate the cancer risks from exposure to multiple carcinogens from all exposure routes considered, the following equation is used:

$$Risk_T = \sum_{c=1}^{c=N} \frac{EPC_{c,water}}{CUL_{c,carcinogen}} \times TR$$

Where:

$Risk_T$	=	Total ELCR for all chemicals
$EPC_{c,water}$	=	90th percentile concentration of contaminant "c" in groundwater (µg/L)
$CUL_{c,carcinogen}$	=	Groundwater cleanup level for contaminant "c", based on carcinogenic effect (µg/L)
TR	=	Target excess lifetime cancer risk for individual hazardous substance for unrestricted land use (10^{-6})
N	=	The number of chemicals contributing to the HI

6.4.2.2 Noncancer Risk Estimation Method

For noncancer effects, the likelihood that a receptor will develop an adverse effect is estimated by comparing the predicted level of exposure for a particular chemical with the highest level of exposure that is considered protective (that is, its RfD). The ratio of the chronic daily intake divided by RfD is termed the HQ.

When the HQ for a chemical exceeds 1 (exposure exceeds RfD), there is a concern for potential noncancer health effects. To assess the potential for noncancer effects posed by exposure to multiple chemicals, an HI approach was used according to EPA/540/1-89/002. This approach assumes that the noncancer hazard associated with exposure to more than one chemical is additive; therefore, synergistic or antagonistic interactions between chemicals are not accounted for. The HI may exceed 1, even if all the individual HQs are less than 1. In this case, the chemicals may be segregated by similar mechanisms of toxicity and toxicological effects. Separate HIs may then be derived based on mechanism and effect.
To estimate the HQ from all exposure routes considered for an individual hazardous substance, the following equation is used:

$$HQ = \frac{EPC_{water}}{CUL_{noncarcinogen}}$$

Where:

HQ	=	HQ for individual chemical
EPC_{water}	=	90th percentile concentration in groundwater (µg/L)
$CUL_{noncarcinogen}$	=	Groundwater cleanup level based on noncarcinogenic effects (µg/L)

To estimate the HI from all exposure routes considered for multiple hazardous substances, the following equation is used:

$$HI_T = \sum_{c=1}^{c=N} \frac{EPC_{c,water}}{CUL_{c,noncarcinogen}}$$

Where:

HI_T	=	Total HI for all chemicals
$EPC_{c,water}$	=	90th percentile concentration of contaminant "c" in groundwater (µg/L)
$CUL_{c,noncarcinogen}$	=	Groundwater cleanup level for contaminant "c", based on noncarcinogenic effects (µg/L)
N	=	The number of chemicals contributing to the HI

6.4.2.3 Estimating the Sum of Fractions and 4 mrem/yr Dose Equivalent

An annual cumulative dose equivalent of less than 4 mrem to the total body or any internal organ is considered protective of human health. The sum of fractions is used to determine whether the contribution of each radioisotope is equal to, or greater than, the cumulative annual dose equivalent of 4 mrem. The following equation is used to determine whether the 4 mrem standard is exceeded when there is a mixture of radioisotopes present:

$$Sum\ of\ Fractions = \left(\frac{A\left(\frac{pCi}{L}\right)}{MCL_A\left(\frac{pCi}{L}\right)} + \frac{B\left(\frac{pCi}{L}\right)}{MCL_B\left(\frac{pCi}{L}\right)} + .\bullet\bullet\bullet \right)$$

The 4 mrem standard is not exceeded if the sum of fractions is less than or equal to 1. Each fraction is converted to a dose equivalent by multiplying the fraction by 4.

6.4.3 Results of the Comparison to Federal and State Cleanup Levels

A comprehensive set of action levels (federal and state MCLs and state cleanup levels) that are considered protective of human health were used to identify final COPCs. As explained in Section 6.1.2, the lowest of these available concentrations were selected to set the action levels used for comparison. With the exception of the contaminants listed in Table 6-11, the EPC values for all COPCs were less than the action levels; and are not expected to pose an unacceptable level of risk.

Table 6-11 provides a summary of the final COPCs, the 90th percentile groundwater concentration, federal and state MCLs, and the WAC 173-340-720 groundwater cleanup standards for carcinogenic and noncarcinogenic effects. The action levels are highlighted in yellow in this Table.

Table 6-11. Summary of Current Conditions 90th Percentile Groundwater Concentrations, Federal and State MCLs and WAC 173-340-720 Groundwater Cleanup Levels

Final COPCs	Units	90th Percentile Value	Federal MCL	State MCL	WAC 173-340-720 Cleanup Levels		
					Noncarcinogens	Carcinogens at 10^{-6} Risk Level	Carcinogens at 10^{-5} Risk Level
Iodine-129	pCi/L	3.5	1	--	--	--	--
Strontium-90	pCi/L	0.66	8	--	--	--	--
Technetium-99	pCi/L	4,150	900	--	--	--	--
Tritium	pCi/L	51,150	20,000	--	--	--	--
Carbon Tetrachloride	µg/L	189	5	5	5.6	0.34	3.37
Chloroform	µg/L	7.2	80	--	--	1.4	14
1,4-Dioxane	µg/L	6.0	--	--	800	4.0	40
Tetrachloroethene	µg/L	1.0	5	5	80	0.081	0.81
Trichloroethene	µg/L	3.3	5	5	2.4	0.49	4.9
Chromium	µg/L	99	100	100	24,000	--	--
Hexavalent Chromium	µg/L	52	--	--	48	--	--
Nitrate	µg/L	133,000	45,000	45,000	113,600	--	--
Nitrate as N	µg/L	30,060	10,000	10,000	25,600		
Uranium	µg/L	206	30	--	48	--	--

Source: WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

6.4.3.1 Protectiveness Evaluation

The protectiveness evaluation is performed to help determine whether a CERCLA remedial action is appropriate. EPA 540-R-97-013, *Rules of Thumb for Superfund Remedy Selection*, states that a remedial action is generally appropriate when a regulatory standard that helps define protectiveness (federal or state MCLs or nonzero MCL goals) for current or potential drinking water aquifers is exceeded.
The 90th percentile groundwater concentration for iodine-129, technetium-99, and tritium are greater than their respective federal MCLs developed for the protection of human health. As Table 6-12 shows, potential exposure to groundwater as a drinking water source would result in a dose greater than 4 mrem per year from each of these three isotopes. Iodine-129, technetium-99, and tritium are identified as COPCs, thus indicating the need to evaluate potential remedial technologies for these radionuclides. Of the 93 wells, 18 monitoring wells were reported with iodine-129 concentrations greater than the federal MCL of 1 pCi/L, 24 monitoring wells were reported with technetium-99 concentrations greater than the federal MCL of 900 pCi/L, and 22 wells were reported with tritium concentrations greater than the federal MCL of 20,000 pCi/L.

The 90th percentile groundwater concentration of strontium-90 is less than the federal MCL developed for the protection of human health and is a minimal contribution to overall dose. Strontium-90 has only been detected in Well 299-W22-10 at concentrations above the federal MCL, indicating its presence is localized downgradient from the 216-S-1 and 216-S-2 Cribs. Although the 90th percentile is less than the federal MCL, strontium-90 is identified as a COPC, and its presence warrants design considerations for any engineered controls or remedial actions performed in this OU.

Table 6-12. Summary of 90th Percentile Current Groundwater Radiological Contaminant Concentrations and Associated Sum of Fractions

Final COPC	Units	90th Percentile Value	Federal MCL	Individual Fraction	Annual Dose (mrem)
Iodine-129	pCi/L	3.5	1	3.5	14
Strontium-90	pCi/L	0.66	8	.08	0.3
Technetium-99	pCi/L	4,150	900	4.6	18.4
Tritium	pCi/L	51,150	20,000	2.6	10.4
Sum of Fractions and Cumulative Annual Dose (mrem)				**10.8**	**43.1**

Note: MCL; Derived single-nuclide MCL-equivalent activity concentration

The 90th percentile groundwater concentration for chromium is approximately equal to the federal and state MCL of 100 µg/L. This concentration indicates that potential exposure to groundwater as a drinking water source would result in adverse health effects. The 90th percentile groundwater concentration is greater than the federal and state MCLs developed for the protection of human health. Of the 93 monitoring wells, 5 monitoring wells were reported with concentrations of chromium above 100 µg/L. Chromium is identified as a COPC, thus indicating the need to evaluate potential remedial technologies for this contaminant.

Federal and state MCL values are not available for hexavalent chromium; therefore, the protectiveness evaluation was not performed. The risks associated with hexavalent chromium are discussed in the risk evaluation presented in Section 6.4.3.2

The 90th percentile groundwater concentration for uranium is greater than the federal MCL value of 30 µg/L developed for the protection of human health. This concentration indicates that potential exposure to groundwater as a drinking water source may result in adverse health effects. Of the 93 monitoring wells, 15 monitoring wells were reported with concentrations of uranium above 30 µg/L. Uranium is identified as a COPC, indicating the need to evaluate potential remedial technologies for this contaminant.

The 90th percentile groundwater concentration for carbon tetrachloride is greater than the federal MCL value of 5 µg/L. This concentration indicates that potential exposure to groundwater as a drinking water source may result in adverse health effects. Of the 93 monitoring wells, 56 monitoring wells were reported with concentrations of carbon tetrachloride above 5 µg/L. The 90th percentile groundwater concentrations for chloroform, PCE, and TCE are less than their respective federal MCLs. The applicable MCL for chloroform is not chemical-specific, but it is the limit for total trihalomethanes. The need to evaluate remedial technologies for these VOCs is not established based on the comparison of the 90th percentile value to the MCL.

The 90th percentile groundwater concentration for nitrate (NO_3) is greater than the federal and state MCL of 45,000 µg/L. This concentration indicates that potential exposure to groundwater as a drinking water source may result in adverse health effects. Of the 93 wells, 82 monitoring wells were reported with concentrations of nitrate above the state and federal MCL of 45,000 µg/L. Nitrate is identified as a COPC, indicating the need to evaluate remedial technologies for this contaminant.

6.4.3.2 Risk Evaluation

The risk evaluation is also performed to help determine whether a CERCLA remedial action is appropriate. EPA 540-R-97-013 states that a remedial action is generally appropriate when the estimated risk calculated in a risk assessment exceeds a noncarcinogenic level for an adverse health effect or the upper end of the NCP (40 CFR 300) risk range for "cumulative carcinogenic site risk" to an individual based on the reasonable maximum exposure for current and future land use. The potential cumulative ELCR from all nonradiological carcinogenic COPCs is 5.8×10^{-4}, which is greater than the WAC 173-340-780 risk threshold of 1×10^{-5} for multiple hazardous substances and the upper NCP (40 CFR 300) threshold of 1×10^{-4}. Table 6-13 shows the contributors to risk: carbon tetrachloride (5.6×10^{-4}, 95.6 percent contribution); chloroform (5.1×10^{-6}, 0.9 percent contribution); 1,4-dioxane (1.5×10^{-6}, 0.3 percent contribution); PCE (1.2×10^{-5}, 2.1 percent contribution); and TCE (6.7×10^{-6}, 1.2 percent contribution).

Table 6-13. Summary of 90th Percentile Current Groundwater Concentrations, Associated Cancer Risk, and Noncancer Hazard Index

Final COPC	Units	90th Percentile Value	WAC 173-340-720 Cleanup Levels			
			Non-carcinogens	HQ (% Contribution)	Carcinogens at 10-6 Risk Level	ELCR (% Contribution)
Carbon Tetrachloride	µg/L	189	5.6	34 (81%)	0.34	5.6×10^{-4} (95.6%)
Chloroform	µg/L	7.2	80	0.09 (~0.2%)	1.4	5.1×10^{-6} (0.9%)
1,4-Dioxane	µg/L	6.0	800	<0.01 (<0.02%)	4.0	1.5×10^{-6} (0.3%)
Tetrachloroethene	µg/L	1.0	80	0.01 (~0.02%)	0.081	1.2×10^{-5} (2.1%)
Trichloroethene	µg/L	3.3	--	--	0.49	6.7×10^{-6} (1.2%)
Total ELCR					**--**	**5.8×10^{-4} (100%)**
Total Chromium	µg/L	99	24,000	<0.01 (<0.02%)	--	--
Hexavalent Chromium	µg/L	52	48	1.1 (3%)	--	--
Nitrate as NO_3	µg/L	133,000	113,600	1.2 (3%)	--	--
Nitrate as N	µg/L	30,060	25,600	1.2 (3%)		
Uranium (total)	µg/L	206	48	4.3 (10%)	--	- -
Hazard Index				**41 (100%)**		

Source: WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

Although the 90th percentile groundwater concentration of 1,4-dioxane is greater than the groundwater cleanup level, it is a minimal contribution to total risk (0.3 percent contribution). Furthermore, 1,4-dioxane has only been detected in Well 299-W22-20 at concentrations above the groundwater cleanup level, indicating its presence is localized downgradient from the 216-S-20 Crib. Because of the localized presence of 1,4-dioxane, it warrants consideration as a component in the groundwater remedy performance monitoring plan for 200-UP-1 OU.

The HI for the 200-UP-1 OU is 41, which is greater than the EPA and MTCA (WAC 173-340) target HI of 1. The primary contributors to the noncancer HI are carbon tetrachloride (HQ = 34, 81 percent contribution); nitrate (HQ = 1.2, 3 percent contribution); uranium (HQ = 4.3, 10 percent contribution); and hexavalent chromium (HQ = 1.1, 3 percent contribution). The primary noncancer health effects associated with exposure to the primary contributors to the HI are as follows:

- Carbon tetrachloride—liver toxicity
- Nitrate—methemaglobenemia
- Uranium—kidney toxicity
- Hexavalent chromium—nasal septum atrophy

It is appropriate to segregate the individual HQs because of the differences in toxicological effects and target organs.

6.5 Summary of EPA Tap Water Scenario

This section documents the methods used to calculate the potential human health risks and hazards associated with exposure to radionuclides and nonradionuclides in tap water under a residential exposure scenario where the contaminated groundwater is used as a tap water source. Potential health risks and hazards are calculated for ingestion, dermal, and inhalation exposure routes associated with the residential use of tap water.

The results of all exposure routes are summed to provide total ELCRs or HIs from direct contact with tap water by a residential receptor. This methodology is used to calculate intake, ELCR, and HI from exposure to tap water for all detected radionuclide and nonradionuclide contaminants.

6.5.1 Identification of Applicable Toxicity Information

The intake equations and exposure assumptions are quantified using standard equations and procedures as specified in the following references:

- EPA/540/1-89/002
- EPA/540/R-92/003, *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals): Interim*
- EPA/540/R/99/005, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment): Final*
- EPA/540/R-070/002, *Risk Assessment Guidance for Superfund: Volume 1—Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment)*
- ORNL, 2010, RAIS (http://rais.ornl.gov/)
  - RAIS Risk Exposure Models for Chemicals User's Guide (http://rais.ornl.gov/tools/rais_chemical_risk_guide.html)

– RAIS Risk Exposure Models for Radionuclides User's Guide (http://rais.ornl.gov/tools/rais_rad_risk_guide.html)

6.5.2 Exposure Routes

Potentially complete exposure routes associated with the tap water scenario (represents potential exposure to a resident) are as follows:

- Ingestion of tap water
- Inhalation of volatiles when showering or bathing and other domestic purposes using tap water
- Dermal exposure from showering or bathing and other domestic purposes using tap water

It should be noted that EPA considers external radiation to be a significant exposure route only for radionuclides in soil (EPA/540/1-89/002). External radiation from radionuclides in water is considered insignificant because of water's shielding effects. EPA does not publish radionuclide cancer slope factors to quantify cancer risk from external or dermal exposure to radioactive COPCs in groundwater. Radionuclide cancer risk is therefore calculated in this evaluation only for ingestion and inhalation exposures.

6.5.3 Results of EPA Tap Water Scenario

To provide a comprehensive evaluation of current risks, potential exposure to groundwater as a tap water source was evaluated. Results from this analysis were used to provide baseline conditions for all contaminants with available toxicity information. Tables 6-14 and 6-15 present the contribution to risk and hazard by contaminant. Table 6-16 provides a summary of the risk estimates by exposure route. In addition, Tables 6-14 to 6-16 provide overall summaries of the tap water scenario for all detected contaminants, as well as for initial and final COPCs identified in Section 6.1.

The cumulative ELCR is 6.6×10^{-4} for nonradiological COPCs and 3.1×10^{-4} for radiological COPCs, which is greater than the EPA upper target risk threshold of 1×10^{-4} (see Table 6-16). Results in Table 6-14 show that the major contributors to the ELCR are carbon tetrachloride (4.7×10^{-4}; 49 percent contribution), technetium-99 (2.2×10^{-4}; 22 percent contribution), tritium (5.7×10^{-5}; 5.8 percent contribution), PCE (1.3×10^{-5}; 1.3 percent contribution), and iodine-129 (9.7×10^{-6}; 1.0 percent contribution), all of which have been identified as final COPCs in Section 6.1. In addition, contribution to the ELCR is elevated for arsenic (1.5×10^{-4}, 15 percent contribution), where measured concentrations are within natural background values. Contributions from 1,4-dioxane (9.9×10^{-7}, 0.1 percent contribution), chloroform (4.4×10^{-6}; 0.45 percent contribution), and TCE (5.4×10^{-6}; 0.56 percent contribution) fall below 1 percent, but they are identified as final COPCs in Section 6.1 based on their action levels and the localized measurements.

The HI is 18, which is greater than the EPA target HI of 1.0. Results in Table 6-15 show the major contributors to HI are carbon tetrachloride (HQ = 9.4, 53 percent contribution), uranium (HQ = 1.9, 11 percent contribution), hexavalent chromium (HQ = 0.67, 3.8 percent contribution), and nitrate (HQ = 0.52, 2.9 percent contribution), all of which have been identified as final COPCs in Section 6.1. Additional contaminants that contribute greater than 1 percent of the HI include acrolein (HQ = 0.89, 5.0 percent contribution), antimony (HQ = 2.0, 11 percent contribution), arsenic (HQ = 0.61, 3.4 percent contribution), cobalt (HQ = 0.25, 1.4 percent contribution), fluoride (HQ = 0.22, 1.2 percent contribution), molybdenum (HQ = 0.33, 1.9 percent contribution), and vanadium (HQ = 0.20, 1.1 percent contribution).

Table 6-14. 200-UP-1 OU Tap Water Risk Assessment--Summary of Tap Water Scenario Cancer Risk Results for Nonradiological and Radiological Contaminants in Groundwater

						All Contaminants		Initial COPCs		Final COPCs	
Contaminant Name	90th Percentile Concentration in Groundwater (mg/L or pCi/L)	Volatile[a]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribu-tion	Total Risk	% Contribu-tion	Total Risk	% Contribu-tion
1,1,2-Trichloro-ethane	5.00E-04	Yes	4.24E-07	3.84E-08	3.97E-08	5.02E-07	0.052	5.02E-07	0.054	--	--
1,1-Dichloroethane	5.00E-04	Yes	--	--	--	--	--	--	--	--	--
1,1-Dichloroethene	5.00E-04	Yes	--	--	--	--	--	--	--	--	--
1,2-Dichloroethane	5.00E-04	Yes	6.77E-07	3.20E-08	6.46E-08	7.73E-07	0.080	7.73E-07	0.083	--	--
1,4-Dichlorobenzene	5.00E-04	Yes	4.02E-08	2.60E-08	2.73E-08	9.34E-08	0.0096	--	--	--	--
1,4-Dioxane	0.0060	--	9.82E-07	3.40E-09	--(b)	9.85E-07	0.10	9.85E-07	0.11	9.85E-07	0.13
2,3,4,6-Tetrachloroph enol	0.0014	--	--	--	--(b)	--	--	--	--	--	--
2-Butanone	9.00E-04	Yes	--	--	--	--	--	--	--	--	--
2-Butoxyethanol	0.066	--	--	--	--(b)	--	--	--	--	--	--
2-Pentanone, 4-Methyl	5.00E-04	Yes	--	--	--	--	--	--	--	--	--
4-Nitrophenol	0.0014	--	--	--	--(b)	--	--	--	--	--	--
Acetone	0.0031	Yes	--	--	--	--	--	--	--	--	--
Acrolein	0.0014	Yes	--	--	--	--	--	--	--	--	--
Aluminum	0.096	--	--	--	--(b)	--	--	--	--	--	--
Antimony	0.028	--	--	--	--(b)	--	--	--	--	--	--
Arsenic	0.0066	--	1.47E-04	7.93E-07	--(b)	1.48E-04	15	1.48E-04	16	--	--
Barium	0.069	--	--	--	--(b)	--	--	--	--	--	--
Benzene	5.00E-04	Yes	4.09E-07	6.04E-08	1.94E-08	4.89E-07	0.050	4.89E-07	0.052	--	--
Beryllium	0.0020	--	--	--	--(b)	--	--	--	--	--	--
Bis(2-ethylhexyl) phthalate	0.0018	--	3.75E-07	5.59E-07	--(b)	9.34E-07	0.096	9.34E-07	0.10	--	--
Boron	0.055	--	--	--	--(b)	--	--	--	--	--	--
Bromodichlorometha ne	0.0025	Yes	2.31E-06	1.82E-07	4.59E-07	2.95E-06	0.30	2.95E-06	0.32	--	--
Bromoform	0.0025	--	2.94E-07	1.97E-08	--(b)	3.13E-07	0.032	--	--	--	--
Bromomethane	0.0050	Yes	--	--	--	--	--	--	--	--	--
Cadmium	0.0020	--	--	--	--(b)	--	--	--	--	--	--
Carbon disulfide	5.00E-04	Yes	--	--	--	--	--	--	--	--	--
Carbon tetrachloride	0.19	Yes	3.64E-04	9.41E-05	1.40E-05	4.73E-04	49	4.73E-04	51	4.73E-04	61
Chloride	31	--	--	--	--(b)	--	--	--	--	--	--

Table 6-14. 200-UP-1 OU Tap Water Risk Assessment--Summary of Tap Water Scenario Cancer Risk Results for Nonradiological and Radiological Contaminants in Groundwater

						All Contaminants		Initial COPCs		Final COPCs	
Contaminant Name	90th Percentile Concentration in Groundwater (mg/L or pCi/L)	Volatile[a]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribu-tion	Total Risk	% Contribu-tion	Total Risk	% Contribu-tion
Chlorobenzene	0.0025	Yes	--	--	--	--	--	--	--	--	--
Chloroform	0.0072	Yes	3.30E-06	2.90E-07	8.17E-07	4.40E-06	0.45	4.40E-06	0.47	4.40E-06	0.57
Chromium	0.099	--	--	--	--(b)	--	--	--	--	--	--
cis-1,2-Dichloroethylene	5.00E-04	Yes	--	--	--	--	--	--	--	--	--
Cobalt	0.0028	--	--	--	--(b)	--	--	--	--	--	--
Copper	0.0050	--	--	--	--(b)	--	--	--	--	--	--
Cyanide	0.0024	Yes	--	--	--	--	--	--	--	--	--
Ethylbenzene	5.00E-04	Yes	8.18E-08	4.75E-08	6.21E-09	1.35E-07	0.014	--	--	--	--
Fluoride	0.47	--	--	--	--(b)	--	--	--	--	--	--
Hexavalent Chromium	0.052	--	--	--	--(b)	--	--	--	--	--	--
Iron	0.41	--	--	--	--(b)	--	--	--	--	--	--
Isobutyl alcohol	0.015	Yes	--	--	--	--	--	--	--	--	--
Lead	0.0037	--	--	--	--(b)	--	--	--	--	--	--
Lithium	0.0089	--	--	--	--(b)	--	--	--	--	--	--
Manganese	0.018	--	--	--	--(b)	--	--	--	--	--	--
Mercury	5.00E-05	--	--	--	--(b)	--	--	--	--	--	--
Methylene chloride	0.0011	Yes	1.17E-07	4.24E-09	2.45E-09	1.24E-07	0.013	1.24E-07	0.013	--	--
Molybdenum	0.060	--	--	--	--(b)	--	--	--	--	--	--
Nickel	0.018	--	--	--	--(b)	--	--	--	--	--	--
Nitrate	133	--	--	--	--(b)	--	--	--	--	--	--
Nitrite	0.11	--	--	--	--(b)	--	--	--	--	--	--
Phenol	0.0020	--	--	--	--(b)	--	--	--	--	--	--
Selenium	0.023	--	--	--	--(b)	--	--	--	--	--	--
Silver	0.0053	--	--	--	--(b)	--	--	--	--	--	--
Strontium	0.26	--	--	--	--(b)	--	--	--	--	--	--
Styrene	0.0025	Yes	--	--	--	--	--	--	--	--	--
Sulfate	39	--	--	--	--(b)	--	--	--	--	--	--
Tetrachloroethene	0.0010	Yes	8.03E-06	4.62E-06	2.93E-08	1.27E-05	1.3	1.27E-05	1.4	1.27E-05	1.6
Thallium	0.0050	--	--	--	--(b)	--	--	--	--	--	--

Table 6-14. 200-UP-1 OU Tap Water Risk Assessment--Summary of Tap Water Scenario Cancer Risk Results for Nonradiological and Radiological Contaminants in Groundwater

						All Contaminants		Initial COPCs		Final COPCs	
Contaminant Name	**90th Percentile Concentration in Groundwater (mg/L or pCi/L)**	**Volatile[a]**	**Risk (Ingestion)**	**Risk (Dermal)**	**Risk (Inhalation)**	**Total Risk**	**% Contribu-tion**	**Total Risk**	**% Contribu-tion**	**Total Risk**	**% Contribu-tion**
Tin	0.0036	--	--	--	--(b)	--	--	--	--	--	--
Toluene	5.00E-04	Yes	--	--	--	--	--	--	--	--	--
trans-1,3-Dichloropropene	0.0025	Yes	3.72E-06	1.96E-07	4.97E-08	3.96E-06	0.41	--	--	--	--
Tributyl phosphate	6.50E-04	--	8.89E-08	--	--(b)	8.89E-08	0.0092	--	--	--	--
Trichloroethene	0.0033	Yes	4.30E-06	7.19E-07	4.03E-07	5.42E-06	0.56	5.42E-06	0.58	5.42E-06	0.70
Uranium	0.21	--	--	--	--(b)	--	--	--	--	--	--
Vanadium	0.037	--	-	--	--(b)	--	--	--	--	--	--
Xylenes (total)	5.00E-04	Yes	--	--	--	--	--	--	--	--	--
Zinc	0.027	--	--	--	--(b)	--	--	--	--	--	--
Carbon-14	14	--	4.04E-07	--	--(b)	4.04E-07	0.042	--	--	--	--
Gross alpha	4.1	--	--	--	--(b)	--	--	--	--	--	--
Iodine-129	3.5	--	9.66E-06	--	--(b)	9.66E-06	1.00	9.66E-06	1.0	9.66E-06	1.2
Neptunium-237	0.039	--	4.58E-08	--	--(b)	4.58E-08	0.0047	--	--	--	--
Protactinium-231	0.15	--	4.90E-07	--	--(b)	4.90E-07	0.051	--	--	--	--
Selenium-79	56	--	7.76E-06	--	--(b)	7.76E-06	0.80	--	--	--	--
Strontium-90	0.66	--	6.96E-07	--	--(b)	6.96E-07	0.072	6.96E-07	0.075	6.96E-07	0.089
Technetium-99	4,150	--	2.16E-04	--	--(b)	2.16E-04	22	2.16E-04	23	2.16E-04	28
Tritium	51,150	Yes	4.90E-05	--	7.52E-06	5.65E-05	5.8	5.65E-05	6.1	5.65E-05	7.3
Uranium-234	14	--	1.90E-05	--	--(b)	1.90E-05	2.0	--	--	--	--
Uranium-235	0.68	--	8.94E-07	--	--(b)	8.94E-07	0.092	--	--	--	--
Uranium-238	2.4	--	2.92E-06	--	--(b)	2.92E-06	0.30	--	--	--	--
		Total Cumulative ELCR	8.43E-04	1.02E-04	2.35E-05	9.69E-04	100	9.33E-04	100	7.79E-04	100

a. Volatile contaminants as defined by EPA, 2009, "Regional Screening Levels for Chemical Contaminants at Superfund Sites" or as defined by EPA 540-R-97-036, *Health Effects Assessment Summary Tables: FY 1997 Update*, April 16, 2001 Update: Radionuclide Toxicity, Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors.

b. Nonvolatile constituents are not considered in the inhalation exposure route.
-- = Indicates toxicity criteria were not available to quantify contaminant's cancer risk via this exposure route.

Some of the metals (arsenic and cobalt) and fluoride are within natural background levels for the Site. For antimony, the analytical method used for the measurements has a high method detection limit, making the data unreliable for risk characterization. As discussed in Section 6.1, acrolein measurements are considered anomalous (1 detection in 122 measurements, with about 5 years of nondetections at the same well where that detection was measured). Measurements of molybdenum greater than the action level (discussed in Section 6.1) are not associated with a trend or an exposure point. All detected vanadium concentrations and method detection limits are consistently less than the action level.

The summary in Table 6-16 demonstrates that the screening process does not result in any significant underestimation of risk or HIs. For example, considering all detected contaminants results in an estimated ELCR of about 9.7×10^{-4} versus 7.8×10^{-4} for the final COPC list. Given the uncertainties outlined in Section 6.8, this difference is within the range expected. In addition, the uncertainty in the EPC calculations increases significantly, as explained in Section 6.1.4.1, with the decreased frequency of detection, which is the case for most contaminants not identified as final COPCs.

Finally, to compare EPA to the MTCA (WAC 173-340) procedures, the EPA tap water scenario ELCR value for nonradionuclides is 5.0×10^{-4} versus 5.8×10^{-4} for the MTCA (WAC 173-340) scenario (Table 6-13), which is within the expected range and reflects the differences in the two calculations. For the HI, considering all detected contaminants results in an estimated HI of about 18 versus 13 for the final COPCs. The difference is largely because of background concentrations (for example, arsenic, cobalt, and fluoride), in addition to the same uncertainties listed for the ELCR calculations. However, the calculated HI for the final COPCs is clearly above the threshold of 1.0 and indicates the need for review in an FS.

Table 6-15. 200-UP-1 OU Tap Water Risk Assessment--Summary of Tap Water Scenario Noncancer Hazard Results for Nonradiological Contaminants in Groundwater

						All Contaminants		Initial COPCs		Final COPCs	
Contaminant Name	90th Percentile Concentration in Groundwater (mg/L or pCi/L)	Volatile[a]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribu-tion	Total HQ	% Contribu-tion	Total HQ	% Contribu-tion
1,1,2-Trichloro-ethane	5.00E-04	Yes	0.0034	3.22E-04	--	0.0037	0.021	0.0037	0.022	--	--
1,1-Dichloro-ethane	5.00E-04	Yes	6.85E-05	5.36E-06	8.28E-06	8.21E-05	4.65E-04	--	--	--	--
1,1-Dichloro-ethene	5.00E-04	Yes	2.74E-04	3.79E-05	2.90E-05	3.41E-04	0.0019	--	--	--	--
1,2-Dichloro-ethane	5.00E-04	Yes	6.85E-04	3.36E-05	2.41E-06	7.21E-04	0.0041	7.21E-04	0.0042	--	--
1,4-Dichloro-benzene	5.00E-04	Yes	1.96E-04	1.31E-04	7.24E-06	3.34E-04	0.0019	--	--	--	--
1,4-Dioxane	0.0060	--	0.0016	5.90E-06	--(b)	0.0016	0.0093	0.0016	0.010	0.0016	0.013
2,3,4,6-Tetra-chlorophenol	0.0014	--	0.0013	--	--(b)	0.0013	0.0072	--	--	--	--
2-Butanone	9.00E-04	Yes	4.11E-05	3.88E-07	2.09E-06	4.36E-05	2.46E-04	--	--	--	--
2-Butoxyethanol	0.066	--	0.0036	5.76E-05	--(b)	0.0037	0.021	--	--	--	--
2-Pentanone, 4-Methyl	5.00E-04	Yes	1.71E-04	5.47E-06	1.93E-06	1.79E-04	0.0010	--	--	--	--
4-Nitrophenol	0.0014	--	0.0048	3.49E-04	--(b)	0.0051	0.029	--	--	--	--

Table 6-15. 200-UP-1 OU Tap Water Risk Assessment--Summary of Tap Water Scenario Noncancer Hazard Results for Nonradiological Contaminants in Groundwater

						All Contaminants		Initial COPCs		Final COPCs	
Contaminant Name	90th Percentile Concentration in Groundwater (mg/L or pCi/L)	Volatile[a]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribu-tion	Total HQ	% Contribu-tion	Total HQ	% Contribu-tion
Acetone	0.0031	Yes	9.28E-05	--	1.14E-06	9.40E-05	5.32E-04	--	--	--	--
Acrolein	0.0014	Yes	0.077	4.58E-04	0.81	0.89	5.0	0.89	5.2	--	--
Aluminum	0.096	--	0.0026	1.38E-05	--(b)	0.0027	0.015	0.0027	0.016	--	--
Antimony	0.028	--	1.9	0.067	--(b)	2.0	11	2.0	12	--	--
Arsenic	0.0066	--	0.60	0.0031	--(b)	0.61	3.4	0.61	3.6	--	--
Barium	0.069	--	0.0094	7.03E-04	--(b)	0.010	0.057	--	--	--	--
Benzene	5.00E-04	Yes	0.0034	5.24E-04	1.93E-04	0.0041	0.023	0.0041	0.024	--	--
Beryllium	0.0020	--	0.027	0.020	--(b)	0.048	0.27	0.048	0.28	--	--
Bis(2-ethylhexyl) phthalate	0.0018	--	0.0025	0.0038	--(b)	0.0063	0.036	0.0063	0.037	--	--
Boron	0.055	--	0.0076	3.96E-05	--(b)	0.0076	0.043	--	--	--	--
Bromodichlorome thane	0.0025	Yes	0.0034	2.80E-04	--	0.0037	0.021	0.0037	0.022	--	--
Bromoform	0.0025	--	0.0034	2.38E-04	--(b)	0.0037	0.021	--	--	--	--
Bromomethane	0.0050	Yes	0.098	0.0031	0.012	0.11	0.64	--	--	--	--
Cadmium	0.0020	--	0.11	0.011	--(b)	0.12	0.68	0.12	0.71	--	--
Carbon disulfide	5.00E-04	Yes	1.37E-04	2.42E-05	8.28E-06	1.69E-04	9.59E-04	--	--	--	--
Carbon tetrachloride	0.19	Yes	7.4	2.0	0.011	9.4	53	9.4	55	9.4	75
Chloride	31	--	--	--	--(b)	--	--	--	--	--	--
Chlorobenzene	0.0025	Yes	0.0034	0.0012	5.79E-04	0.0052	0.030	--	--	--	--
Chloroform	0.0072	Yes	0.020	0.0018	8.45E-04	0.022	0.13	0.022	0.13	0.022	0.18
Chromium	0.099	--	0.0018	7.27E-04	--(b)	0.0025	0.014	0.0025	0.015	0.0025	0.020
cis-1,2-Dichloro-ethylene	5.00E-04	Yes	0.0014	1.22E-04	--	0.0015	0.0084	--	--	--	--
Cobalt	0.0028	--	0.25	5.24E-04	--(b)	0.25	1.4	0.25	1.5	--	--
Copper	0.0050	--	0.0034	1.79E-05	--(b)	0.0034	0.019	--	--	--	--
Cyanide	0.0024	Yes	0.0032	1.68E-05	--	0.0032	0.018	--	--	--	--
Ethylbenzene	5.00E-04	Yes	1.37E-04	8.24E-05	5.79E-06	2.25E-04	0.0013	--	--	--	--
Fluoride	0.47	--	0.21	0.0011	--(b)	0.22	1.2	0.22	1.3	--	--
Hexavalent Chromium	0.052	--	0.47	0.20	--(b)	0.67	3.8	0.67	3.9	0.67	5.4
Iron	0.41	--	0.016	8.28E-05	--(b)	0.016	0.090	0.016	0.094	--	--
Isobutyl alcohol	0.015	Yes	0.0013	--	--	0.0013	0.0075	--	--	--	--
Lead	0.0037	--	--	--	--(b)	--	--	--	--	--	--

Table 6-15. 200-UP-1 OU Tap Water Risk Assessment--Summary of Tap Water Scenario Noncancer Hazard Results for Nonradiological Contaminants in Groundwater

						All Contaminants		Initial COPCs		Final COPCs	
Contaminant Name	90th Percentile Concentration in Groundwater (mg/L or pCi/L)	Volatile[a]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribu-tion	Total HQ	% Contribu-tion	Total HQ	% Contribu-tion
Lithium	0.0089	--	0.12	6.33E-04	--(b)	0.12	0.69	--	--	--	--
Manganese	0.018	--	0.021	0.0027	--(b)	0.023	0.13	0.023	0.14	--	--
Mercury	5.00E-05	--	0.0046	3.41E-04	--(b)	0.0049	0.028	--	--	--	--
Methylene chloride	0.0011	Yes	4.79E-04	1.80E-05	1.22E-05	5.10E-04	0.0029	5.10E-04	0.0030	--	--
Molybdenum	0.060	--	0.33	0.0017	--(b)	0.33	1.9	0.33	1.9	--	--
Nickel	0.018	--	0.024	6.29E-04	--(b)	0.025	0.14	0.025	0.15	--	--
Nitrate	133	--	0.51	0.0027	--(b)	0.52	2.9	0.52	3.0	0.52	4.1
Nitrite	0.11	--	0.0096	5.01E-05	--(b)	0.0096	0.055	0.0096	0.057	--	--
Phenol	0.0020	--	1.83E-04	8.93E-06	--(b)	1.92E-04	0.0011	--	--	--	--
Selenium	0.023	--	0.13	6.61E-04	--(b)	0.13	0.72	--	--	--	--
Silver	0.0053	--	0.029	0.0023	--(b)	0.031	0.18	--	--	--	--
Strontium	0.26	--	0.012	6.17E-05	--(b)	0.012	0.067	--	--	--	--
Styrene	0.0025	Yes	3.42E-04	1.54E-04	2.90E-05	5.25E-04	0.0030	--	--	--	--
Sulfate	39	--	--	--	--(b)	--	--	--	--	--	--
Tetrachloroethene	0.0010	Yes	0.0027	0.0016	4.29E-05	0.0044	0.025	0.0044	0.026	0.0044	0.035
Thallium	0.0050	--	--	--	--(b)	--	--	--	--	--	--
Tin	0.0036	--	1.64E-04	8.58E-07	--(b)	1.65E-04	9.35E-04	--	--	--	--
Toluene	5.00E-04	Yes	1.71E-04	5.95E-05	1.16E-06	2.32E-04	0.0013	--	--	--	--
trans-1,3-Dichloro propene	0.0025	Yes	0.0023	1.25E-04	0.0014	0.0039	0.022	--	--	--	--
Tributyl phosphate	6.50E-04	--	8.90E-05	--	--(b)	8.90E-05	5.04E-04	--	--	--	--
Trichloroethene	0.0033	Yes	--	--	0.0011	0.0011	0.0061	0.0011	0.0063	0.0011	0.0086
Uranium	0.21	--	1.9	0.0098	--(b)	1.9	11	1.9	11	1.9	15
Vanadium	0.037	--	0.20	0.0010	--(b)	0.20	1.1	--	--	--	--
Xylenes (total)	5.00E-04	Yes	6.85E-05	4.46E-05	5.79E-05	1.71E-04	9.67E-04	--	--	--	--
Zinc	0.027	--	0.0025	7.72E-06	--(b)	0.0025	0.014	--	--	--	--
		Hazard Index	**15**	**2.3**	**0.84**	**18**	**100**	**17**	**100**	**12.8**	**100**

a. Volatile contaminants as defined by EPA, 2009, "Regional Screening Levels for Chemical Contaminants at Superfund Sites."

b. Nonvolatile constituents are not considered in the inhalation exposure route.

-- = Indicates toxicity criteria were not available to quantify contaminant's cancer risk via this exposure route.

Table 6-16. Risk Estimates from Use of Groundwater as a Potential Drinking Water Source Using EPA Tap Water Equations

Exposure Route	ELCR			HI		
Nonradionuclide Contaminants						
	All Contaminants	**Initial COPCs**	**Final COPCs**	**All Contaminants**	**Initial COPCs**	**Final COPCs**
Ingestion	5.4×10^{-4}	3.8×10^{-4}	3.8×10^{-4}	15	13.9	10.6
Dermal	1.0×10^{-4}	1.0×10^{-4}	1.0×10^{-5}	2.3	2.3	2.2
Inhalation	1.6×10^{-5}	1.6×10^{-5}	1.5×10^{-5}	0.8	0.8	0.0
Total	$\mathbf{6.6 \times 10^{-4}}$	$\mathbf{6.5 \times 10^{-4}}$	$\mathbf{5.0 \times 10^{-4}}$	**18**	**17**	**12.8**
Radionuclide Contaminants						
	All Contaminants	**Initial COPCs**	**Final COPCs**			
Ingestion	3.1×10^{-4}	2.8×10^{-4}	2.8×10^{-4}	--	--	--
Inhalation	7.5×10^{-6}	7.5×10^{-6}	7.5×10^{-6}	--	--	--
Total	$\mathbf{3.1 \times 10^{-4}}$	$\mathbf{2.8 \times 10^{-4}}$	$\mathbf{2.8 \times 10^{-4}}$	**--**	**--**	**--**
Total ELCR*	$\mathbf{9.7 \times 10^{-4}}$	$\mathbf{9.3 \times 10^{-4}}$	$\mathbf{7.8 \times 10^{-4}}$	**--**	**--**	**--**

* Sum of total ELCR values for nonradionuclides and radionuclides.

-- = HI is not applicable.

6.6 Future Conditions

The purpose of estimating future risk conditions in groundwater is to estimate changes in COPC concentrations that may occur within the aquifer system over the period of time selected to indicate the practical duration of administrative control over the Site. Future groundwater concentrations were calculated up to 1,000 years, to identify the time frame within which each groundwater COPC meets the action level. The methodology used to estimate future groundwater concentrations within the 1,000-year fate and transport simulation period is described in Chapter 5 and represents the exposure area spatially and chemically for the purpose of estimating future risks. The future conditions analysis used the maximum concentration value (Cmax) and the 90th percentile concentration value (Cmax).

Step 1—Identify Final COPCs in Exposure Area. Table 6-17 lists the final COPCs. Future groundwater concentrations were estimated for the final COPCs that are identified as major contributors to overall risk and/or hazard.

Future groundwater conditions were not estimated for carbon tetrachloride measured in the 200-UP-1 OU because the source of carbon tetrachloride originates from the 200-ZP-1 Groundwater OU and is actively being treated as part of the remedial design for that OU. Additionally, the groundwater modeling analysis that was performed for the 200-ZP-1 OU ROD and the system design in the remedial design/remedial action work plan included the portion of the carbon tetrachloride plume that resides in 200-UP-1.

Future groundwater conditions were not estimated for 1,4-dioxane and strontium-90. These contaminants are localized and each one is measured in one well (Wells 299-W22-20 and 299-W22-10, respectively), are collocated in the central portion of the OU where other COPC plumes are present, and will be treated with the major risk driving COPCs.

Step 2—Identify Monitoring Well Locations within the OU. Monitoring well locations reported with concentrations of final COPCs greater than the action levels are identified in Appendix D (ECF-200UP1-10-0231). Table 7-6 of this environmental calculation lists the monitoring wells from each exposure area that report concentrations of final COPCs greater than their action levels. Of the 93 wells in the 200-UP-1 OU, 90 wells were reported to have concentrations above the action level for one or more final COPCs. A subset of 23 wells was selected to provide spatial and chemical representation of contamination within the OU (Table 6-17). These wells were selected based on their locations, representations of past site disposal practices, and current contaminant conditions.

Step 3—Calculate Future Groundwater Concentrations. Table 6-17 lists the future groundwater concentrations calculated for each of the final COPCs at each of the monitoring well locations. To determine the approximate time frame for when action levels are attained, future groundwater concentrations were selected at 25-year intervals for up to 200 years, and at 100-year intervals thereafter for each location and each final COPC, using the Cmax values for each COPC.

Cmax concentrations attenuate to below their action levels within 25 years for chloroform and PCE (year 2034), within 50 years for tritium (year 2059), within 75 years for technetium-99 (year 2084), within 175 years for chromium (year 2184), within 300 years for hexavalent chromium (year 2309), and within 175 years for nitrate (year 2184).

The Cmax concentration for iodine-129 and uranium does not attenuate below its action level within the 1,000-year fate and transport simulation period. Based on the fate and transport model, it takes about 150 years for the maximum TCE concentration to drop to the 1 μg/L level, and no attempt was made to predict TCE concentrations at lower levels.

Step 4—Calculate 90th Percentile Groundwater Concentrations. A 90th percentile groundwater concentration was calculated for each final COPC at each 25-year and 100-year time interval. The methodology, inputs, and equations used in the calculation are documented in Appendix D (ECF-200UP1-10-0230, *Exposure Point Concentrations Based on Predicted Future Concentrations of Final COPCs in 200-UP-1 Operable Unit*). The 90th percentile groundwater concentrations were then compared to the federal and state MCLs and the WAC 173-340-720 groundwater cleanup levels. The year when the 90th percentile value achieved the MCL or the WAC 173-340-720 was then identified. A summary of the 90th percentile concentrations and maximum projected concentrations (up to the 1,000-year) is presented in Table 6-18. Table 6-18 also lists the federal and state MCLs, and the WAC 173-340-720 groundwater cleanup standards for carcinogenic and noncarcinogenic effects, which represent the chemical-specific ARARs that were exceeded in the exposure areas.

Step 5—Calculate Total Risk and Total Dose. The total risk and total dose are calculated to determine the time frame adequate for achieving groundwater cleanup levels. An annual cumulative dose equivalent of less than 4 mrem to the total body or any internal organ is considered protective of human health. MTCA (WAC 173-340) states that cancer risks resulting from multiple hazardous substances should not exceed 1×10^{-5} and should not exceed an HI of 1 for noncancer health effects.

Table 6-17. 200-UP-1 OU Monitoring Wells Selected for Calculating Future Groundwater Concentrations

Well Name	Iodine-129 (1 pCi/L)	Technetium-99 (900 pCi/L)	Tritium (20,000 pCi/L)	Chromium (100 µg/L)	Hexavalent Chromium (48 µg/L)	Nitrate (45,000 µg/L)	Uranium (30 µg/L)	Chloroform (1.4 µg/L)	PCE (0.081 µg/L)	TCE (0.49 µg/L)
299-W14-71								x	x	x
299-W18-15						x	x	x		
299-W18-21						x	x			
299-W18-30		X		x		x		x		x
299-W19-101		X				x	x	x		x
299-W19-35		X				x	x	x	x	x
299-W19-36		X				x	x	x	x	x
299-W19-40	x					x	x			
299-W19-48	x	X				x	x	x	x	x
299-W22-44		X		x		x				
299-W22-47		X	x	x		x		x		x
299-W22-72	x		x							
299-W22-83		X		x	x	x		x		
299-W22-86		X			x	x		x		
299-W23-19		X	x			x				
299-W23-4			x				x	x	x	x
699-30-66					x			x		
699-33-74	x	X						x		
699-34-72	x		x			x		x		x
699-36-66B	x					x				
699-36-70B	x				x	x		x		
699-37-68	x					x		x	x	
699-38-70	x					x	x	x	x	x

Table 6-18. Summary of Cmax and 90th Percentile Future Groundwater Concentrations, Federal and State MCLs, WAC 173-340-720 Groundwater Cleanup Levels, and Identification of Year that Action Levels are Projected to be Attained

						WAC 173-340-720 Cleanup Levels		
Final COPC	Units	Cmax	90th Percentile Concentration	Year	Federal or State MCL	Noncarcinogens	Carcinogens at 10^{-6} Risk Level	Carcinogens at 10^{-5} Risk Level
Iodine-129[a]	pCi/L	39	3.5	2009	1	—	—	—
		27	6.7	2034				
		23	6.9	2059				
		19	6.6	2084				
		16	6.1	2109				
		14	5.2	2134				
		14	4.2	2159				
		13	3.4	2184				
		12	2.8	2209				
		11	1.5	2309				
		9.7	0.6	2409				
		8.0	0.1	2509				
		5.9	<0.1	2609				
		4.7	<0.1	2709				
		3.4	<0.1	2809				
		2.2	<0.1	2909				
		1.3	<0.1	3009				
Technetium-99	pCi/L	137,000	4,150	2009	900	—	—	—
		1,438	688	2034				
		919	485	2059				
		655	336	2084				
		515	264	2109				
		442	155	2134				

Table 6-18. Summary of Cmax and 90th Percentile Future Groundwater Concentrations, Federal and State MCLs, WAC 173-340-720 Groundwater Cleanup Levels, and Identification of Year that Action Levels are Projected to be Attained

						WAC 173-340-720 Cleanup Levels		
Final COPC	**Units**	**Cmax**	**90th Percentile Concentration**	**Year**	**Federal or State MCL**	**Noncarcinogens**	**Carcinogens at 10^{-6} Risk Level**	**Carcinogens at 10^{-5} Risk Level**
Tritium	pCi/L	1,020,000	51,150	2009	20,000	—	—	—
		96,027	21,557	2034				
		19,313	3,684	2059				
		3,991	695	2084				
		889	138	2109				
		205	24	2134				
Chloroform	µg/L	35	7.2	2009	80	80	1.4	14
		5.1	<0.001	2034				
		2.1	<0.001	2059				
		1.0	<0.001	2084				
		0.4	<0.001	2109				
		0.2	<0.001	2134				
Tetrachloroethene	µg/L	3.8	1.0	2009	5	80	0.081	0.81
		0.011	<0.081	2034				
		0.007	<0.081	2059				
		0.005	<0.081	2084				
		0.004	<0.081	2109				
		0.003	<0.081	2134				
Trichloroethene[b]	µg/L (not modeled to end-point)	13	3.3	2009	5	—	0.49	4.9
		4.9	0.03	2034				
		3.9	0.003	2059				
		3.0	0.001	2084				
		3.0	<0.001	2109				
		2.0	<0.001	2134				
		1.0 (est)	<0.081	2159				

Table 6-18. Summary of Cmax and 90th Percentile Future Groundwater Concentrations, Federal and State MCLs, WAC 173-340-720 Groundwater Cleanup Levels, and Identification of Year that Action Levels are Projected to be Attained

						WAC 173-340-720 Cleanup Levels		
Final COPC	**Units**	**Cmax**	**90th Percentile Concentration**	**Year**	**Federal or State MCL**	**Noncarcinogens**	**Carcinogens at 10^{-6} Risk Level**	**Carcinogens at 10^{-5} Risk Level**
Chromium	µg/L	846	99	2009	100	24,000	—	—
		145	38	2034				
		138	8.4	2059				
		129	2.8	2084				
		125	2.3	2109				
		118	1.8	2134				
		105	1.8	2159				
		87	1.8	2184				
		69	1.5	2209				
		23	0.2	2309				
Hexavalent Chromium	µg/L	236	52	2009	—	48	—	—
		145	38	2034				
		138	8.4	2059				
		129	2.8	2084				
		125	2.3	2109				
		118	1.8	2134				
		105	1.8	2159				
		87	1.8	2184				
		69	1.5	2209				
		23	0.2	2309				
		7	0.02	2409				
		6	<0.02	2509				
		6	<0.02	2609				
		6	<0.02	2709				
		5	<0.02	2809				
		5	<0.02	2909				
		5	<0.02	3009				

Table 6-18. Summary of Cmax and 90th Percentile Future Groundwater Concentrations, Federal and State MCLs, WAC 173-340-720 Groundwater Cleanup Levels, and Identification of Year that Action Levels are Projected to be Attained

						WAC 173-340-720 Cleanup Levels		
Final COPC	Units	Cmax	90th Percentile Concentration	Year	Federal or State MCL	Noncarcinogens	Carcinogens at 10^{-6} Risk Level	Carcinogens at 10^{-5} Risk Level
Nitrate[c]	µg/L	1,740,000	133,000	2009	45,000	113,600	—	—
		174,490	76,439	2034				
		125,920	51,952	2059				
		102,060	37,363	2084				
		83,578	30,263	2109				
		66,966	21,504	2134				
		53,543	16,290	2159				
		43,481	15,239	2184				
		35,023	13,083	2209				
		28,107	1,523	2309				
		21,177	108	2409				
		16,091	4	2509				
		12,602	0.2	2609				
		10,110	0.2	2709				
		8,366	0.1	2809				
		6,942	0.1	2909				
		5,981	0.1	3009				
Uranium	µg/L	613	206	2009	30	48	—	—
		479	383	2034				
		362	307	2059				
		325	302	2084				
		280	279	2109				
		261	249	2134				
		235	216	2159				
		216	185	2184				
		199	156	2209				
		160	114	2309				
		128	82	2409				
		99	49	2509				
		75	25	2609				
		58	12	2709				

Table 6-18. Summary of Cmax and 90th Percentile Future Groundwater Concentrations, Federal and State MCLs, WAC 173-340-720 Groundwater Cleanup Levels, and Identification of Year that Action Levels are Projected to be Attained

						WAC 173-340-720 Cleanup Levels		
Final COPC	**Units**	**Cmax**	**90th Percentile Concentration**	**Year**	**Federal or State MCL**	**Noncarcinogens**	**Carcinogens at 10^{-6} Risk Level**	**Carcinogens at 10^{-5} Risk Level**
		53	4.9	2809				
		49	2.1	2909				
		43	1.0	3009				

Source: WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

Note: Highlighted cells indicate the maximum and 90th percentile projected groundwater concentrations and the years at which the target action level (federal MCL) is achieved. Nitrate is presented as the NO3 and N forms (45,000 µg/l and 10,000 µg/L).

a. Cmax for iodine-129 is not shaded because it does not attain the federal MCL during the 1,000 year fate and transport simulation period.

b. Cmax for trichloroethene is not shaded because it does not attain the WAC 173-340-720 groundwater cleanup level during the 1,000 year fate and transport simulation period.

c. Cmax for nitrate is not shaded because it does not attain the federal MCL during the 1,000 year fate and transport simulation period.

d. Cmax for uranium is not shaded because it does not attain the federal MCL during the 1,000 year fate and transport simulation period.

Table 6-19 shows the Cmax future groundwater concentrations for each of the final radiological COPCs. Table 6-20 shows the Cmax future groundwater concentrations for each of the final nonradiological COPCs.

Table 6-19. Comparison of Cmax Future Groundwater Concentrations for Final Radiological COPCs to Federal DWSs and Associated Individual Fractions

Final COPC	Units	Cmax	Year	Federal DWS	Individual Fraction
Iodine-129	pCi/L	1.3	3009+	1	1.3
Strontium-90*	pCi/L	--	--	8	--
Technetium-99	pCi/L	665	2084	900	0.74
Tritium	pCi/L	19,313	2059	20,000	0.97

Note: Sum of the fractions and cumulative annual dose were not calculated because the projected year for attainment of action levels (federal MCLs) is different for each final radiological COPC.

* Future groundwater concentrations were not modeled for strontium-90 because its presence is localized and measure in only one well (299-W22-10).

The concentration of technetium-99 is below the federal MCL within 75 years of the fate and transport simulation and tritium is below the federal MCL within 50 years of fate and transport simulation (Table 6-19). The concentration of iodine-129 does not reach the federal MCL of 1 pCi/L at any point during the 1,000-year fate and transport simulation. A sum of the fractions and cumulative annual dose were not calculated because the projected year for attainment of the federal MCL is different for each final radiological COPC.

Based on the Cmax projected concentrations shown in Table 6-20, the individual cancer risks for chloroform (7.1×10^{-7}) and tetrachloroethene (1.4×10^{-7}) are each less than the lower NCP (40 CFR 300) threshold of 1×10^{-6} at the time the WAC 173-340-720 groundwater cleanup level is attained. The individual cancer risk for trichloroethene (2.0×10^{-6}) is less than the WAC 173-340-780 risk threshold of 1×10^{-5} for multiple hazardous substances and within the NCP (40 CFR 300) risk range of 1×10^{-4} to 1×10^{-6} at the year the WAC-173-340-720 groundwater cleanup level is attained (Table 6-20). Cumulative total risk was not calculated because the projected year for attainment of federal or state MCL or WAC 173-340-720 Groundwater cleanup level is different for each final nonradiological COPC.

Based on the Cmax projected concentrations shown in Table 6-20, the noncancer HQs are less than 1 for all final COPCs. An HI was not calculated because the projected year for attainment of federal or state MCL or WAC 173-340-720 Groundwater cleanup level is different for each final COPC.

6.7 Ecological Risk

An ecological risk assessment was not performed because there are no potentially complete exposure pathways to the Columbia River for aquatic receptors. Section 3.8 presents a description of the unique features, habitats, and threatened and endangered species of the area that could be affected later in the project, if remedial actions are required.

Table 6-20. Comparison of Cmax Future Groundwater Concentrations for Final Nonradiological COPCs to Federal and State MCL, WAC 173-340-720 Groundwater Cleanup Levels, and Associated Individual Cancer Risk and Noncancer Hazard Quotient

Final COPC	Units	Cmax	Year	Federal or State MCL	WAC 173-340-720 Cleanup Levels			
					Non-carcinogens	HQ	Carcinogens at 10^{-6} Risk Level	ELCR
Chloroform	µg/L	1.0	2084	80	80	0.01	1.4	7.1×10^{-7}
Tetrachloroethene	µg/L	0.011	2134	5	80	<0.01	0.081	1.4×10^{-7}
Trichloroethene	µg/L	1.0	2159	5	—	—	0.49	2.0×10^{-6}
Chromium	µg/L	87	2184	100	24,000	<0.01	—	—
Hexavalent Chromium	µg/L	23	2309	—	48	0.48	—	—
Nitrate	µg/L	43,481	2184	45,000	113,600	0.38	—	—
Nitrate as N	µg/L	9,771	2409	10,000	25,600	0.38		
Uranium	µg/L	43	3009+	30	48	0.90	—	—

Source: WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

Note: Cumulative total risk and hazard index were not calculated because the projected year for attainment of federal or state MCL or WAC 173-340-720 groundwater cleanup level is different for each final nonradiological COPC.

6.8 Uncertainties in Risk Assessment

The purpose of this risk assessment is to determine whether a groundwater remedial action is warranted under CERCLA. Estimating and evaluating health risk from exposure to environmental contaminants is a complex process with inherent uncertainties. Uncertainty reflects limitations in knowledge, and simplifying assumptions must be made to quantify health risks.

In this assessment, uncertainties relate to the selection of COPCs and the development of media concentrations to which receptors may be exposed, the assumptions about exposure and toxicity, and the characterization of health risks. Uncertainties exist regarding the quantification of health risks in terms of several assumptions about exposure and toxicity, including site-specific and general uncertainties. Based on the anticipation of uncertainty when quantifying exposure and toxicity, the health risks and hazards presented in this risk assessment are more likely to overestimate risk.

6.8.1 Uncertainties Associated with Sampling and Analysis Data

Current baseline conditions are represented by groundwater data collected over a defined 5-year period from 93 monitoring wells within the 200-UP-1 OU. The groundwater dataset for the COPCs consists of more than 1,000 samples available from more than 93 wells that have been routinely sampled. Therefore, the groundwater dataset is considered adequate for risk assessment.

New wells are generally sampled quarterly the first year after installation, semi-annually the second year after installation, and annually thereafter. Biennial sampling is used for existing perimeter wells that have

shown stable concentrations for several years. If irregular, decreasing, or increasing trends appear, the sampling frequencies are adjusted accordingly.

Sampling and analysis results from these programs comprehensively define the suite of contaminants associated with existing source area plumes. Differences in sampling frequencies (annually or triannually) may create uncertainties associated with the temporal representative qualities of the dataset. However, the differences in sampling frequencies are not anticipated to influence the overall concentrations of COPCs in groundwater. Differences in method detection limits for the same sample and between samples create uncertainties associated with confirmation of the presence or absence of COPCs at or below the action level. Method detection limits vary as a result of changes that have occurred between laboratory contracts.

Filtered (dissolved) and unfiltered (total) analyses results are available for some metals in the groundwater dataset. However, only unfiltered results are used for selecting COPCs. Use of filtered sampling results may underestimate chemical and radiological concentrations in water from an unfiltered tap and are not used for the COPC selection process. Generally, there are more filtered metal results available than unfiltered results; however, exclusion of filtered results does not eliminate metals from the COPC process or underestimate EPCs.

6.8.2 Uncertainties Associated with Exposure Point Concentrations

The EPCs for groundwater are calculated as the 90th percentile concentration. The protectiveness and risk evaluation methodology uses a reasonable maximum exposure concentration for each COPC with an exposure area, rather than performing the evaluation on a specific well or location. In general, EPA Superfund guidance recommends using a 95 percent UCL on the average for estimating EPCs. However, experience at the Hanford Site indicates that averages and UCLs cannot be reliably calculated for groundwater datasets using this approach. The 200-UP-1 OU exhibits an aquifer setting where multiple groundwater contaminants are in overlapping plumes, and the highest concentrations have different locations within the plumes. The 90th percentile from a distribution of groundwater concentration data as an EPC is a different approach from Superfund guidance for estimating EPCs in risk assessments (OSWER 9285.6-10). As shown in the following description, the 90th percentile exposure is identified in EPA risk assessment guidance for describing and characterizing health risks and produces risk estimates that correspond to a reasonable maximum exposure.

Table 6-21 provides additional information on possible ranges of concentrations in groundwater EPCs for the COPCs. The table provides the percentile concentrations used for the protectiveness and risk evaluations, as well as the maximum, average, and 95 percent UCL concentrations using all of the data within an exposure area. For the final COPCs listed in the table, the 90th percentile concentrations are greater than the 95 percent UCL values for all COPCs.

The groundwater dataset is considered robust when the 90th percentile value is greater than the 95 percent UCL value. Generally, when datasets are large, the 95 percent UCL will approach the mean concentration. For nitrate, the 95 percent UCL is 98,692 µg/L and the mean is 76,922 µg/L; in contrast, the 90th percentile is 133,000 µg/L. Therefore, 90th percentile values are reasonable upper bounds of concentrations for the purposes of the risk assessment. However, if a well was drilled at the location of the maximum concentration, risks would be significantly underestimated for the COPCs where the maximum concentration is considerably larger than the 90th percentile value. This is true for three COPCs whose maximum concentrations are more than an order of magnitude larger than the 90th percentile. The results with greater than the 90th percentile value are iodine-129 at 11 percent, nitrate at 10 percent, and tritium at 10 percent.

Table 6-21. Percentile Concentrations and Summary Statistics

Final COPC	Units	Number of Measurements	Number of Detections	90th Percentile	Maximum	Mean	95 Percent UCL
Carbon Tetrachloride	µg/L	628	564	189	1,600	95	127
Chloroform	µg/L	614	506	7.2	35	3.7	3.4
Chromium	µg/L	280	191	99	846	80	92
Hexavalent Chromium	µg/L	74	42	52	236	25	32
Iodine-129	pCi/L	452	79	3.5	39	7.3	3.0
Nitrate	µg/L	1,044	1,043	133,000	1.74E+06	76,922	98,692
Nitrate as N	µg/L	1,044	1,043	30,060	3.93E+05	17,400	22,400
Technetium-99	pCi/L	1,094	952	4,150	13,700	2,730	4,110
Tetrachloroethene	µg/L	605	47	1	3.8	0.78	0.2
Trichloroethene	µg/L	631	244	3.3	13	2.3	1.2
Tritium	pCi/L	451	348	51,150	1.02E+6	30,661	43,718
Uranium	µg/L	743	736	206	613	56	81

6.8.3 Uncertainties Associated with Exposure Assumptions

The exposure assumptions used in this risk assessment represent a reasonable maximum exposure. For estimating the reasonable maximum exposure, 95 percent UCL values (or upper-bound estimates of national averages) are generally used for exposure assumptions, and exposed populations and exposure scenarios are also selected to represent upper-bound exposures. The intent of the reasonable maximum exposure, as discussed by the EPA Deputy Administrator and the Risk Assessment Council (Habicht, 1992, "Guidance on Risk Characterization for Risk Managers and Risk Assessors"), is to present risks as a range from central tendency to high-end risk (above the 90th percentile of the population distribution). This descriptor is intended to estimate the risks that are expected to occur in small but definable high-end segments of the subject population (Habicht, 1992). EPA distinguishes between those scenarios that are possible but highly improbable and those that are conservative but more likely to occur within a population, with the latter being favored in risk assessment. In general, these assumptions are intended to be conservative and yield an overestimate of the true risk or hazard.

6.8.4 Uncertainties Associated with Dermal Contact Exposure

The exposure scenarios for protection of humans using groundwater as a drinking water source consider ingestion and inhalation of vapors as complete and significant pathways. Dermal contact is considered a complete but insignificant pathway of exposure for the contaminants detected in groundwater.
The exclusion of the dermal contact exposure route from the assessment may have the potential to underestimate the actual cleanup level.

EPA considers the dermal contact route to be significant if it contributes at least 10 percent of its exposure to the oral pathway. These results are based on comparing two main household daily uses of water: as a source for drinking and for showering or bathing (EPA/540/R/99/005). Exhibit B-3 and Exhibit B-4 of EPA/540/R/99/005 provide a screening tool to focus the dermal risk assessment on those chemicals that are more likely to make a contribution to the overall risk. Exhibit B-3 indicates that contributions from the dermal exposure routes exceeds 10 percent of the contributions from the drinking water exposure route for chromium, hexavalent chromium, carbon tetrachloride, PCE, and TCE. The ratio of the dermal absorbed dose from dermal to oral is 40 percent for chromium, 42 percent for hexavalent chromium, 27 percent for carbon tetrachloride, 60 percent for PCE, and 17 percent for TCE. Based on this comparison, the action levels identified in Section 6.1.2 may have the potential to underestimate exposure to these final COPCs.

6.8.5 Uncertainties Associated with Toxicity Assessment

The toxicological database was also a source of uncertainty. EPA has outlined some of the sources of uncertainty as defined in the risk assessment guidance (EPA/540/1-89/002) and (Cook, 2003), including the extrapolation from high to low doses and from animals to humans. This extrapolation is contingent on the species, gender, age, and strain differences in the uptake, metabolism, organ distribution, and target site susceptibility of a toxin. The human population's variability with respect to diet, environment, activity patterns, and cultural factors are also sources of uncertainty.

Traditionally, EPA has developed toxicity criteria for carcinogens by assuming that all carcinogens are nonthreshold contaminants. However, EPA has recently published revised cancer guidelines (EPA/630/P-03/001F), in which EPA has modified its former position of assuming nonthreshold action for all carcinogens. This new guidance emphasizes establishing the specific toxicokinetic mode of action that leads to development of cancer. In the future, toxicity criteria for carcinogens in the United States will be developed assuming no threshold for contaminants that exhibit genotoxic modes of action, or where the mode of action is not known. However, currently available EPA toxicity criteria for carcinogens were all derived assuming a nonthreshold model.

In most of the world, nonthreshold toxicity criteria are developed only for those carcinogens that appear to cause cancer through a genotoxic mechanism (TERA, 2011, International Toxicity Estimates for Risk). Specifically, for genotoxic contaminants, the cancer dose response model is based on high- to low-dose extrapolation and assumes there is no lower threshold for the initiation of toxic effects. Cancer effects observed at high doses are found in laboratory animals or are extrapolated from occupational or epidemiological studies. Cancer effects observed at low doses are commonly found in environmental exposures. These models are essentially linear at low doses so that no dose is without some risk of cancer.

6.8.5.1 Slope Factors for Trichloroethene

The oral cancer potency factor of 0.089 $(mg/kg\text{-}day)^{-1}$ is used to develop the WAC 173-340-720 groundwater cleanup level and is obtained from HEAST (January 1, 1991). HEAST has not been updated since 1997, so the oral cancer potency factor does not reflect the most current source of information.

The oral slope factor currently recommended by EPA for TCE is established by the CalEPA Office of Environmental OEHHA. The source of this toxicity value is consistent with the hierarchy of toxicity values recommended in Cook (2003). The oral slope factor is 0.013 $(mg/kg\text{-}day)^{-1}$ (OEHHA,1999, *Public Health Goal for Trichloroethylene In Drinking Water*).

The OEHHA value is lower than the value of 0.089 $(mg/kg\text{-}day)^{-1}$ for oral exposures published in the 1991 HEAST.

If the CalEPA value was used to calculate the WAC 173-340-720 groundwater cleanup level, the groundwater concentration would increase from 0.49 µg/L to 3.4 µg/L. The groundwater risks at the 90th percentile would decrease from 6.7×10^{-6} to 9.7×10^{-7} in groundwater. However, the cumulative risk would remain above 1×10^{-5}. Use of the oral cancer potency factor from HEAST results in an overestimation of risks when compared to the oral slope factor established by CalEPA.

6.8.6 Uncertainties Associated with Risk Characterization

In the risk characterization, the assumption was made that the total risk of developing cancer from exposure to site contaminants is the sum of the risk attributed to each individual contaminant. Likewise, the potential for the development of noncancer adverse effects is the sum of the HQs estimated for exposure to each individual contaminant. This approach, in accordance with EPA guidance, did not account for the possibility that constituents act synergistically or antagonistically.

As discussed in Section 6.3.2, MCLs for radionuclides are set at 4 mrem/yr for the sum of the doses from beta particle and photon emitters, 15 pCi/L for gross alpha emitter activity (including Ra-226 but excluding uranium and radon), and 5 pCi/L combined for Ra-226 and Ra-228. A mass concentration MCL has been established for uranium as 30 µg/L. At this time, no additional federal or state standards are associated with evaluating the effects of exposure to radionuclides.

Risks were estimated for radioisotopes identified as final COPCs using inputs and equation 720-2 from WAC 173-340-720(4)(iii)(B) and radionuclide slope factors from HEAST. The federal MCL concentrations reported for each of the final radionuclide COPCs do not individually exceed the 10^{-4} ELCR end of the NCP (40 CFR 300) risk range (Table 6-12).

Table 6-22. Summary of 90th Percentile Radioactive COPCs Current Concentrations, Associated Cancer Risk and Associated Sum of Fractions

Final COPC	90th Percentile Value (pCi/L)	Federal DWS (pCi/L)	ELCR at Federal MCL	Individual Fraction	Individual ELCR
Iodine-129	3.5	1	2.8×10^{-6}	3.5	9.80×10^{-6}
Strontium-90	0.66	8	8.5×10^{-6}	0.08	6.80×10^{-7}
Technetium-99	4,150	900	4.7×10^{-5}	4.6	2.16×10^{-4}
Tritium	51,150	20,000	1.9×10^{-5}*	2.6	4.94×10^{-5}
Sum of Fractions				**10.8**	**-**
Cumulative Annual Dose (mrem)				**42.8**	**-**
Cumulative ELCR for Radioactive COPCs				**-**	**2.76×10^{-4}**

* An excess lifetime cancer risk for tritium, which includes the ingestion and inhalation exposure routes, would be 1.3×10^{-4}. The ELCR for tritium would be 1.9×10^{-5} for the ingestion exposure route only.

6.9 Summary and Conclusions

A BRA was conducted to evaluate risks to human health by exposure to contaminated groundwater within the 200-UP-1 OU boundary and to provide information that can be used in the development and evaluation of remedial alternatives. The action levels identified in the BRA included ingestion and inhalation routes of exposure (dermal exposure was also evaluated quantitatively and qualitatively). This

assessment demonstrated that cancer risks and HIs are clearly above threshold levels, individual contaminant concentrations are above action levels, and that a review of remedial technologies in a Feasibility Study is warranted.

Sampling results from 93 monitoring wells, yielding 67,806 records for 237 contaminants, were used in the BRA. The contaminants were screened against action levels to define the initial COPCs. If a contaminant was detected in any well within the OU above the specific action level, that contaminant was defined as an initial COPC. Further evaluations of the initial COPCs were completed to refine the initial COPCs to final COPCs. This refining step included reviewing background levels of the initial COPCs, reviewing persistence trends and locations for the COPCs in the aquifer, and reviewing the laboratory methods and qualifiers associated with each initial COPC sample result.

Risks associated with all contaminants, the initial COPCs, and the final COPCs were also quantified using EPA's tap water scenario. This scenario was used to quantify risks from ingestion of tap water, inhalation of volatiles, and dermal exposure from showering, bathing, or performing other domestic activities. The risk posed by each specific initial COPC was then quantified and compared individually and collectively to the CERCLA (10^{-4} to 10^{-6}) and MTCA (10^{-5} and 10^{-6}) threshold risk ranges. Additionally the quantified risks were used to confirm that the COPC identification and screening process (that is, all contaminants screened to initial COPCs and then screened to final COPCs) was reasonable and representative of the measured concentrations within the 200-UP-1 OU. The results of this confirmation analysis indicate that the final COPCs are representative and appropriate for assessing risk and for making contaminant-specific remedial action decisions. If the contaminant had a quantified risk level that was above EPA's acceptable risk range, the contaminant was defined as a final COPC subject to remedial technology review in the FS. Additionally, at the request of the Yakama Nation and the CTUIR, two risk exposure scenarios provided by the Tribal Nations were evaluated, the results of which are presented in Appendix E.

Finally, an evaluation of potential future conditions risk was performed to determine the year in which each final COPC would reach the action level, if no remedial action was taken (fate and transport or no action scenario). This step helped reveal the effect natural attenuation would have on the contaminants' fate in the environment and identify what role natural attenuation might serve in a remedy decision. Table 6-23 presents the final COPCs.

Table 6-23. Final Groundwater COPCs for the 200-UP-1 OU

Metals	Volatile Organic Compounds	Radionuclides
Total Chromium Hexavalent Chromium Uranium	1,4-Dioxane* Carbon Tetrachloride Chloroform Tetrachloroethene Trichloroethene	Iodine-129 Strontium-90* Technetium-99 Tritium
		Anions
		Nitrate

* EPC did not exceed action level, but the VOC was retained as a final COPC because of localized contamination.

A domestic groundwater-user scenario (ingestion, dermal, and inhalation) was developed because the NCP (40 CFR 300) expects that useable groundwater will be returned to beneficial use wherever practicable, and the State of Washington has determined that the highest beneficial use of groundwater at Hanford is as a potential source of drinking water. Thus, the contaminants and related risk associated with

the hypothetical use of the groundwater in the 200-UP-1 OU (as a source of domestic drinking water) was evaluated. The results of the risk evaluation indicate that there are no current risks to onsite industrial workers or offsite human receptors from the contaminated groundwater because the existing Hanford Site access and institutional controls prevent groundwater use and exposure. However, there is potential future risks to human health that exceed the acceptable EPA incremental lifetime cancer risk range and the HQ in the absence of controls preventing consumption of groundwater.

The risk evaluation for current conditions indicated that carbon tetrachloride is a final COPC and is the largest contributor to incremental lifetime cancer risk and noncancer health risk. In addition to carbon tetrachloride, 12 other final COPCs (iodine-129, strontium-90, technetium-99, uranium, tritium, chloroform, 1,4-dioxane, PCE, TCE, chromium [total and hexavalent] and nitrate) exceed their respective action levels and all warrant evaluation in the Feasibility Study to align with the CERCLA guidance, which indicates that remedial action for groundwater is generally warranted when risk thresholds are exceeded (Clay, 1991). With the exception of 1,4-dioxane and strontium-90, all final COPCs were identified because the 90th percentile concentration exceeded the action level. Furthermore,1,4-Dioxane and strontium-90 were identified as final COPCs because they are in localized areas with long-term trends (or hot spots).

The cumulative ELCR is 6.6×10^{-4} for all nonradiological contaminants and 2.8×10^{-4} for all radiological contaminants (Table 6-16), both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to ELCR are carbon tetrachloride (4.7×10^{-4}, 49 percent), technentium-99 (2.2×10^{-4}, 22 percent), tritium (5.7×10^{-5}, 5.8 percent), PCE (1.3×10^{-5}, 1.3 percent), and iodine-129 (9.7×10^{-5}, 1.0 percent). In addition, contributions to ELCR are elevated for arsenic (4.5×10^{-4}; 15 percent), where measured concentrations are within natural background values. Contributions from 1,4-dioxane (9.9×10^{-7}, 0.1 percent), chloroform (4.4×10^{-6}, 0.45 percent), and TCE (5.4×10^{-6}, 0.56 percent) fall below 1 percent, but they are identified as final COPCs based on the action levels and localized measurements.

The HI is 18, which is greater than the EPA target HI of 1.0. The major contributors to HI are carbon tetrachloride (HQ = 9.4, 53 percent), uranium (HQ = 1.9, 11 percent), hexavalent chromium (HQ = 0.67, 3.8 percent), and nitrate (HQ = 0.52, 2.9 percent). Additional contaminants (mostly metals) that contribute greater than 1 percent of the HI include acrolein (HQ = 0.89; 5.0 percent), antimony (HQ = 2.0; 11 percent), arsenic (HQ = 0.61; 3.4 percent), cobalt (HQ = 0.25; 1.4 percent), fluoride (HQ = 0.22; 1.2 percent), molybdenum (HQ = 0.33; 1.9 percent), and vanadium (HQ = 0.20; 1.1 percent).

The final COPCs make up 80.4 percent of the total cancer risk (Table 6-16). Arsenic was not included as a final COPC and contributes 15 percent of the remaining cancer risk, which is attributable to natural site background. The final COPCs make up 71 percent of the total noncancer risk (Table 6-16). The majority of the remaining total noncancer risk (about 26 percent) is attributed to metals that occur naturally in background groundwater (antimony at 11 percent, arsenic 3.4 percent, cobalt at 1.4 percent, molybdenum at 1.9 percent, vanadium at 1.1 percent, fluoride at 1.2 percent, and cadmium at 0.68 percent) and also to very low frequencies of detection or laboratory contamination (acrolein 5 percent and bromomethane 0.64 percent). The remaining 3 percent of the risk is made up of contaminants that contribute less than 0.5 percent each).

Table 6-24 and Table 6-25 (taken from earlier parts of this chapter), present a summary of the 90th Percentile Current Groundwater Concentrations and Associated Cancer Risks and Noncancer HI using MTCA Guidance, and a summary of the 90th Percentile Radioactive COPCs Current Concentrations, Cancer Risk and Sum of Fractions.

Future risks were estimated using fate and transport modeling, which assumed no remedial actions occur to determine the contaminant's fate in the environment. The model was used to estimate the amount of time required to reach the action level and the path the plumes would likely take over a 1,000-year time window. During the transport simulations, a 90th percentile groundwater concentration was calculated for each final COPC at 25-year and 100-year time intervals, and Cmax was also tracked.

Table 6-24. Summary of 90th Percentile Current Groundwater Concentrations for Final Nonradiological COPCs, Associated Cancer Risk, and Noncancer Hazard Index

Final COPC	Units	90th Percentile Value	WAC 173-340-720 Cleanup Levels			
			Noncarcinogens	HQ	Carcinogens at 10^{-6} Risk Level	ELCR
Carbon Tetrachloride	µg/L	189	5.6	34	0.34	5.6×10^{-4}
Chloroform	µg/L	7.2	80	0.09	1.4	5.1×10^{-6}
1,4-Dioxane	µg/L	6.0	800	<0.01	4.0	1.5×10^{-6}
Tetrachloroethene	µg/L	1.0	80	0.01	0.081	1.2×10^{-5}
Trichloroethene	µg/L	3.3	--	--	0.49	6.7×10^{-6}
Total ELCR					**--**	**5.8×10^{-4}**
Total Chromium	µg/L	99	24,000	<0.01	--	--
Hexavalent Chromium	µg/L	52	48	1.1	--	--
Nitrate as NO_3	µg/L	133,000	113,600	1.2	--	--
Nitrate as N	µg/L	30,060	25,600	1.2		
Uranium (total)	µg/L	206	48	4.3	--	- -
Hazard Index				**41**		

Source: WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

The 90th percentile groundwater concentrations were then compared to the federal and state MCLs and the WAC 173-340-720 groundwater cleanup levels. This comparison yielded the number of years required to meet the DWSs or WAC 173-340-720 cleanup levels. The results showed that:

- The uranium plume, beginning with an initial 90th percentile concentration of 206 µg/L, attenuates to 25 µg/L in 600 years. The federal DWS is 30 µg/L.
- The Tc 99 plumes, begin with an initial 90th percentile concentration of 4,150 pCi/L, attenuate to 688 pCi/L in 25 years. The federal DWS is 900 pCi/L.
- The tritium plume, beginning with an initial 90th percentile concentration of 51,150 pCi/L, attenuates to 3,684 pCi/L in 50 years. The federal DWS is 20,000 pCi/L.
- The iodine-129 plume, beginning with an initial 90th percentile concentration of 3.5 pCi/L, attenuates to 0.6 pCi/L in 400 years. The federal DWS is 1 pCi/L.

- The nitrate plume (reported as NO_3), beginning with an initial 90th percentile concentration of 133 mg/L, attenuates to 38 mg/L in 75 years. The federal DWS for NO_3 is 45 mg/L and the federal DWS is 10 mg/L, when reported as N.
- The total chromium plumes begin with an initial 90th percentile concentration of 99 µg/L which is below the federal DWS of 100 µg/L at initial conditions. These same plumes, reported as hexavalent chromium, begin with an initial 90th percentile concentration of 52 µg/L and attenuate to 38 µg/L in 25 years. The Washington State WAC 173-340-720 Cleanup Level is 48 µg/L for hexavalent chromium.
- The carbon tetrachloride plume, beginning with an initial 90th percentile concentration of 189 µg/L was not simulated for the portion of the plume residing in 200-UP-1. The federal and state DWS's are 5 µg/L and the Washington State WAC 173-340-720 Cleanup Level is 3.4 µg/L.

Ecological exposure to 200-UP-1 OU contaminants is not expected because of a lack of direct or indirect exposure by ecological receptors to groundwater now or in the future. While none of the identified COPCs is expected (under the no action scenario) to reach the Columbia River at any significant level, remedial action necessary for human health risk mitigation and restoration of the aquifer for beneficial use will also prevent contaminants from reaching the Columbia River. Such remedial action will mitigate potential future ecological risks associated with the groundwater pathway and its connection to the river. Therefore, no baseline quantitative ecological risk evaluation was conducted in support of the need to take action. The BRA demonstrated that cancer risks and HIs are clearly above threshold levels and individual contaminant action levels, and a review of remedial technologies in the Feasibility Study is warranted.

Table 6-25. Summary of 90th Percentile Current Groundwater Concentrations for Final Radiological COPCs, Associated Cancer Risk and Associated Sum of Fractions

Final COPC	90th Percentile Concentration (pCi/L)	Federal DWS (pCi/L)	ELCR at Federal DWS	Individual Fraction	Individual ELCR
Iodine-129	3.5	1	2.8×10^{-6}	3.5	9.80×10^{-6}
Strontium-90	0.66	8	8.5×10^{-6}	0.08	6.80×10^{-7}
Technetium-99	4,150	900	4.7×10^{-5}	4.6	2.16×10^{-4}
Tritium	51,150	20,000	1.9×10^{-5}*	2.6	4.94×10^{-5}
			Sum of Fractions	**10.8**	**-**
			Cumulative Annual Dose (mrem)	**42.8**	**-**
			Cumulative ELCR for Final Radioactive COPCs	**-**	**2.76×10^{-4}**

* An excess lifetime cancer risk for tritium, which includes the ingestion and inhalation exposure routes, would be 1.3×10^{-4}. The ELCR for tritium would be 1.9×10^{-5} for the ingestion exposure route only.

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7 Identification and Screening of Technologies

The primary objective of the FS is to develop and applicable range of remedial alternatives for evaluation. Section 7.1 presents the information used to develop the RAOs that address the primary risk-contributing contaminants identified through the BRA in Chapter 6 (final COPCs), which were further refined into COCs and presented in Section 7.1.1. The ARARs, which are used to define the PRGs, are presented in Section 7.1.2. Section 7.1.3 presents the RAOs, and Section 7.1.4 presents the PRGs. Section 7.2 presents the GRAs and a description of the remedial technologies and process options assembled for review and screening to address the COCs. The technology screening process presented in Section 7.3 was performed in accordance with EPA guidance (EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final*) and the NCP (40 CFR 300.430(e)(1)(I), "Remedial Investigation/Feasibility Study and Selection of Remedy"). The retained technologies from this screening step are assembled into remedial alternatives presented in Chapter 8 and evaluated and compared to each other in Chapter 9.

7.1 Basis for Remedial Action Objectives

RAOs are descriptions of what the remedial action is expected to accomplish including medium-specific and site-specific goals for protecting human health and the environment. RAOs include statements that are defined as specifically as possible to address the following:

- Media of interest (groundwater)
- COCs (radionuclides and chemical contaminants)
- Defined potential receptors (humans)
- Exposure pathways (dermal contact, ingestion, or inhalation)
- Contaminant concentrations or PRGs to be achieved

7.1.1 Contaminants of Concern

As part of the RAO development process, the list of final COPCs from the BRA in Chapter 6 (Table 6-14) was further evaluated to develop a list of COCs to guide the remedial technology screening and remedial alternatives development process. Based on the results of this COPC-to-COC evaluation, the list of 13 final COPCs has been refined to 8 COCs. These COCs are listed in Table 7-1, and the groundwater plumes for these contaminants are presented on Figure 7-1. The eight COCs include carbon tetrachloride, uranium, chromium (total), hexavalent chromium, nitrate, Tc-99, I-129, and tritium.

Table 7-1. Final Groundwater COCs for the 200-UP-1 OU

Metals	Volatile Organic Compounds	Radionuclides	Anions
Total Chromium Hexavalent Chromium Uranium	Carbon Tetrachloride	Iodine-129 Technetium-99 Tritium	Nitrate

The contaminants not retained as COCs from the list of final COPCs include; 1,4-dioxane, Sr-90, PCE, TCE, and chloroform. These COPCs were infrequently detected in the 200-UP-1 OU monitoring network, and they are not significant risk contributors nor do they occur with persistence above the DWS. These COPCs are collocated with other COCs so that remediation of the larger COC plumes will remove the limited risk associated with these contaminants. These COPCs will be included in the final remedy performance monitoring program.

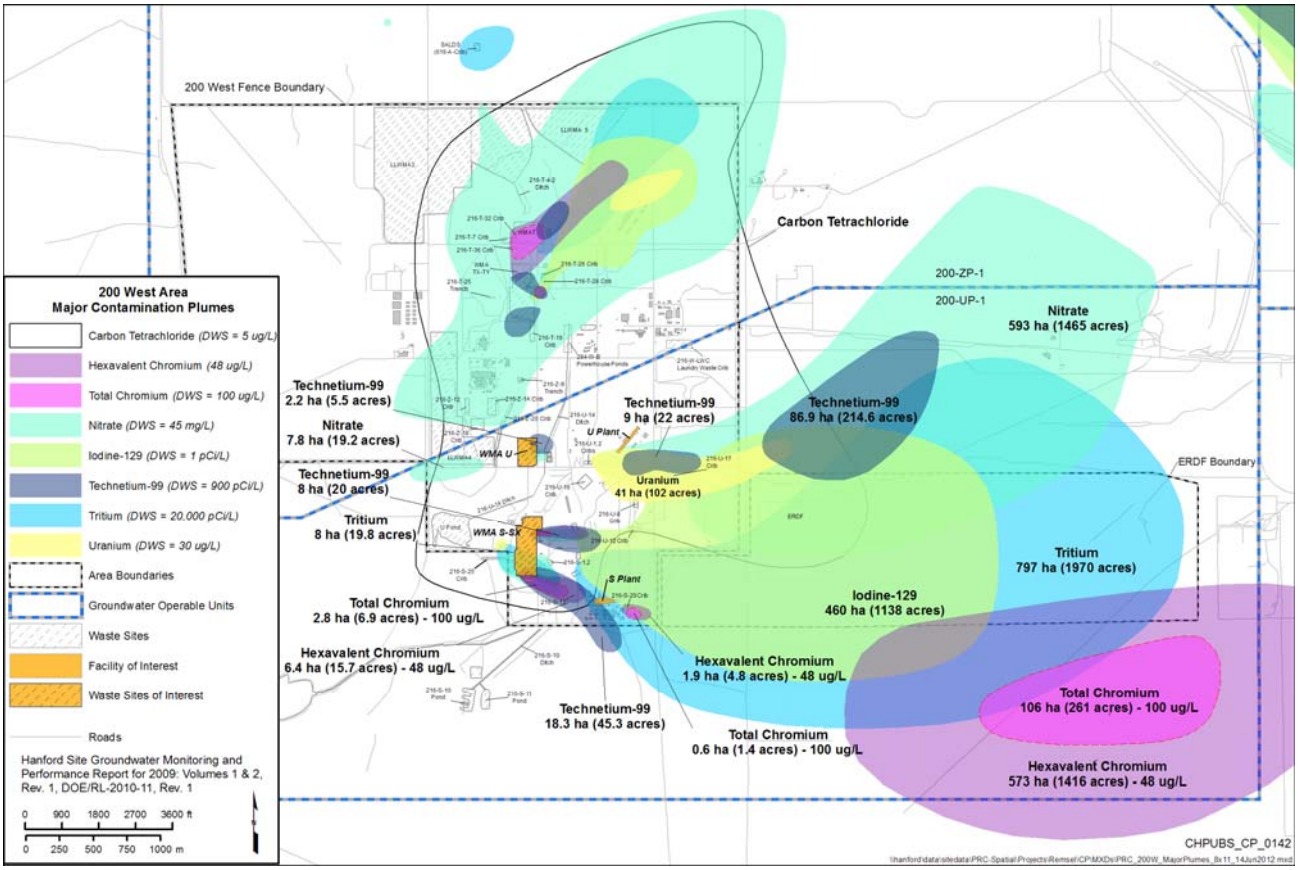

Figure 7-1. 200-UP-1 OU Map

The risk associated with the final COPCs for chemical carcinogenic exposure is 5.8×10^{-4} and an HI of 41 (Table 7-2). Carbon tetrachloride accounts for a majority of the risk (97 percent cancer and 84 percent noncancer). Chloroform accounts for less than 1 percent of the cancer and noncancer risk, 1,4-dioxane for less than 0.3 percent of the cancer and noncancer risk, PCE for less than 2 percent of the cancer and noncancer risk, and TCE for about 1 percent of the cancer and noncancer risk. The risk associated with the final COPCs for radiological exposure is 2.76×10^{-4}, with Tc-99 contributing 78 percent of the risk (2.16×10^{-4}). The individual risk levels for each of the four radiological final COPCs (I-129, Sr-90, Tc-99, and tritium) are presented in Table 7-3.

Table 7-2. 90th Percentile Current Groundwater Chemical Concentrations, Associated Cancer Risk, and Noncancer Hazard Index

Final COPC	Units	90th Percentile Concentration	WAC 173-340-720 Cleanup Levels			
			Noncarcinogens	HQ	Carcinogens at 10^{-6} Risk Level	ELCR
Carbon Tetrachloride	µg/L	189	5.6	34	0.34	5.6×10^{-4}
Chloroform	µg/L	7.2	80	0.09	1.4	5.1×10^{-6}
1,4-Dioxane	µg/L	6.0	800	<0.01	4.0	1.5×10^{-6}

Table 7-2. 90th Percentile Current Groundwater Chemical Concentrations, Associated Cancer Risk, and Noncancer Hazard Index

Final COPC	Units	90th Percentile Concentration	WAC 173-340-720 Cleanup Levels			
			Noncarcinogens	HQ	Carcinogens at 10^{-6} Risk Level	ELCR
PCE	µg/L	1.0	80	0.01	0.081	1.2×10^{-5}
TCE	µg/L	3.3	--	--	0.49	6.7×10^{-6}
Total ELCR					**--**	**5.8×10^{-4}**
Total Chromium	µg/L	99	24,000	<0.01	--	--
Hexavalent Chromium	µg/L	52	48	1.1	--	--
Nitrate, as NO_3	mg/L	133	113.6	1.2	--	--
Nitrate, as N	mg/L	30.1	25.6	1.2		
Uranium	µg/L	206	48	4.3	--	- -
Hazard Index				**41**		

Source: WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

Table 7-3. 90th Percentile Radioactive COPCs Current Concentrations, Associated Cancer Risk, and Associated Sum of Fractions

Final COPC	90th Percentile Value (pCi/L)	Federal DWS (pCi/L)	ELCR at Federal DWS	Individual Fraction	Individual ELCR
Iodine-129	3.5	1	2.8×10^{-6}	3.5	9.80×10^{-6}
Strontium-90	0.66	8	8.5×10^{-6}	0.08	6.80×10^{-7}
Technetium-99	4,150	900	4.7×10^{-5}	4.6	2.16×10^{-4}
Tritium	51,150	20,000	1.9×10^{-5}*	2.6	4.94×10^{-5}
Sum of Fractions				**10.8**	**-**
Cumulative Annual Dose (mrem)				**42.8**	**-**
Cumulative ELCR for Radioactive COPCs				**-**	**2.76×10^{-4}**

* An ELCR for tritium, which includes the ingestion and inhalation exposure routes, would be 1.3×10^{-4}. The ELCR for tritium would be 1.9×10^{-5} for the ingestion exposure route only.

The risk associated with PCE comes from the MTCA groundwater cleanup level, which is equal to the laboratory detection limit. These contaminants are not significant risk contributors and do not warrant being defined as COCs, which are subject to remedial action. However, because many of the lesser

risk- contributing COPCs are co-mingled with the COC plumes, such as carbon tetrachloride, remedial actions that reduce COCs will reduce the final COPCs not retained as COCs.

Table 7-4 presents the COC plume concentration, area, thickness, volume, and mass for the COCs originating in the 200-UP-1 OU. Carbon tetrachloride is not presented because it was previously characterized in the 200-ZP-1 RI and FS Reports. The individual COC plumes range in size from tritium (the largest) at approximately 805 ha (1,989 ac) to uranium (the smallest) at approximately 41 ha (102 ac).

Table 7-4. 200-UP-1 OU COC Plume Area, Mass, and Pore Volume Estimates

COC	Porosity[a]	Plume Area[b] (ha/acres)	Estimated Plume Thickness[c] (m/ft)	Plume Pore Volume (billion L/gal)	90th Percentile	Estimated COC Mass Based on 90th Percentile
Uranium	0.2	41/102	15/50	1.26/0.33	206 µg/L	570 lb (260 kg)
Nitrate, as NO3	0.2	601/1,484	24/80	29/7.7	133 mg/L	8,600,000 lbs (3,900,000 kg)
Total Chromium	0.2	109/269	24/80	5.3/1.4	99 µg/L	1,150 lbs (525 kg)
Hexavalent Chromium	0.2	581/1,437	24/80	28/7.5	52 µg/L	3,243 lbs (1,474 kg)
Tritium	0.2	805/1,989	30/100	49/13	51,150 pCi/L	2,510 Ci
Technetium-99	0.2	124/307	20/65	4.9/1.3	4,150 pCi/L	20.5 Ci
Iodine-129	0.2	460/1,138	30/100	28/7.4	3.5 pCi/L	0.1 Ci

a. Porosity of 0.2 from DOE/RL-2007-28, *Feasibility Study Report for the 200-ZP-1 Groundwater Operable Unit*, Table D-58.

b. Plume areas above PRG estimated by digitizing the boundaries presented in DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*.

c. Average plume thickness estimated from plume cross section depictions shown in Chapter 4.

The areas and volumes are based on COC distributions measured in 2009 and the average plume thickness as estimated from the plume cross-sections presented in Chapter 4. This approach may overestimate the volume of contaminated groundwater associated with each COC plume; however, it provides a reasonable estimate for the purposes of remedial technology screening and remedial alternative development and evaluation. The COC mass estimates were also developed by multiplying the plume pore volume by the 90th percentile EPC.

There are five different Tc-99 plumes. The largest Tc-99 plume resides in the northeastern portion of the OU and measures 87 ha (215 acres). While this plume is the largest of the Tc-99 plumes, it is the most diluted, and those Tc-99 plumes associated with WMA U and WMA S-SX are smaller but more concentrated. Of three chromium plumes, one is in the southeastern portion of the OU which is the largest at 106 ha (261 ac). Two smaller plumes are near WMA S-SX that measure 2.8 ha (6.9 ac). Within 200-UP-1, the carbon tetrachloride plume is comingled with the 200-UP-1 COCs. As such, the removal of carbon tetrachloride is a common component to each of the 200-UP-1 remedial alternatives.

DOE operated the interim action 200-ZP-1 OU P&T system near the middle of the 200 West Area from 1994 to 2012, which removed carbon tetrachloride as the primary COC. In September 2008, the final remedy for the 200-ZP-1 OU was defined in the *Record of Decision, Hanford 200 Area, 200-ZP-1 Operable Unit Superfund Site, Benton County, Washington* (EPA, 2008). The remedy was Alternative 2, "Pump-and-Treat, MNA, Flow-Path Control, and Institutional Controls." This ROD identified use of an expansive pump-and-treat system as part of the remedy. The remedy is expected to take approximately 25 years for the 200 West Pump-and-treat system to reduce the carbon tetrachloride contaminant mass by 95 percent, followed by approximately 100 years of MNA to achieve the PRGs. Carbon tetrachloride concentrations above 100 µg/L corresponded to approximately 95 percent of the mass of carbon tetrachloride residing in the aquifer. The plume is expected to remain on the Central Plateau geographic area through the remediation time frame. The 100 µg/L concentration contour covers areas within the 200-ZP-1 and 200-UP-1 OUs. No distinction was made between the two OUs when the carbon tetrachloride mass was calculated in the 200-ZP-1 RI/FS. The COCs for 200-ZP-1 are the same as those for 200-UP-1, with the exception of the uranium near U Plant in 200-UP-1.

The scope of 200-ZP-1 final remedy included capturing that portion of the carbon tetrachloride plume that migrated across the boundary into 200-UP-1. Since the ROD was signed, the well field layout has been refined as part of the remedial design process (Figure 7-2), and several 200-ZP-1 remediation wells have been installed near the OU boundary and within the 200-UP-1. As the 200-ZP-1 remedy progresses, installation of additional wells may be done (if needs are defined) to optimize plume capture and achieve the RAOs. The source of the 200 West Area carbon tetrachloride plume originated within the 200-ZP-1 OU from the disposal of liquid waste into cribs and trenches associated with plutonium concentration and recovery operations at the Z Plant facilities. After effluents were discharged to these disposal sites, carbon tetrachloride (which is mobile in the environment) migrated through the vadose zone to the groundwater. After reaching groundwater, the plume migrated south and east to the 200-UP-1 OU.

A vadose zone removal action using soil vapor extraction is currently ongoing (since 1992) as part of the 200-PW-1 source OU to remove carbon tetrachloride from the soil. This removal action will continue under the final ROD recently issued for the 200-PW-1 OU. In support of the 200-ZP-1 OU remedial design effort, groundwater flow and contaminant transport modeling was performed for the 200 West Area carbon tetrachloride plume and reported in DOE/RL-2009-38, *Description of Modeling Analyses in Support of the 200-ZP-1 Remedial Design/Remedial Action Work Plan*. The simulations indicated that the 200-ZP-1 OU remedy can meet the RAO and recover the mass of carbon tetrachloride equivalent to or exceeding 95 percent of the dissolved mass of carbon tetrachloride in the 200 West Area aquifer. The sample data used to define the plume and support the transport simulations in the 200-ZP-1 RI/FS report included wells in 200-UP-1 and that portion of the carbon tetrachloride plume that extends into the 200-UP-1. Table A-1 in DOE/RL-2009-38 lists the wells used to calculate the carbon tetrachloride mass and evaluate the pumping needs.

7.1.2 Applicable or Relevant and Appropriate Requirements

ARARs are reviewed to identify federal and state standards that could affect the development and selection of a remedial alternative. The ARARs identification process presented in this section is based on CERCLA (EPA/540/G-89/006, *CERCLA Compliance with Other Laws Manual: Interim Final*) and EPA RI/FS guidance (EPA/540/G-89/004).

Remedial actions under CERCLA, as amended under Title 42, Chapter 103, must attain the required levels of cleanup for the protection of human health and the environment from hazardous substances released. The *Superfund Amendments and Reauthorization Act of 1986* specifies that a selected remedial action must achieve a level of control that attains requirements legally applicable to the hazardous

substances of concern, or requirements that are relevant and appropriate under the circumstances of the release or potential release.

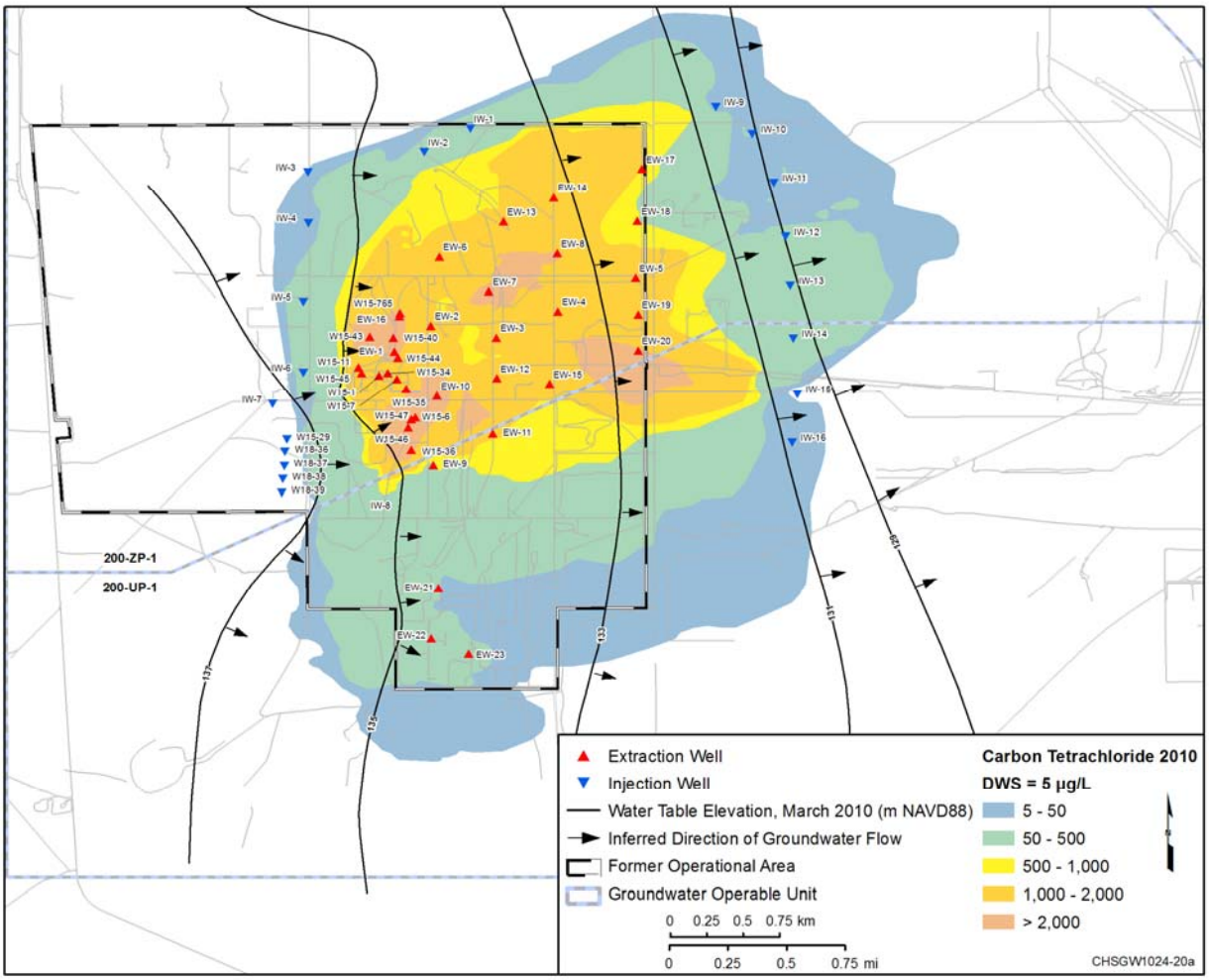

Figure 7-2. Preliminary 200-ZP-1 OU Remedy Injection and Extraction Well Locations with Inferred Groundwater Flow Direction

7.1.2.1 Definition and Determination of ARARs

The identification of ARARs is a two-step process. First, it must be determined what laws or regulations are applicable. If a law or regulation is not applicable, it must then be determined whether the law or regulation is relevant and appropriate. The terms "applicable" and "relevant and appropriate" are defined in 40 CFR 300.5, "National Oil and Hazardous Substances Pollution Contingency Plan," "Definitions," and as follows:

- "Applicable" means those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal or state environmental laws or facility citing laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by the state in a timely manner and are more stringent than federal requirements may be applicable.

- "Relevant and Appropriate Requirements" means those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal or state environmental laws or facility siting laws that, although not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site, such that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate.

In evaluating the relevance and appropriateness of a requirement, the following eight comparison factors described in 40 CFR 300.400(g)(2), "National Oil and Hazardous Substances Pollution Contingency Plan," "General," were 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 affected by the release or CERCLA action
7. The type and size of structure or facility regulated and affected by the release or contemplated by the CERCLA action
8. Any consideration of use or potential use of affected resources in the requirement and the use or potential use of the affected resource at the CERCLA site

To Be Considered (TBC) information is another category of nonpromulgated advisories or guidance issued by the federal or state governments that are not legally binding and do not have the status of ARARs. In some circumstances, TBC information is evaluated, along with ARARs, in selecting the remedial action necessary to protect human health and the environment. TBC information complements ARARs in determining protectiveness at a CERCLA site or in assessing implementation of certain actions. For example, because cleanup standards are not available for all contaminants, health advisories (TBC information) may be helpful in defining a PRG.

ARARs are divided into three categories: chemical-specific, location-specific, and action-specific as follows:

- Chemical-specific requirements are risk-based numerical values or methodologies used to derive numerical PRGs. When applied to site-specific conditions, these requirements result in the establishment of public and worker protection levels and site-specific PRGs.
- Location-specific requirements are restrictions placed on the residual concentration of hazardous substances or the conduct of certain activities solely because they occur in special geographic areas.
- Action-specific requirements are technology- or activity-based requirements or limitations triggered by the remedial actions performed at the site.

A distinction and clarification related to ARARs involves onsite and offsite actions. Onsite actions are defined as "the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action" (400 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan"). Onsite actions must comply with ARARs but need only comply with the substantive parts of those requirements. Offsite actions must comply with the substantive and administrative requirements. For onsite activities, a requirement under federal and state environmental laws may be either applicable or relevant and appropriate, but not both.

In summary, a requirement is applicable if the specific terms or jurisdictional prerequisites of the law or regulations directly address the circumstances at a site. If not applicable, a requirement may nevertheless be relevant and appropriate: (1) if circumstances at the site are sufficiently similar to the problems or situations regulated by the requirement, and (2) if the requirement uses the site productively. Only the substantive requirements 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), "Cleanup Standards," Permits and Enforcement"). It is expected that the CERCLA onsite permitting exemption will be extended to all CERCLA remedial and RCRA corrective action activities conducted for the 200-UP-1 OU.

Tables 7-5 and 7-6 (respectively) list the preliminary federal and state ARARs that have been identified as potentially applicable to the 200-UP-1 OU remedial action. Because 200-UP-1 OU groundwater will be remediated under a CERCLA decision document, remedial actions are required to meet ARARs. Final ARARs for remediation of the 200-UP-1 OU will also be consistent with those established for groundwater in the 200-ZP-1 OU ROD.

7.1.2.2 Potential Chemical-specific ARARs

Chemical-specific requirements that are most likely to be applicable or relevant and appropriate to remediation of groundwater in the 200-UP-1 OU include elements of the federal and state regulations that implement the DWSs. The federal DWSs are defined under 40 CFR 141, "National Primary Drinking Water Regulations," while state DWSs are defined under WAC 173-340-200, "Model Toxics Control Act—Cleanup," "Definitions." Ecology has also defined cleanup levels under the MTCA (WAC 173-340). Groundwater cleanup levels and health protection are defined under "Ground Water Cleanup Standards" (WAC 173-340-720(4)(b)(iii)(A) and (B) and WAC 173-340-720(7)(b), respectively).Because federal and state DWSs and the groundwater cleanup levels defined under MTCA (WAC 173-340) are considered ARARs, the remedial action alternatives assembled in Chapter 8 will be developed to achieve ARARs for each identified COC, such that 200-UP-1 OU groundwater can be used as a future drinking water source.

The NCP (40 CFR 300.430(a)(1)(iii)(A)) requires that the remedy use treatment to address the principal threats posed by a site. Contaminated groundwater is not considered a principal threat waste because it is not source material (EPA, 1991, *A Guide to Principal Threat and Low Level Wastes*). If principal threat waste is encountered during construction, it will be addressed using appropriate construction procedures that protect workers and the environment and meet disposal requirements. Principal threat waste will be disposed of offsite at the Waste Isolation Pilot Plant, which is an approved facility for principal threat wastes.

7.1.2.3 Potential Location-specific ARARs

Potential location-specific ARARs identified in Tables 7-5 and 7-6 for the 200-UP-1 OU remedial action include those that protect cultural, historical, and Native American sites and artifacts, as well as those that protect critical habitats of federally listed endangered and threatened species.

Table 7-5. Identification of Potential Federal ARARs move to where table is called

ARAR Citation	Relevancy and Category	Requirement	Rationale for Use
Safe Drinking Water Act of 1974 **(Public Law 93-523, as amended; 42 USC 300f, et seq.); "National Primary Drinking Water Regulations" (40 CFR 141)**			
"Maximum Contaminant Levels for Organic Contaminants," 40 CFR 141.61	ARAR-chemical	Establishes MCLs for drinking water that are designed to protect human health from the potential adverse effects of organic contaminants in drinking water.	Make one entry as this is repeated 3 times below. The groundwater in the 200-UP-1 OU is not currently used for drinking water. However, Central Plateau groundwater may be considered a potential drinking water source, and because the groundwater discharges to the Columbia River (which is used for drinking water), the substantive requirements in 40 CFR 141.61 for organic constituents are applicable.
"Maximum Contaminant Levels for Inorganic Contaminants," 40 CFR 141.62	ARAR-chemical	Establishes MCLs for drinking water that are designed to protect human health from the potential adverse effects of inorganic contaminants in drinking water.	The groundwater in the 200-UP-1 OU is not currently used for drinking water. However, Central Plateau groundwater may be considered a potential drinking water source, and because the groundwater discharges to the Columbia River (which is used for drinking water), the substantive requirements in 40 CFR 141.62 for inorganic constituents are applicable.
"Maximum Contaminant Levels for Radionuclides," 40 CFR 141.66	ARAR-chemical	Establishes MCLs for drinking water that are designed to protect human health from the potential adverse effects of radionuclides in drinking water.	The groundwater in the 200-UP-1 OU is not currently used for drinking water. However, Central Plateau groundwater may be considered a potential drinking water source, and because the groundwater discharges to the Columbia River (which is used for drinking water), the substantive requirements in 40 CFR 141.66 for radionuclides are applicable.
Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites (EPA/540/R-99/009)	TBC-action	Provides the framework and appropriateness for using the MNA as a remedy component for organic and inorganic contaminants.	Groundwater in the 200-UP-1 OU contains contaminants that may require remediation. The use of MNA as a remedy may be appropriate.

Table 7-5. Identification of Potential Federal ARARs move to where table is called

ARAR Citation	Relevancy and Category	Requirement	Rationale for Use
Other Federal ARARs			
Archeological and Historic Preservation Act of 1974, 16 USC 469a-1 – 469a-2(d)	ARAR-location	Requires that RAs at the 200-UP-1 OU do not cause the loss of any archaeological or historic data. This act mandates preservation of the data and does not require protection of the actual historical sites.	Archeological and historic sites have been identified within the 200 Area; therefore, the substantive requirements of this act are applicable to actions that might disturb these sites.
National Historic Preservation Act of 1966, 16 USC 470, Section 106, et seq. "Protection of Historic Properties" (36 CFR 800)	ARAR-location	Requires federal agencies to consider the impacts of their undertaking on cultural properties through identification, evaluation, and mitigation processes.	Cultural and historic sites have been identified within the 200 Area; therefore, the substantive requirements of this act are applicable to actions that might disturb these types of sites.
Native American Graves Protection and Repatriation Act of 1990, 25 USC 3001, et seq. "Native American Graves Protection and Repatriation Regulations" (43 CFR 10)	ARAR-location	Establishes federal agency responsibility for discovery of human remains, associated and unassociated funerary objects, sacred objects, and items of cultural patrimony. Requires Native American Tribal consultation in the event of discovery.	Substantive requirements of this act are applicable if remains and sacred objects are found during remediation.
Endangered Species Act of 1973, Public Law 93-205, as amended; 7 USC Section 136; 16 USC Ch. 1531, et seq. (50 CFR 402, "Interagency Cooperation—Endangered Species Act of 1973, as Amended")	ARAR-location	Prohibits actions by federal agencies that are likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of habitat critical to them. Mitigation measures must be applied to actions that occur within critical habitats or surrounding buffer zones of listed species, in order to protect the resource.	Substantive requirements of this act are applicable if threatened or endangered species are identified in areas where RAs will occur.
Migratory Bird Treaty Act of 1918 (16 USC 703-712; Ch. 128; 40 Stat. 755), as amended	ARAR-location	Protects all migratory bird species and prevents "take" of protected migratory birds, their young, or their eggs."	Migratory birds occur in the 200 West Area were 200-UP-1 OU remedial activities will take place.

Note: Regulations pursuant to the Resource Conservation and Recovery Act of 1976 are implemented through WAC 173-303, "Dangerous Waste Regulations" (see Table 7-2).

Table 7-6. Identification of Potential State ARARs

ARAR Citation	Relevancy and Category	Requirement	Rationale for Use
"Hazardous Waste Cleanup -- Model Toxics Control Act" (RCW 70.105D, as amended); "Model Toxics Control Act—Cleanup" (WAC 173-340)			
"Ground Water Cleanup Standards" (WAC 173-340-720) "Method B Cleanup Levels for Potable Ground Water" (WAC 173-340-720(4)(b)(i-iii) (A)&(B)) "Adjustments to Cleanup Levels" (WAC 173-340-720(7))	ARAR-chemical	Groundwater cleanup levels are based on estimates of the highest beneficial use and the reasonable maximum exposure expected to occur under both current and potential future site use conditions. Method B equations (720-1 and 720-2) to calculate groundwater cleanup levels for noncarcinogens and carcinogens, respectively, only if "sufficiently protective, health-based criteria or standards have not been established under applicable state and federal laws. Groundwater cleanup levels are established at concentrations that do not directly or indirectly cause violations of surface water, sediments, soil, or air cleanup standards.	The groundwater in the 200-UP-1 OU is not currently used for drinking water. However, the ARAR requires that the groundwater cleanup levels shall be based on the highest beneficial use, both current and potential future site use. The Central Plateau and the 200-UP-1 OU groundwater is considered potable under WAC 173-340-720. The substantive requirements are WAC 173-340-720(4)(b)(iii)(A) and (B).
"Public Health and Safety," "Hazardous Waste Management" (RCW 70.105, as amended); "Dangerous Waste Regulations" (WAC 173-303)			
"Identifying Solid Waste" WAC 173-303-016	ARAR-action	Identifies those materials that are and are not solid wastes.	Substantive requirements of these regulations are applicable because they define how to determine which materials are subject to the designation regulations. Specifically, materials that are generated during the remedial action would, if a solid waste, be subject to the requirements for solid wastes.
"Recycling Processes Involving Solid Waste" WAC 173-303-017	ARAR-action	Identifies materials that are and are not solid wastes when recycled.	Substantive requirements of these regulations are applicable because they define how to determine which materials are subject to the designation regulations. Specifically, materials that are generated during the remedial action would, if a solid waste, be subject to the requirements for solid wastes.

Table 7-6. Identification of Potential State ARARs

ARAR Citation	Relevancy and Category	Requirement	Rationale for Use
"Designation of Dangerous Waste" WAC 173-303-070(3)	ARAR-action	Establishes whether a solid waste is, or is not, a dangerous waste or an extremely hazardous waste.	Substantive requirements of these regulations are applicable to materials generated during the remedial action. Specifically, solid waste that is generated during this remedial action would, if a dangerous waste, be subject to the dangerous waste regulations.
"Excluded Categories of Waste" WAC 173-303-071	ARAR-action	Describes those categories of wastes that are excluded from the requirements of WAC 173-303 (excluding WAC 173-303-050).	This regulation is applicable to remedial actions in the 200-UP-1 OU, should wastes identified in WAC 173-303-071 be generated.
"Conditional Exclusion of Special Wastes" WAC 173-303-073	ARAR-action	Establishes the conditional exclusion and the management requirements of special wastes, as defined in WAC 173-303-040.	Substantive requirements of these regulations are applicable to special wastes generated during the remedial action. Specifically, the substantive standards for management of special waste are relevant and appropriate to the management of special waste that will be generated during the remedial action.
"Requirements for Universal Waste" WAC 173-303-077	ARAR-action	Identifies those wastes exempted from regulation under WAC 173-303-140 and WAC 173-303-170 through 173-303-9906 (excluding WAC 173-303-960). These wastes are subject to regulation under WAC 173-303-573.	Substantive requirements of these regulations are applicable to universal waste generated during the remedial action. Specifically, the substantive standards for management of universal waste are relevant and appropriate to the management of universal waste that will be generated during the remedial action.
"Recycled, Reclaimed, and Recovered Wastes" WAC 173-303-120 Specific subsections: WAC 173-303-120(3) WAC 173-303-120(5)	ARAR-action	These regulations define the requirements for recycling materials that are solid and dangerous waste. Specifically, WAC 173-303-120(3) provides for the management of certain recyclable materials, including spent refrigerants, antifreeze, and lead-acid batteries. WAC 173-303-120(5) provides for the recycling of used oil.	Substantive requirements of these regulations are applicable to certain materials that might be generated during the remedial action. Eligible recyclable materials can be recycled or conditionally excluded from certain dangerous waste requirements.

Table 7-6. Identification of Potential State ARARs

ARAR Citation	Relevancy and Category	Requirement	Rationale for Use
"Land Disposal Restrictions" WAC 173-303-140(4)	ARAR-action	This regulation establishes state standards for land disposal of dangerous waste and incorporates, by reference, federal land disposal restrictions of 40 CFR 268 that are relevant and appropriate to solid waste that is designated as dangerous or mixed waste in accordance with WAC 173-303-070(3).	The substantive requirements of this regulation are applicable to materials generated during the remedial action. Specifically, dangerous/mixed waste that is generated during the remedial action would be subject to the relevant and appropriate substantive land disposal restrictions. The offsite treatment, disposal, or management of such waste would be subject to all applicable substantive and procedural laws and regulations, including land disposal restriction requirements.
"Requirements for Generators of Dangerous Waste" WAC 173-303-170	ARAR-action	Establishes the requirements for dangerous waste generators.	Substantive requirements of these regulations are applicable to materials generated during the remedial action. Specifically, the substantive standards for management of dangerous or mixed waste are relevant and appropriate to the management of dangerous waste that will be generated during the remedial action. For purposes of this remedial action, WAC 173-303-170(3) includes the substantive provisions of WAC 173-303-200 by reference. WAC 173-303-200 further includes certain substantive standards from WAC 173-303-630 and -640 by reference.
"Requirements" (WAC 173-303-64620(4))	ARAR-action	Establishes the standards for implementing corrective action for releases of dangerous waste and constituents under the HWMA. Corrective action is implemented by requiring corrective action follow certain sections of WAC 173-340 (WAC 173-303-64620(4).	Corrective action applies to the entire Hanford site. Corrective action applies to all releases of dangerous waste and dangerous constituents as stated in WAC 173-303-64620(1). CERCLA may be the authority being used to clean up the release; the cleanup must be "consistent with" corrective action. The substantive portions of WAC 173-340 establish minimum requirements for HWMA corrective action.

Table 7-6. Identification of Potential State ARARs

ARAR Citation	Relevancy and Category	Requirement	Rationale for Use
"Solid Waste Management—Reduction and Recycling" (RCW 70.95, as amended); "Solid Waste Handling Standards" (WAC 173-350)			
"On-Site Storage, Collection and Transportation Standards," WAC 173-350-300	ARAR-action	Establishes the requirements for the temporary storage of solid waste in a container onsite and the collecting and transporting of the solid waste.	The substantive requirements of this newly promulgated rule are applicable to the onsite collection and temporary storage of solid wastes for the 200-UP-1 OU remediation activities. Compliance with this regulation is being implemented in phases for existing facilities.
"Water Well Construction" (RCW 18.104, as amended); "Minimum Standards for Construction and Maintenance of Wells" (WAC 173-160)			
"How Shall Each Water Well Be Planned and Constructed?" (WAC 173-160-161)	ARAR-action	Identifies well planning and construction requirements.	The substantive requirements of these regulations are ARARs to actions that include construction of wells used for groundwater extraction, monitoring, or injection of treated groundwater or wastes. The substantive requirements of WAC 173-160-161, 173-160-171, 173-160-181, 173-160-400, 173-160-420, 173-303-430, 173-160-440, 173-160-450, and 173-160-460 are relevant and appropriate to groundwater well construction, monitoring, or injection of treated groundwater or wastes in the 200-UP-1 OU.
"What Are the Requirements for the Location of the Well Site and Access to the Well?" (WAC 173-160-171)	ARAR-action	Identifies the requirements for locating a well.	
"What Are the Requirements for Preserving the Natural Barriers to Ground Water Movement Between Aquifers?" (WAC 173-160-181)	ARAR-action	Identifies the requirements for preserving natural barriers to groundwater movement between aquifers.	
"What Are the Minimum Standards for Resource Protection Wells and Geotechnical Soil Borings?" (WAC 173-160-400)	ARAR-action	Identifies the minimum standards for resource protection wells and geotechnical soil borings.	
"What Are the General Construction Requirements for Resource Protection Wells?" (WAC 173-160-420)	ARAR-action	Identifies the general construction requirements for resource protection wells.	
"What Are the Equipment Cleaning Standards?" (WAC 173-160-430)	ARAR-action	Identifies the minimum casing standards.	

Table 7-6. Identification of Potential State ARARs

ARAR Citation	Relevancy and Category	Requirement	Rationale for Use
"What Are the Minimum Casing Standards?" (WAC 173-160-440)	ARAR-action	Identifies the equipment cleaning standards.	
"What Are the Well Sealing Requirements?" (WAC 173-160-450)	ARAR-action	Identifies the well sealing requirements.	
"What Is the Decommissioning Process for Resource Protection Wells?" (WAC 173-160-460)	ARAR-action	Identifies the decommissioning process for resource protection wells.	
"Underground Injection Control" WAC 173-218			
"UIC Well Classification Including Allowed and Prohibited Wells" (WAC 173-218-040)	ARAR-action	Identifies what an injection well is and types of prohibited wells.	The substantive requirements of these regulations are ARARs to actions that discharge liquid effluents to injection wells. WAC 173-218-040(4) allows for injection of treated groundwater into the same formation from where it was drawn as part of a removal or remedial action approved by EPA in accordance with CERCLA.
"Washington Clean Air Act" (RCW 70.94, as amended); "General Regulations for Air Pollution Sources" (WAC 173-400)			
"General Regulations for Air Pollution Sources" (WAC 173-400)	ARAR-action	Defines methods of control to be employed to minimize the release of air contaminants associated with fugitive emissions resulting from materials handling, construction, demolition, or other operations. Emissions are to be minimized through application of best available control technology.	Groundwater remedial actions implemented in the 300 Area provide the potential for emissions subject to these standards because hazardous contaminants detected in 200-UP-1 OU groundwater include covered hazardous air pollutants.

Table 7-6. Identification of Potential State ARARs

ARAR Citation	Relevancy and Category	Requirement	Rationale for Use
"General Standards for Maximum Emissions" (WAC 173-400-040) "Emission Standards for Sources Emitting Hazardous Air Pollutants" (WAC 173-400-075)	ARAR-action	Requires all sources of air contaminants to meet emission standards for visible, particulate, fugitive, odors, and hazardous air emissions. Requires use of reasonably available control technology. This state regulation is as stringent as or more stringent than the equivalent federal program requirement. Establishes national emission standards for hazardous air pollutants. Adopts, by reference, 40 CFR 61, "National Emission Standards for Hazardous Air Pollutants," and appendices.	Substantive requirements of these standards are ARARs to this remedial action because there may be visible, particulate, fugitive, and hazardous air emissions and odors resulting from remedial activities. As a result, standards established for the control and prevention of air pollution are relevant and appropriate. Soil or groundwater hazardous contaminants detected in 100-K include covered regulated hazardous air pollutants. This is an action-specific requirement.
"Washington Clean Air Act" (RCW 70.94, as amended); "Controls for New Sources of Toxic Air Pollutants" (WAC 173-460)			
"Purpose" (WAC 173-460-010) "Applicability" (WAC 173-460-030) "Control Technology Requirements" (WAC 173-460-060) "Ambient Impact Requirement" (WAC 173-460-070) "First Tier Review" (WAC 173-460-080) "Table of ASIL, SQER and de Minimis Emission Values" (WAC 173-460-150)	ARAR-action	Establishes control of new sources emitting toxic air pollutants to prevent air pollution, reduce emissions to the extent reasonably possible, and maintain such levels of air quality as will protect human health and safety. Toxic air pollutants include carcinogens and noncarcinogens listed in WAC 173-460-150. Three major requirements of this regulation are implementation of best available control technology for toxics, quantification of toxic air pollutant emissions, and demonstration of health and safety protection.	Substantive requirements of these standards are ARARs to this remedial action because of the potential for toxic air pollutants to become airborne as a result of remedial activities. As a result, standards established for the control of toxic air contaminants are relevant and appropriate.

Table 7-6. Identification of Potential State ARARs

ARAR Citation	Relevancy and Category	Requirement	Rationale for Use
"Washington Clean Air Act" (RCW 70.94, as amended); "Ambient Air Quality Standards and Emission Limits for Radionuclides" (WAC 173-480)			
"Ambient Standard" (WAC 173-480-040)	ARAR-action	Defines the maximum allowable level for radionuclides in the ambient air, which shall not cause a maximum accumulated dose equivalent of 25 mrem/yr to the whole body or 75 mrem/yr to any critical organ. However, ambient air standard under 40 CFR 61, Subpart H, "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities," and Subpart I, "National Emission Standards for Radionuclide Emissions from Federal Facilities Other Than Nuclear Regulatory Commission Licensees and Not Covered by Subpart H," are not to exceed amounts that result in an effective dose equivalent of 10 mrem/yr to any member of the public.	Hazardous contaminants detected in the groundwater in 200-UP-1 OU include radionuclides that could be emitted to ambient air during remedial actions.
"General Standards for Maximum Permissible Emissions" (WAC 173-480-050)	ARAR-action	At a minimum, all emission units shall make every reasonable effort to maintain radioactive materials in effluents to unrestricted areas; control equipment of sites operating under ALARA shall be defined as reasonably available control technology and as low as reasonably achievable control technology.	Substantive requirements are ARARs when fugitive and diffuse emissions resulting from excavation occur, and related activities will require assessment and reporting.
"Emission Monitoring and Compliance Procedures" (WAC 173-480-070)	ARAR-action	Requires that radionuclide emissions shall be determined by calculating the dose to members of the public using Department of Health approved sampling procedures at the point of maximum annual air concentration in an unrestricted area where any member of the public may be.	The substantive requirements of this standard are ARARs to remedial actions involving disturbance or ventilation of radioactively contaminated areas or structures, because airborne radionuclides may be emitted to unrestricted areas where any member of the public may be.

Table 7-6. Identification of Potential State ARARs

ARAR Citation	Relevancy and Category	Requirement	Rationale for Use
"Emission Standards for New and Modified Emission Units" (WAC 173-480-060)	ARAR-action	Requires that construction, installation, or establishment of new air emission control units use best available radionuclide control technology.	Hazardous contaminants detected in 200-UP-1 groundwater include radionuclides that could be emitted from air emission control units during remedial actions.
"Nuclear Energy and Radiation" (RCW 70.98, as amended); "Radiation Protection—Air Emissions" (WAC 246-247)			
"National Standards Adopted by Reference for Sources of Radionuclide Emissions" (WAC 246-247-035) "National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities" (WAC 246-247-035(1)(a)(i) [adopts by reference 40 CFR 61.12, "Compliance with Standards and Maintenance Requirements"])	ARAR-action	Requires the owner or operator of each stationary source of hazardous air pollutants subject to a national emission standard for a hazardous air pollutant to determine compliance with numerical emission limits in accordance with emission tests established in "Emission Tests and Waiver of Emission Tests" (40 CFR 61.13) or as otherwise specified in an individual subpart. Compliance with design, equipment, work practice, or operational standards shall be determined as specified in the individual subpart. Also, maintain and operate the source, including associated equipment for air pollution control, in a manner consistent with good air pollution control practice for minimizing emissions.	Substantive requirements of this standard are ARARs because this remedial action may provide airborne emissions of radioactive particulates to unrestricted areas. As a result, requirements limiting emissions apply. This is a risk-based standard for the purposes of protecting human health and the environment.
(WAC 246-247-035 (1)(a)(i) [adopts by reference 40 CFR 61.14, "Monitoring Requirements"])	ARAR-action	Requires the owner or operator to maintain and operate each monitoring system as specified in the applicable subpart, and in a manner consistent with good air pollution control practice for minimizing emissions. Approvals of alternatives to any monitoring requirements or procedures are obtained from the regulatory agency.	Hazardous contaminants that would be subject to EPA's National Emission Standards for Hazardous Air Pollutants (NESHAP) and resultant requirements may be detected in, and potentially emitted from, structures, components, debris, soil, or groundwater involved in the remedial actions in 200-UP-1 OU. The hazardous contaminants will be monitored as identified under each applicable NESHAP subpart.

Table 7-6. Identification of Potential State ARARs

ARAR Citation	Relevancy and Category	Requirement	Rationale for Use
(WAC 246-247-035 (1)(a)(ii) [adopts by reference 40 CFR 61.93, "Emission Monitoring and Test Procedures"])	ARAR-action	Specifies that radionuclide emissions shall be determined and effective dose equivalent values to members of the public calculated to determine compliance with the 10 mrem/yr effective dose equivalent standard. Radionuclide emissions shall be collected and measured using approved methods. A quality assurance program shall be conducted that meets the performance requirements described in Appendix B, Method 114. Measurement by methods specified in the paragraph (b) shall be made at all release points that have the potential to discharge radionuclides to the air in quantities that cause an effective dose equivalent in excess of 1 percent of the 10 mrem/yr standard. For other release points that have a potential to release radionuclides into the air, periodic confirmatory measurements shall be made to verify the low emissions.	Hazardous radionuclide contaminants that would be subject to NESHAP., Radionuclide air pollutant standards and resultant requirements may be detected in, and potentially emitted from, structures, components, debris, soil, or groundwater involved in the remedial actions in 200-UP-1 OU. The hazardous contaminants will be monitored as identified under each applicable NESHAP subpart.
"General Standards" WAC 246-247-040(3) WAC 246-247-040(4)	ARAR-action	Requires that emissions be controlled to ensure ALARA-based and best available control standards are not exceeded.	Substantive requirements of this standard are ARARs because fugitive, diffuse, and point source emissions of radionuclides to the ambient air may result from remedial activities, such as excavation of contaminated soils and operation of exhauster and vacuums, performed during the remedial action. This standard exists to ensure compliance with emission standards.

Table 7-6. Identification of Potential State ARARs

ARAR Citation	Relevancy and Category	Requirement	Rationale for Use
"Monitoring, Testing and Quality Assurance" WAC 246-247-075	ARAR-action	Establishes the monitoring, testing, and quality assurance requirements for radioactive air emissions. Emissions from nonpoint and fugitive sources of airborne radioactive material will be measured. Measurement techniques may include but are not limited to sampling, calculation, smears, or other reasonable method for identifying emissions as determined by the lead agency.	Substantive requirements of this standard are ARARs when fugitive and nonpoint source emissions of radionuclides to the ambient air may result from activities, such as operation of exhauster and vacuums, performed during a RA. This standard exists to ensure compliance with emission standards.

7.1.2.4 Potential Action-specific ARARs

Potential action-specific ARARs identified in Tables 7-5 and 7-6 include the State's solid and dangerous waste regulations (for management and characterization of remediation wastes), the water well construction regulations, and the underground injection control regulations. State of Washington regulations also identify air emissions limits and control requirements for remedial actions that produce hazardous substances.

A variety of waste streams may be generated under the proposed remedial alternatives in Chapter 8 of this RI/FS. It is anticipated that most of the waste derived from monitoring and extraction well installation and other balance-of-plant construction will be designated as dangerous or mixed waste. The identification, storage, treatment, and disposal of hazardous waste and the hazardous component of mixed waste generated during the remedial action will be subject to the substantive provisions of RCRA. In the State of Washington, RCRA is implemented through the state's dangerous waste program (WAC 173-303, "Dangerous Waste Regulations"). The substantive portions of the dangerous waste standards for generation and storage would apply to the management of any dangerous or mixed waste generated. Treatment standards for dangerous or mixed waste that is subject to RCRA land disposal restrictions are specified in WAC 173-303-140, "Dangerous Waste Regulations," "Land Disposal Restrictions," which incorporates 40 CFR 268 "Land Disposal Restrictions," by reference.

Low-level waste that meets ERDF waste acceptance criteria is assumed to be disposed of 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, dangerous or mixed waste would be treated as needed to meet land disposal restrictions and ERDF acceptance criteria. The ERDF is engineered to meet minimum technical requirements for landfills under WAC 173-303-665, "Dangerous Waste Regulations," "Landfills." Applicable packaging and pre-transportation requirements for dangerous or mixed waste would be identified and implemented before any waste is moved. Alternate disposal locations may be considered when the remedial action is performed if a suitable and more cost-effective location is identified. Any potential alternate disposal location will be evaluated for performance standards and compliance with the CERCLA offsite disposal rule to ensure it is adequately protective of human health and the environment. Waste designated as transuranic will be stored onsite at the Central Waste Complex, with eventual disposal at the Waste Isolation Pilot Plant in New Mexico.

CERCLA states that where two or more noncontiguous facilities are reasonably related on the basis of geography, or are a threat or potential threat to the public health, welfare, or the environment, the two facilities can be treated as one facility for purposes of CERCLA response actions. Consistent with this, the 200-UP-1 OU, ERDF, the 200 Area ETF, and the 200 West Area Treatment Plant are considered onsite facilities for purposes of CERCLA Section 104, "Response Authorities," and waste may be transferred between these 200-UP-1 OU facilities without a permit. Liquid effluent discharged to the ground after treatment under any remedial action must comply with the requirements of WAC 173-216. Because the treated groundwater (treatment plant effluent) will be injected back into the aquifer, it will be necessary to comply with WAC 173-218, "Underground Injection Control Program."

The remedial action will be implemented under a CERCLA decision document and will be performed in compliance with dangerous and mixed waste requirements. Waste streams will be characterized, and a waste determination will be made and managed in compliance with ARARs. Before disposal, waste will be managed in a protective manner to prevent releases to the environment and stop unnecessary personnel exposure.

The proposed remedial actions presented herein and in Chapter 8 have the potential to generate airborne emissions during well drilling and general balance–of-plant construction activities. Radioactive and chemical contaminants could be released. RCW 70.94, "Public Health and Safety," "Washington Clean Air Act," regulates radioactive air pollutants. The State of Washington 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 standards under the *Clean Air Act of 1990* and the implementing regulation (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"). The Washington State standards protect the public by establishing conservative exposure standards applicable to the maximally exposed public individual, be that individual real or hypothetical. The standards address any member of the public, at the point of maximum annual air concentration in an unrestricted area where any member of the public is allowed to be present. Radionuclide airborne emissions from a construction activity or treatment facility shall not exceed exposure to the public of 10 mrem/yr effective dose equivalent. The Washington State implementing regulation, WAC 246-247, "Radiation Protection—Air Emissions" (which adopts the WAC 173-480 standards), and 40 CFR 61, Subpart H, require verification of compliance with the 10 mrem/yr standard and would be applicable to the remedial action.

WAC 246-247 further addresses 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 action.

The implementing regulations listed previously further address control of radioactive airborne emissions where economically and technologically feasible (WAC 246-247-040(3) and -040(4) 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. If it is determined that there are substantive aspects of the requirement for control of radioactive airborne emissions, then controls will be administered as appropriate using reasonable and effective methods.

7.1.2.5 Waivers from Applicable or Relevant and Appropriate Requirements

The NCP allows selection of a remedial action (40 CFR 300.430(f)(1)(ii)(C)) that does not attain ARARs. Section 121 of the *Superfund Amendments and Reauthorization Act of 1986* identifies six circumstances in which EPA may waive ARARs for onsite remedial actions:

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

- In the case of Section 104 (Superfund-financed remedial actions), compliance with the ARAR will not provide a balance between protecting human health and the environment and the availability of Superfund money for response at other facilities.
- Technical impracticability waivers only apply to that portion of the groundwater contaminant plume for which restoration to ARARs is determined to be technically impracticable.

7.1.2.6 200-UP-1 OU Groundwater Beneficial Use

The NCP establishes an expectation to "return useable groundwaters to its beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site" (40 CFR 300.430(a)(1)(iii)(F)). EPA generally defers to state definitions of groundwater classification provided under EPA-endorsed Comprehensive State Groundwater Protection Programs (EPA/540/G-88/003, *Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites*).

Based on the anticipated yield and natural water quality, the State of Washington has determined that the aquifer setting for the 200-UP-1 OU meets the WAC 173-340-720 definition for potable groundwater, which is the highest recognized beneficial use. Under EPA's groundwater classification program, 200-UP-1 OU groundwater would be designated Class II-B, groundwater that is not a current source of drinking water but is a potential future source. Consistent with the beneficial use determinations of Washington State and EPA, DOE's intensions are to remediate the groundwater to drinking water standards.

7.1.3 Remedial Action Objectives

Under CERCLA and the NCP, a groundwater remedy must be protective of human health and the environment and meet ARARs (or satisfy criteria for an ARAR to be waived). Based on these requirements and NCP expectations for groundwater restoration, the proposed RAOs for 200-UP-1 OU are the following:

- **RAO 1:** Return the 200-UP-1 OU groundwater to beneficial use as a potential drinking water source.
- **RAO 2:** Apply ICs to prevent groundwater use until drinking water standards are achieved.

To achieve RAO 1, COC concentrations in groundwater will be reduced to levels corresponding to federal DWSs or WAC 173-340-720 groundwater cleanup levels.

RAO 2 will be achieved through the use of institutional controls similar to those in the following documents. The ROD will specify the specific institutional controls:

- The 200-UP-1 OU IRAs ROD (EPA/541/R-97/048, *Record of Decision for the 200-UP-1 Operable Unit Interim Remedial Action, Hanford Site, Benton County, Washington*)
- Ecology, 2009b, *Explanation of Significant Differences for the Interim Action Record of Decision for the 200-UP-1 Groundwater Operable Unit Hanford Site Benton County, Washington*
- Restricting groundwater use as described in DOE/RL-2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions*, until RAO 1 is achieved. DOE will report on the effectiveness of the groundwater use restrictions in the annual reports required by DOE/RL-2001-41.

Remedy performance monitoring will be conducted according to the performance monitoring plan, which will be developed during remedial design. The monitoring plan will define the system performance measures required to effectively operate the P&T system. The sampling locations,

parameters, and performance criteria will be defined in the plan. The performance information will be routinely collected and reported annually.

7.1.4 Preliminary Remediation Goals

The PRGs constitute a core component of the overall technology screening and remedial alternative evaluation process and are numerical values expressed as concentrations for chemicals and radionuclides in groundwater. Achieving the PRGs results in residual contamination that is protective of human health and the environment (40 CFR 300.430(e)(2)(i)). PRGs were also used to identify the area and volume of environmental groundwater (Figure 7-1 and Table 7-3) that must be addressed. Numerical PRGs are generally not required for groundwater alternatives that employ containment technologies (DOE/EH-413/9711, *Development of Remediation Goals under CERCLA*). Current groundwater concentrations, federal DWSs, MTCA cleanup levels, and the proposed 200-UP-1 PRGs are shown in Table 7-7. The final remediation goals will be developed from these PRGs and will be specified in a ROD with the selected remedial alternative.

Table 7-7. 200-UP-1 OU Proposed PRGs, Federal DWSs, and State Cleanup Levels

COCs	Units	90th Percentile Groundwater Concentrations	Federal Drinking Water Standard[a]	Model Toxics Control Act Method B Cleanup Levels		200-UP-1 OU PRGs[b]
				Non-Carcinogens at HQ = 1	Carcinogens at 1×10^{-5} Risk Level	
Iodine-129	pCi/L	3.5	1	–	–	1[e]
Technetium-99	pCi/L	4,150	900	–	–	900
Tritium	pCi/L	51,150	20,000	–	–	20,000
Uranium	µg/L	206	30	–	–	30
Nitrate[c] (as NO3)	mg/L	133	45	113.6	–	45
Nitrate[c] (as N)	mg/L	29.6	10	25.6	–	10
Chromium (total)	µg/L	99	100	24,000	–	100
Hexavalent Chromium	µg/L	52	-- [d]	48	–	48
Carbon Tetrachloride	µg/L	189	5	5.6	3.4	3.4[f]

Notes:

See the risk evaluation section of Chapter 6 for ELCR and HI risk values.

a. Federal DWS from 40 CFR 141, "National Primary Drinking Water Regulations," with I-129 and Tc-99 values from EPA 816-F-00-002, *Implementation Guide for Radionuclides*.

b. The final cleanup levels achieved at the conclusion of the remedial action will correspond to an ELCR less than 1×10^{-5} and HI of less than 1.

c. Nitrate may be expressed as nitrate (NO_3) or as nitrate-nitrogen (NO_3-N). The federal DWS for NO_3-N is 10,000 µg/L and 45,000 µg/L for NO_3^-. The state DWS is 10,000 µg/Las NO_3-N.

d. There is no federal or state DWS for hexavalent chromium.

e. Current groundwater treatment technology is insufficient to reach the 1 pCi/L DWS. A technology evaluation to identify potential I-129 treatment options will be completed as part of each remedial alternative. The evaluation will include a feasibility analysis for each identified treatment option.

f. This cleanup level is a risk-based calculation used for the carbon tetrachloride located in the 200-ZP-1 OU which is located in the same aquifer as 200-UP-1.

7.1.5 Restoration Time Frame

The restoration time frame is defined as the period of time required to reach the PRGs within the OU. For the purposes of remedial technology screening, remedial alternatives development, and estimating restoration time frames for each COC plume, the 200-UP-1 OU was divided into five geographic areas. These areas and their associated COCs are identified as the S-SX Area (carbon tetrachloride, Tc-99, hexavalent chromium, and nitrate), the U-Plant Area (carbon tetrachloride, uranium, nitrate [high concentration zone]), Northeast Nitrate Area (dilute nitrate, Tc-99), Southeast Chromium Area (hexavalent chromium), and the I-129 Area (I-129 and tritium). Carbon tetrachloride will require the longest MNA timeframe estimated to be 125 years, consistent with the 200-ZP-1 OU ROD.

7.2 General Response Actions

GRAs are basic actions defined for 200-UP-1 OU that could be undertaken to remediate contaminants. The GRAs are applicable for the COCs and subsurface conditions in the 200-UP-1 OU and were defined based on the range of COC specific concentrations, the nature and extent of the contaminants, the defined RAOs, and the PRGs. For each GRA, several remedial technologies that exist were further divided into process options, where appropriate. Remedial technologies and process options, within each identified GRA category, were further evaluated with respect to their implementability, effectiveness, and relative cost, in accordance with CERCLA RI/FS guidance (EPA/540/G-89/004) and the NCP (40 CFR 300.430(e)).

The RI/FS guidance recommends the development and evaluation of a range of remedial alternatives, including a no action alternative to ensure identification and selection of an appropriate remedy. The overall remedial technology screening process included the following steps:

- Identify GRAs that can achieve PRGs, either individually or in combination with other GRAs
- Identify, screen, and evaluate remedial technology types for each GRA
- Select representative process options

Following the technology screening step, the remedial technologies and associated process options retained from the screening were assembled into remedial alternatives presented in Chapter 8. These remedial alternatives were then evaluated further in the detailed and comparative analyses of alternatives in Chapter 9.

The GRAs identified are the following:

- No action
- Institutional controls
- MNA
- Containment
- Active restoration
- Passive restoration

Additional information on the GRAs identified and their remedial technologies and associated process options is presented in the following subsections.

7.2.1 General Description of Remedial Technologies and Process Options

The remedial technologies and process options were identified using EPA guidance, technology information web sites, and PNNL-15954, *Screening of Potential Remediation Methods for the 200-ZP-1 Operable Unit at the Hanford Site*. Literature surveys and technology reviews for nitrate, I-129,

and uranium (SGW-37783, *Literature Survey for Groundwater Treatment Options for Nitrate, Iodine-129, and Uranium, 200-ZP-l Operable Unit, Hanford Site*; PNNL-16761, *Evaluation and Screening of Remedial Technologies for Uranium at the 300-FF-5 Operable Unit, Hanford Site, Washington*) were also reviewed and relevant information incorporated into this evaluation.
The following subsections describe the remedial technologies and process options associated with each of the six GRAs listed above.

7.2.1.1 No Action

No action is required as a baseline case for comparison against other technologies and remedial alternatives as specified under the NCP (40 CFR 300.430(e)(6)). Under this GRA, no further action would be taken at the site. Because interim actions are underway at this time, a no action decision would terminate these efforts. The existing P&T interim action at U Plant and an interim action at the S-SX WMA would continue to operate until the final ROD is signed, but then both interim actions would be terminated.

7.2.1.2 Institutional Controls

Institutional controls are administrative controls and legal restrictions imposed on land and groundwater use to protect against exposure to hazardous contaminants and to protect the integrity of a remedy. Institutional controls may include land use restrictions, natural resource use restrictions, groundwater use restrictions or management area designations, deed restrictions, deed notices, declaration of environmental restrictions, access controls (digging/drilling permits), security surveillance, information posting or distribution, restrictive covenants, and federal, state, county, or local registries.

Institutional controls also include fences and security to protect against inadvertent exposure to contaminated groundwater (seeps or springs) until PRGs are achieved or an alternate water supply is obtained for users when contaminated groundwater is used as a current drinking water source. Institutional controls have already been implemented for the Hanford Site overall and specifically the 200-UP-1 OU through the interim action ROD and ESD, and the site-wide institutional controls program (DOE/RL-2001-41). The site-wide institutional controls program requires annual reporting to ensure that institutional controls are maintained and enforced for each remedy decision put in place by DOE and EPA.

7.2.1.3 Monitored Natural Attenuation

MNA is the reliance on natural processes (within the context of a carefully controlled and monitored cleanup approach) to achieve site-specific remedial objectives within a time frame that is reasonable compared to that offered by other, more actively engineered methods. MNA processes that would occur under this GRA include physical, chemical, or biological processes. Under favorable conditions, these processes act in situ without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. These processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or natural destruction of contaminants" (EPA/540/R-99/009, *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*).

Although physical processes are included in this definition, EPA/540/R-99/009 states a preference for chemical, biological, and radioactive decay that permanently degrades, destroys, or transforms contaminants. MNA is not a no action approach and requires an understanding of site-specific and contaminant-specific attenuation mechanisms. An MNA program is required to demonstrate that natural attenuation is occurring in accordance with expectations.

MNA is best applied at sites where contaminant plumes are stable or shrinking, attenuation processes are confirmed to be in effect, and attenuation is demonstrated or simulated to be able to achieve PRGs in a time frame comparable with other remedial alternatives. Natural attenuation is rarely appropriate as a sole remedy without other active remedial measures such as groundwater mass reduction through P&T or the use of institutional controls (EPA/540/R-99/009). In a recent study (WSRC-TR-2003-00328, *Natural and Passive Remediation of Chlorinated Solvents: Critical Evaluation of Science and Technology Targets*), MNA was selected for use at 54 percent of the sites where source control measures were also implemented.

MNA is an important component of the 200-ZP-1 OU remedy, and the natural attenuation features of biodegradation, dispersion, dilution, and radioactive decay have been demonstrated to be in effect within the OU. Because of this, and the similarity in aquifer conditions between 200-UP-1 OU and 200-ZP-1 OU, MNA was evaluated as a GRA.

7.2.1.4 Containment

Containment is used to prevent horizontal and vertical contaminant migration in groundwater and can be achieved by physical barriers or through hydraulic control. Physical containment consists of constructing a barrier that encloses a zone of groundwater contamination to isolate it from the remaining portions of the aquifer. Barriers generally span the entire depth of the aquifer and are typically constructed to extend into the first few meters of a basal confining layer to prevent flow beneath the barrier. In aquifer settings where the contaminant plumes do not extend to the base of the aquifer, a hanging-wall-type barrier may be constructed. Physical barriers include slurry walls, grout curtains, and sheet pile walls.

A slurry wall is a nonstructural underground barrier constructed by placing a cement-bentonite slurry into a trench excavated to the desired depth. For deep applications, the slurry can be injected through a series of wells. The slurry composition can be varied to achieve the desired permeability, durability, and compatibility with the varying subsurface 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 contaminants. Sheet pile walls can also be used and are interlocking metal sheets or piles that are driven to the desired depth by a mechanical or vibratory hammer.

Hydraulic containment can also be achieved by controlling groundwater flow and contaminant migration through strategically placed extraction or injection wells. Extraction wells are generally placed at the leading edge of the plume, pumping the wells at the minimum rate needed to hydraulically capture the plume, treating the extracted water to remove contaminants, and re-injecting the water at an upgradient, cross-gradient, or downgradient location. Hydraulic containment via injection is achieved by placing injection wells along the leading edge of the plume and injecting water to block downgradient plume migration. Containment via injection can be particularly advantageous because there is no contaminated flow stream to treat. When injection wells are used for long-term plume containment, it may be necessary to install additional injection wells if the plume begins to migrate around the ends of the injection field. Extraction and injection wells may also be coupled to create groundwater flow path control that increases the overall effectiveness of hydraulic containment by using injection wells to divert the plume toward extraction points.

The effectiveness of a containment GRA is assessed through groundwater monitoring of chemical and physical parameters. Containment is appropriate if some or all or all of the following are present (see Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites EPA/540/G-88/003):

- Groundwater is naturally unsuitable for consumption (Class III aquifers).
- Low-mobility contaminants are present.
- Low aquifer transmissivity conditions occur.
- Contaminant concentrations are low.
- The potential for exposure is low.
- There is a low projected demand for future use of the groundwater.
- Contaminant sources cannot be removed or treated (deep vadose zone or nonaqueous phase liquid sources).
- A technology for treatment of a specific contaminant does not exist.

7.2.1.5 Active Restoration

Active restoration generally includes groundwater P&T with aboveground treatment and discharge of treated water to a surface water body or by returning it to the aquifer. Depending on the aquifer's characteristics, increasing the number of extraction wells or increasing the wells' pumping rates can affect the cleanup time frame. This approach trades higher capital costs with lower ongoing operation and maintenance (O&M) costs.

Active restoration of contaminated groundwater in a deep aquifer setting, such as that at the 200-UP-1 OU, would need to include an array of vertical pumping wells, a treatment system to remove contaminants from extracted groundwater, a re-injection or surface infiltration option to return treated water to the aquifer, and a monitoring program to assess overall remedy performance.

P&T, as an aquifer restoration measure, is best applied at sites where contaminant source control measures have been implemented and where contaminants are relatively mobile in groundwater. Contaminant mobility affects a P&T system's ability to remove contaminants from the aquifer and contaminants with high mobility will readily flow with groundwater toward extraction wells for removal and contaminants with low mobility adhere to the aquifer sediments.

Treatment of extracted groundwater can be accomplished using a variety of methods that are specific to the contaminant type or contaminants with similar physical or chemical characteristics. Because the 200 West Area groundwater treatment system was constructed and has the ability to treat the contaminants in 200-UP-1 OU, this GRA is being evaluated assuming the 200 West Area treatment facility will be used. Additional information on the 200 West Area groundwater treatment facility and other potential treatment technologies for contaminated groundwater are discussed in the following subsections.

Aboveground Treatment for Volatile Organic Compounds. Aboveground treatment for VOCs, such as carbon tetrachloride, PCE, and TCE that will be co-extracted with 200-UP-1 OU COCs, typically includes air stripping and GAC for treatment.

Air Stripping is a widely applied technology in which VOCs are transferred from groundwater to air by passing large volumes of air through the contaminated water. Aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration. Packed towers and tray aeration are the most common methods used in P&T systems. Air strippers can be operated continuously or in a batch process where the air stripper is intermittently fed the contaminated liquid from a collection or storage tank. The batch process ensures consistent air stripper performance and greater energy efficiency than continuously

operated units because mixing in the collection tank balances out and stabilizes VOC concentrations in the feed water composition and sends the stripper a balanced concentration feed stream. Packed tower air stripping is used for carbon tetrachloride removal from 200-ZP-1 OU groundwater in the 200 West Area groundwater treatment facility.

GAC is also a widely applied technology for VOC removal in P&T systems where contaminated groundwater is pumped through two or more vessels containing the GAC media. As the groundwater flows through the media, VOCs are removed by sorbing onto the individual carbon granules. GAC can also remove some inorganic contaminants by filtering rather than sorbing. GAC vessels are often operated in a series, with the first vessel acting as the lead unit, where a majority of the VOC removal occurs, and the second vessel serving as a polishing unit. When the contaminant concentration in the lead vessel effluent exceeds a specified level (generally 75 percent of original capacity), the GAC is replaced with fresh media, and the flow control valves are adjusted such that the second vessel becomes the lead unit. Spent GAC is usually regenerated at an offsite facility, or disposed of at an approved facility such as ERDF, if regeneration is not practical.

Modification of the activated carbon media can make the GAC vessels more resistant to biological fouling and can make the media perform for a broader range of contaminants. Recent laboratory studies (WSRC-TR-2002-00435, *Laboratory Evaluation of I-129 and Tc-99 Removal at the F-Area Water Treatment Units*) have shown that silver-impregnated carbon has the potential to remove I-129 from groundwater, but the exact media chemistry has not been perfected, and the scale of the treatment the media can support has not been defined.

Aboveground Treatment for Metals, Radionuclides, and Nitrate. Several treatment technologies are used for metals and radionuclide removal from aqueous waste streams. The ion exchange process and precipitation, coagulation, and flocculation are the most widely used. The ion exchange process is used in the 200 West Area groundwater treatment facility for uranium and Tc-99 removal from 200-ZP-1 OU groundwater and can be used for the same contaminants from the 200-UP-1 OU.

Ion Exchange—Uranium and Tc-99. The ion exchange process removes soluble ions from the aqueous phase by exchanging benign cations or anions attached to the exchange media for the ions in the groundwater. The exchange media consists of a spherical resin made from synthetic organic materials that contain cation or anion functional groups attached to the individual resin beads. Once the resin capacity is exhausted, the resin is regenerated using a strong acid/base solution or is disposed of at an approved facility. As part of the final design for the 200 West Area groundwater treatment facility, testing was conducted to select the optimum resin for removal of uranium and Tc-99 from groundwater.

Ion Exchange and Silver-impregnated Granular Activated Carbon for I-129. The remedial design for the 200-ZP-1 OU P&T system included an assessment (382519-TMEM-049, *Iodine-129 Removal Process Considerations*) of the effectiveness of I-129 water treatment technologies. This evaluation reviewed several published studies and vendor claims on I-129 removal capabilities. The ion exchange process, silver chloride-impregnated granular activated carbon (AgCl-GAC), and silver bromide-impregnated activated carbon (AgBr-GAC) were the primary treatment technologies evaluated. The ion exchange process, using a strong-base anion exchange resin (SIR-1200), has been shown to remove I-129 to concentrations below the laboratory detection limit (WSRC-TR-2002-00435). However, current information does not indicate that consistent treatment of I-129 to concentrations of 1 pCi/L or less can be achieved in a full scale application. Therefore, pilot testing will be required for I-129 removal to evaluate the feasibility of treatment of this and other media or resin.

AgCl-GAC was also shown to remove I-129, but the process generates an aqueous silver byproduct that requires treatment to control toxicity in downstream biological treatment processes or to comply with related water aquifer re-injection ARARs.

The 200-ZP-1 OU I-129 treatment evaluation concluded the following:

- There are no known ion exchange resins that have sufficient selectivity for iodine to reduce the concentration to 1 pCi/L or less.
- There are no known suppliers of AgCl-GAC. This form of GAC would have to be manufactured by treating silver-impregnated granular activated carbon (Ag-GAC) with hydrochloric acid.
- AgBr-GAC would not generate the aqueous silver byproduct, but I-129 treatment to less than 1 pCi/L would require further study. There are no known suppliers of AgBr-GAC; therefore, it would need to be specifically prepared for Hanford by treating Ag-GAC with hydrobromic acid.

Electrodialysis and Reverse Osmosis—I-129 Treatment. Electrodialysis and reverse osmosis are membrane filtration technologies typically used in desalination plants and ultrapure water applications. Water is pumped through a membrane to remove the target contaminants. In electrodialysis, an electric potential gradient is used to move the ions through the membrane. In reverse osmosis, hydraulic pressure is used to push water though the membrane for ion removal. Both technologies generate a concentrated I-129 waste stream that requires further treatment or stabilization prior to disposal. Consequently, this technology is not an option for I-129 removal because the concentrated liquid stream must be stabilized prior to onsite disposal (to meet ERDF waste acceptance criteria) or shipped offsite for treatment or disposal. These technologies are not contaminant selective and often remove other ions from solutions and increase the volume and mass of materials requiring management and disposal.

Precipitation, Coagulation, and Flocculation—Chromium. Any COC remedial technology involving groundwater extraction will likely extract chromium because of its presence in the environment. If treatment is necessary, precipitation can be used to convert dissolved ionic species (dissolved metals and radionuclides) into solid-phase particulates that can be removed by coagulation settling or filtration. The process often uses pH adjustment, addition of a flocculent aid (polymer), and clarification. Metals typically precipitate from the solution as hydroxides, sulfides, or carbonates. The solubility of the specific metal contaminants and the required treatment standards will determine the process used.

Precipitation of metals has been the primary method of treating metal-laden industrial wastewaters. As a result of its success in industrial applications, this technology has been growing in use for groundwater and surface water runoff remediation at CERCLA sites. Depending on the process design, sludges generated from the coagulation settling or filtration process may be amenable to metal recovery; however, most sludge is dewatered and disposed of at an approved facility.

Biological Treatment—Chromium and Nitrate. Biological treatment includes aerobic or anaerobic treatment performed in open (aerobic) or closed (anaerobic) vessels, in a constructed wetland or in situ in the aquifer. Contaminants are degraded by microorganisms that use the contaminants in oxidation-reduction reactions to support cellular metabolism and growth. In constructed wetlands, contaminants may be removed through biofiltration or through uptake in plant root systems. Several removal mechanisms have been identified for biological treatment of nitrate, such as decomposition, denitrification, settling, volatilization, adsorption, and nutrient uptake. Fluidized bed bioreactors (anaerobic biological treatment) are used in industry and are very effective in reducing nitrate concentrations such as those present in the 200-ZP-1 and 200-UP-1 OU groundwater plumes. A fluidized bed bioreactor is used at the 200 West Area groundwater treatment facility for chromium and nitrate.

A bioreactor for groundwater treatment would generally consist of fixed or suspended media with a large surface area maintained in a vessel to support micro-organism growth. Typically, the groundwater being treated does not provide an adequate food or nutrient source or optimal conditions to sustain and promote biological treatment; therefore, supplemental substrate and nutrients are added to the influent groundwater to provide a carbon source for cellular metabolism and growth.

Constructed wetlands are engineered systems that act as biofilters for removing soluble and particulate contaminants. A constructed wetland provides several contaminant removal mechanisms, such as decomposition, nitrification/denitrification, settling, volatilization, adsorption, and vegetative uptake. A constructed wetland often requires a large area and extended hydraulic retention time compared to a bioreactor, but a wetland typically would not require substrate and nutrient addition or extensive operational oversight. A constructed wetland for 200-UP-1 OU groundwater could be used because there are large portions of open and uncontaminated areas.

Treated Water Discharge. Four general discharge options are used with P&T remedial actions:

1. **Reinjection:** Treated water is injected to the subsurface through wells or horizontal infiltration galleries. Discharge may be upgradient of the contamination, pushing contamination toward an extraction well network; downgradient of the contamination so the migration of contaminants is slowed or hydraulically controlled (flow path control); cross-gradient to push contamination toward a recovery point; or a combination of all three methods.

2. **Infiltration:** Treated water is collected in a pond or basin and allowed to infiltrate back into the soil. These ponds must be in areas where vadose zone contamination is absent or used as part of a vadose zone soil flushing remedy.

3. **Reuse:** Treated water is reused for irrigation or potable water supply. Reuse of treated water reduces or eliminates the need for a facility to use water from other sources, thereby conserving water as a natural resource.

4. **River discharge:** Under the National Pollutant Discharge Elimination System, treated water may be discharged to a surface water body such as the Columbia River.

7.2.1.6 Passive Restoration (in situ)

Passive restoration includes in situ technologies that treat contaminants in the subsurface. In situ treatment generally includes biological, physical, or chemical methods that immobilize contaminants or transform contaminants to less-toxic compounds.

Bioremediation. In situ bioremediation is a process where indigenous or introduced microorganisms metabolize organic contaminants into other compounds or convert inorganic compounds into a lower oxidation state. Enhanced in situ bioremediation accelerates the natural biodegradation process by providing key nutrients, electron acceptors, or acclimated microorganisms that may otherwise be limiting in the subsurface.

In situ bioremediation is generally applied to organic contaminants such as fuel hydrocarbons (aerobic bioremediation) and chlorinated solvents (anaerobic bioremediation). Anaerobic biodegradation has been used successfully to treat hexavalent chromium, uranium, and nitrate where hexavalent chromium is converted to trivalent chromium, hexavalent uranium to trivalent uranium, and nitrate to nitrogen gas.

The stimulation of aerobic bioremediation processes occurs by adding oxygen to the groundwater using air sparging through wells or by adding concentrated liquid hydrogen peroxide. Solid-phase peroxide products (oxygen-release compounds) can also be used for oxygen enhancement. The stimulation of anaerobic bioremediation consists of injecting an organic substrate into the subsurface where biodegradation of the substrate consumes the available oxygen, which in turn creates anaerobic conditions. Solubilized nitrate has also been circulated through groundwater contamination zones to provide an alternative electron acceptor to enhance anaerobic biodegradation of organic contaminants. Development of nitrate enhancement is still at the pilot scale and not widely applied because unreacted nitrate may create a secondary contaminant source.

In situ bioremediation is generally applied in small, well-defined areas of contamination, like groundwater plumes, or in aquifer settings where high concentrations of mobile contaminants can be transported by natural or induced groundwater flow patterns into a constructed treatment zone. The large, broad groundwater plumes on the Hanford Central Plateau are a good example of such areas.

Chemical and Physical Treatment. Several processes are available to chemically destroy contaminants or alter their physical-chemical state to render them immobile or less toxic.

In situ chemical oxidation (ISCO) uses a strong oxidant such as hydrogen peroxide, permanganate, persulfate, percarbonate, or ozone to destroy contaminants. ISCO requires intimate contact between the oxidant and the contaminant, resulting in conversion to carbon dioxide and water. The oxidant is injected into the subsurface using an array of vertically staggered injection wells, or introduced into a constructed treatment zone such as a permeable reactive barrier (PRB). ISCO is applied at sites where the primary contaminants are organics (petroleum hydrocarbons and chlorinated solvents) in well-defined source or hot spot areas. ISCO is generally not applicable for treatment of large or diffuse low concentration plumes.

Stabilization reduces contaminant mobility by altering the geochemical environment to convert contaminants into less-mobile or less-toxic forms. Stabilization agents are generally introduced in a liquid form via injection wells so that the agents can react with target contaminants within a defined treatment zone. Stabilization technology is currently being used in the 100-N Area to immobilize Sr-90 by injecting two separate chemicals (calcium citrate and phosphate) into an array of vertical injection wells to create a PRB. The two chemicals combine in the subsurface to form apatite, which immobilizes Sr-90 through a sequestering process. The 100-N area apatite barrier, when fully constructed, will be 900 m (2,500 ft) long and extend to depths of about 10 m (30 ft). This technology can be used in a variety of settings to immobilize many different types of contaminants. Treatability testing is required to identify the most effective agent and to determine the optimum dose and delivery method. Stabilization is best applied in source zones or at sites where natural or induced groundwater flow patterns can mobilize the contaminants into a treatment zone such as a PRB.

7.3 Identification and Screening of Technology Types and Process Options

The remedial technology and process options were evaluated to determine which technologies are best capable of achieving PRGs for the COCs present. Table 7-8 summarizes the technology screening results, and Table 7-9 presents the list of retained technologies and process options. The retained technologies will be assembled into an array of remedial action alternatives in Chapter 8.

Table 7-8. Technology Screening Results

General Response Action	Technology Type	Process Option	Target Contaminants	Evaluation			Results
				Effectiveness	Implementability	Relative Cost	
No Action	No Action	None	All COCs	Low. Current and planned interim actions will slow uranium and Tc-99 plume migration until they are terminated, but they are not expected to establish hydraulic control or remove significant amounts of mass from the Northeast Nitrate, Southeast Chromium, or Central I-129 Zones. Tritium (half-life of 12.5 years) concentrations will continue to decline through radiological decay.	Good from a technical perspective but may not be administratively implementable.	Low.	Retained as baseline
Institutional Controls	Entry Restrictions	Procedural requirements for access Excavation/drilling permits	All COCs	Moderate. Reduces or eliminates the potential for direct contact with contaminated groundwater when well implemented and maintained for the duration of elevated risk period. Protects integrity of active remedies.	Moderate/Good. Readily implemented, requires periodic surveillance and maintenance.	Low.	Retained
	Land and Groundwater Use Management	Deed restrictions/notices, declaration of environmental restrictions, information distribution, restrictive covenants, federal/state/county/local Registries	All COCs	Moderate. Reduces or eliminates the potential for direct contact with contaminated groundwater when well implemented and maintained for the duration of elevated risk period. Ensures compatible land use.	Very Good. Readily implemented, must identify and comply with all necessary legal requirements.	Low.	Retained
	Waste Site Information Management	Administrative	All COCs	Moderate. Ensures access to information on the location and nature of contamination.	Very Good. Readily implemented, requires maintenance of the information management system.	Low.	Retained
	Access Controls	Fencing Signs	All COCs	Good. Required in areas where contaminated groundwater appears at surface through seeps, springs, or treatment system handling. Effective in preventing or reducing the potential for direct contact with contaminated groundwater if well implemented and maintained for duration of elevated risk period.	Very Good. Readily implemented, requires periodic inspection and maintenance.	Low.	Retained
	Alternate Water Supply	Pump water from clean surface water or groundwater source to point of use	All COCs	Good. Not required at this time because 200-UP-1 OU groundwater not being used.	Moderate. Could be implemented if necessary, alternate water sources are available.	Low.	Rejected. Groundwater not currently needed for drinking purposes.
Monitored Natural Attenuation	MNA	Groundwater sampling Laboratory analysis Data evaluation and reporting	Tritium, carbon tetrachloride, and diffuse (low-level) nitrate	Good for tritium with concentrations reduced to PRG in 25 years. Moderate for carbon tetrachloride and diffuse nitrate plumes. Poor for chromium, high concentration nitrate areas, uranium, Tc-99, and I-129, which require much longer time frames.	Moderate. Readily implemented technically, may be less implementable administratively because of the long time frames required for achieving PRGs, especially for uranium.	Moderate depending on the number of monitoring locations and sampling frequency.	Retained for tritium, diffuse nitrate, and carbon tetrachloride.

Table 7-8. Technology Screening Results

General Response Action	Technology Type	Process Option	Target Contaminants	Evaluation			Results
				Effectiveness	Implementability	Relative Cost	
Containment	Physical Barriers	Slurry walls Grout curtain Sheet pile walls	Uranium, Tc-99, I-129	Poor to very good, depending on integrity of the installation process. Ringold upper mud unit would provide a confining layer for keying the barrier. Slurry walls used at other CERCLA sites primarily for containment of nonaqueous phase liquids acting as a long-term contaminant source to groundwater. Not widely used for dissolved phase plume containment.	Very difficult. The large size of the uranium and I-129 plumes would require barriers totaling several miles in length. Installation depths of 91 to 137 m (300 to 450 ft) exceed the range of trenching equipment and would require an extensive array of jet grouting points. Sheet piling could not be advanced to the required depths because of the cobbly nature of subsurface material.	Very high.	Rejected because of technical implementability (depth and size of plumes) and high cost.
	Hydraulic Containment	Vertical extraction or injection wells	I-129	Good. Extraction and injection wells are used for flow-path control as a component of the 200-ZP-1 OU final remedy. Requires long-term operation because of size and longevity of the I-129 plume.	Good. Readily implemented using conventional drilling and well installation methods, and standard construction practices.	Low to moderate capital costs, moderate O&M costs depending on degree and frequency of well maintenance activities.	Retained. The NCP (40 CFR 300.430(a)(1)(iii)(b)) indicates a preference for containment for waste that poses a relatively low long-term threat or where treatment is impracticable.
		Groundwater monitoring	All COCs	Excellent. An array of monitoring wells is required to evaluate hydraulic containment system performance. Usually comprises existing wells and new wells as necessary.	Good. Monitoring wells are easily installed.	Low to moderate. Cost depends on the number and depth of monitoring wells.	Retained.
		Groundwater treatment – Use 200 West Area groundwater treatment facility Capacity available within existing treatment Trains 1 and 2 Add third treatment train if necessary	Uranium, hexavalent chromium, chromium (total), carbon tetrachloride, nitrate, and Tc-99	Excellent. This facility has at least 946 L/min (350 gal/min) of available capacity for treating 200-UP-1 OU groundwater.	Excellent. Readily implemented. Some piping modifications required to integrate flow. May require pre-treatment for I-129 removal if extraction wells used for containment. No treatment required for injection well containment approach.	Low if 200 West Area groundwater treatment facility used.	Retained.
Active Restoration	P&T	Vertical extraction wells	Uranium, hexavalent chromium, chromium (total), carbon tetrachloride, nitrate, and Tc-99	Good for removing slight to highly mobile contaminants from aquifer; may be less effective for uranium, which is less mobile than other 200-UP-1 OU COCs.	Good. Readily implemented. Vertical extraction wells used at a number of locations on the Site.	Moderate. Depends on the total number of extraction wells required.	Retained.
		Horizontal extraction wells	Uranium, hexavalent chromium, chromium (total), carbon tetrachloride, nitrate, and Tc-99	Good for removing slight to highly mobile contaminants from aquifer; may be less effective for uranium, which is less mobile than other 200-UP-1 OU COCs.	Poor. Very difficult. Depth of contaminant plumes 91 to 137 m (300 to 450 ft) may be beyond the capability of conventional horizontal drilling technology.	High.	Rejected because of technical implementability and cost.
		Groundwater monitoring	All COCs	Good. An array of monitoring wells is also required to evaluate groundwater extraction system performance. Usually comprises existing wells and new wells as necessary.	Good. Monitoring wells are easily installed.	Low to moderate depending on the number and depth of monitoring wells.	Retained.

Table 7-8. Technology Screening Results

General Response Action	Technology Type	Process Option	Target Contaminants	Evaluation			Results
				Effectiveness	Implementability	Relative Cost	
	Aboveground Treatment	Groundwater treatment – Use 200 West Area groundwater treatment facility: Capacity available within existing treatment Trains 1 and 2 Add third treatment train if necessary	Uranium, hexavalent chromium, chromium (total), carbon tetrachloride, nitrate, and Tc-99	Good. Treatment processes for all COCs (except I-129) are available within existing treatment trains. If flow rates are greater than several hundred gal/min, may require construction of a third treatment train. Space and infrastructure already available if this is deemed necessary. Some I-129 treatment may occur within uranium and Tc-99 ion exchange vessels. Ability of ion exchange to remove I-129 to 1 pCi/L or less not demonstrated. Treatability testing required.	Good. Readily implemented. If pretreatment for I-129 removal is required, may require installation of an additional ion exchange treatment train.	Low to moderate depending on whether a third treatment train has to be constructed. Cost for developing and implementing I-129 pretreatment using ion exchange, AgCl-GAC, or AgBr-GAC could be high.	Retained.
		New treatment facility Use similar processes or others (reverse osmosis) as needed	All COCs	Good. Treatment technologies have already been developed for all COCs as part of 200-ZP-1 OU remedial design. Ability of ion exchange to remove I-129 to 1 pCi/L or less not demonstrated. Treatability testing required. No information available on electrodialysis and reverse osmosis effectiveness for I-129.	Good but likely redundant with 200 West Area groundwater treatment facility, which already has some hydraulic capacity set aside for 200-UP-1 OU groundwater, and space available for a third treatment train if necessary.	High to very high. The cost for constructing a new treatment facility of a scale proportionate to 200 West Area groundwater treatment facility based on hydraulic and contaminant-loading requirements is high. Additionally, a separate treatment facility would likely require an independent team of O&M personnel, which would further add to the cost.	Rejected because of cost. Expansion was accounted for in the 200 West Area groundwater treatment facility design. Expansion of existing treatment facility is possible.
	Treated Water Discharge	Reinjection	All COCs	Good. Reinjection used successfully at a number of locations on the Site. Can increase remedy effectiveness by providing more aggressive flushing of high-concentration areas and by providing supplemental recharge, should water-limiting conditions develop.	Good. Readily implemented.	Low to moderate depending on the number of wells required.	Retained.
		Infiltration		Good if subsurface soil characteristics are favorable. May require infiltration tests to assess feasibility. Not an option if vadose zone contamination is present. Not used elsewhere on the Site for CERCLA remedial actions.	Moderate.	Moderate.	Rejected. Presence of vadose zone contamination and limited use for CERCLA response actions at Site.
		Reuse		Poor. No re-use opportunities identified at this time. Not used elsewhere on the Site for CERCLA remedial actions.	Poor. May not be administratively implementable.	Low to high depending on location of re-use point.	Rejected. No re-use opportunities identified.
		River discharge		Good. River water discharge used in the 100 Area during reactor operation period.	Poor. May not be administratively implementable and would likely require more rigorous monitoring of effluent discharge.	Moderate to high, given proximity of river to 200-UP-1 OU site.	Rejected. Administrative implementability.

Table 7-8. Technology Screening Results

General Response Action	Technology Type	Process Option	Target Contaminants	Evaluation			Results
				Effectiveness	Implementability	Relative Cost	
Passive Restoration (in situ)	Biological (anaerobic)	Subsurface delivery and recirculation of various organic substrates in a regular pattern of wells in the aquifer to stimulate anaerobic bioreduction of hexavalent chromium and reduction of nitrate. Hexavalent chromium and nitrate on groundwater that is reinjected would be reduced in situ.	Carbon tetrachloride, Hexavalent chromium, uranium, and nitrate	Moderate/High. Reactive life of biological electron donors is longer than chemical reductants so that reactive strength is maintained over relatively longer distances compared to in situ chemical treatment. Iron and sulfate reduction increases reductive capacity of subsurface, which makes the formation less sensitive to rebound.	Moderate. Requires large number of wells to cover a large area.	Moderate depending on number and type of wells	Rejected because of the large size of the defined COC plumes. Would require large number of injection wells.
	Chemical/Physical	In situ chemical oxidation	All COCs except radionuclides	Poor for most inorganics including 200-UP-1 OU COCs.	Poor. Technically very difficult because of depth and large size of COC plumes.	Very high. Cost of chemicals alone would be prohibitive.	Rejected because of large area and volume of media requiring treatment.
	Stabilization	Permeable reactive barrier	Nitrate, chromium	Moderate/Good. Reduction of nitrate to nitrogen gas and hexavalent chromium to trivalent chromium is readily accomplished through manipulation of aquifer redox conditions. This technology has been pilot tested using calcium polysulfide and full scale implementation performed with other reductants in the 100-D Area.	Poor. Technically very difficult because of plume size and depth.	Very high.	Rejected. Requires additional field demonstrations. Depth and size of treatment area expected to make cost prohibitive.
		Polyphosphate	Uranium	Good. May require further field demonstration trials to build on experience gained through pilot testing conducted in the 300 Area prior to full-scale implementation. Would require long-term controls to protect against inadvertent intrusion into the reactive zone.	Poor. Difficult because of depth of uranium plume (91 to 137 m [300 to 450 ft]) and lower permeability of Ringold Formation in this area. Site-specific treatability studies required to determine optimum additive concentrations and potential effects of co-contaminants.	Moderate to high.	Rejected. Requires additional field demonstrations. Depth and size of treatment area expected to make cost prohibitive.
		Zero-valent iron	Nitrate, chromium	Moderate. This technology has been employed at a number of CERCLA sites but not widely applied for nitrate. Zero-valent iron was used to augment the 100-D In Situ Redox Manipulation Barrier for hexavalent chromium treatment. Treatability testing required to assess the effects on other COCs.	Very difficult because of the depth and broad distribution of COC plumes.	Very high.	Rejected. Requires additional field demonstrations. Depth and size of treatment area expected to make cost prohibitive.
		Redox manipulation	Nitrate, chromium, and uranium	Good. This technology has been demonstrated at a number of CERCLA sites and in the 100 Area for hexavalent chromium treatment. Treatability testing will be required to assess effects on other co-contaminants. Would require long-term controls to protect against inadvertent intrusion into the reactive zone.	Very difficult because of the depth and broad distribution of COC plumes.	Very high.	Rejected because of large area and volume of media requiring treatment.
		Univalent copper precipitation	I-129	Moderate. Expected to be good. Will require treatability testing to confirm effectiveness and assess effects on other COCs. Would require long-term controls to protect against inadvertent intrusion into the reactive zone.	Very difficult because of the depth and broad distribution of I-129 plume.	Very high.	Rejected because of large area and volume of media requiring treatment.

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Table 7-9. Remedial Technologies Retained for Remedial Alternatives Development

General Response Action	Technology Type	Process Options	Target Contaminants
No Action	No Action	No action	All COCs
Institutional Controls	Entry Restrictions	Procedural requirements for access, excavation/drilling permits	
	Land and Groundwater Use Management	Deed restrictions/notices, declaration of environmental restrictions, information distribution, restrictive covenants, federal/state/county/local registries	All COCs All COCs
	Waste Site Information Management	Administrative	
	Access Controls	Signs/fences/security guards	
Monitored Natural Attenuation	MNA	Groundwater monitoring – includes sampling, laboratory analysis, data evaluation, and reporting	Tritium, carbon tetrachloride, and low-level nitrate
Containment	Hydraulic Containment	Hydraulic control using injection wells Groundwater monitoring	I-129
Active Restoration	Pump-and-treat	Groundwater extraction using vertical wells Groundwater monitoring – includes sampling, laboratory analysis, data evaluation, and reporting	Uranium, hexavalent chromium, chromium (total), carbon tetrachloride, nitrate, and Tc-99
	Aboveground Treatment	Groundwater treatment using 200 West Area treatment facility	
	Treated Water Discharge	Injection wells	

The technology screening approach used followed that described in EPA/540/G-89/004, *Guidance for Conducting Remedial Investigation and Feasibility Studies under CERCLA*, focusing on three criteria: effectiveness, implementability, and relative cost. Effectiveness considers the (1) ability of each remedial technology to handle the large volumes of contaminated groundwater present, (2) ability of each remedial technology to achieve RAOs and PRGs, (3) potential impacts to human health and the environment associated with construction and implementation of the technology, and (4) the reliability of the technology with respect to treatment of the COCs. Implementability focused on the technical and administrative feasibility of implementing the technology. Costs were evaluated on a relative scale (low, moderate, or high) only.

7.3.1 No Action

Development of a no action alternative is required by the NCP (40 CFR 300.430(e)(6)). The no action alternative serves as a baseline for evaluating other remedial action alternatives and is generally retained throughout the FS process. As described in Section 7.2, no action implies that no remediation is implemented to address existing Site conditions.

7.3.1.1 Evaluation

Effectiveness: Under no action, the interim groundwater P&T actions in the U Plant and S-SX zones would be shut down, and no further action would be taken.

No action will result in potential long-term impacts to human health if groundwater is developed for drinking water purposes. No action will also result in long-term impacts to the environment until COC concentrations are reduced to PRGs through natural processes.

Implementability: No technical challenges are associated with implementing no action; however, no action may not be implementable from an administrative standpoint because it does not protect human health and the environment Therefore, no action could not be selected in accordance with the CERCLA remedy selection requirements.

Relative Cost: There are no costs associated with no action.

Screening Result: No action is retained as a baseline for comparison to other remedial action technologies according to NCP requirements.

7.3.2 Institutional Controls

Institutional controls have already been implemented within most Hanford Site OUs, including the 200-UP-1 OU, through EPA/ROD/R10-97/048. *Interim Remedial Action Record of Decision for the 200-UP-1 Operable Unit, Hanford Site, Benton County, Washington*; Ecology, 2009b; and DOE/RL-2001-41. Institutional controls are used to protect human health against inadvertent exposure and to protect the environment by monitoring and controlling land and groundwater use in areas where groundwater COC concentrations exceed PRGs. Institutional controls and engineering controls may also be a component of other alternatives to protect the integrity of ongoing or completed remedial actions. At the Hanford Site, these controls include administrative measures and access restrictions as described in the following subsections. It is expected that the institutional controls for the 200-UP-1 OU remedial action would be the same as those identified in the 200-ZP-1 OU ROD.

7.3.2.1 Administrative Measures

Administrative measures are used at the Site to protect against inadvertent intrusion into contaminated soil and groundwater, and to prevent land and groundwater development for purposes other than their designated uses. These measures include DOE/EIS-0222-F, *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*; DOE/EIS-0222-SA-01, *Supplement Analysis: Hanford Comprehensive Land-Use Plan Environmental Impact Statement*; public notices; DOE directives; environmental checklists; work control processes; a Waste Information Data System (WIDS) database; excavation permits; and groundwater use management.

The *Final Hanford Comprehensive and Land-Use Plan Environmental Impact Statement* (DOE/EIS-0222-F and DOE/EIS-0222-SA-01): This document provides a comprehensive listing of all areas at the Site that have institutional controls for protection of human health and the environment. The minimum required information includes the location of the area, the objectives for the restrictions, and the tools and procedures that will be applied to implement the restrictions or controls. The information in the

HCP-EIS is reviewed annually to ensure that it is current, effective, and sufficient for each site. The document also tracks or includes, by reference, any permitting changes, renovation work on structures, well placement and drilling, construction, or other activities that could occur on institutionally controlled Hanford CERCLA sites. The CERCLA module is available on the Internet. Those portions of the document that contain specific information considered sensitive for security reasons are currently available for official use only by DOE or its subcontractors at the site.

Public Notices: Public notice is provided as needed to inform stakeholders of institutional control changes. For land use changes and property leasing or transfers, stakeholders and news media are contacted and provided with the appropriate information, in accordance with the *Hanford Site Tri-Party Agreement Public Involvement Community Relations Plan* (Ecology et al., 2002).

DOE Directives: DOE directives include policies, orders, notices, manuals, and guides intended to direct, guide, inform, and instruct Tri-Party and contractor employees, and the public. DOE directives are legally binding on DOE and its contractors by inclusion into their contracts. Future directives and guidance concerning restrictions on groundwater use and access are being considered for the Site as part of the evaluation of controls to protect human health and the environment. These may include additional well drilling restrictions or 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.

Activities involving drilling new wells and maintaining existing wells are subject to regulatory review processes that occur under CERCLA planning and decision documents, or environmental impact analyses under NEPA.

DOE Environmental Checklist: In accordance with the "National Environmental Policy Act Policy Statement" (O'Leary, 1994), DOE relies on the CERCLA planning and decision documents to incorporate NEPA values, to the extent practicable. This information is made available to the public in accordance with CERCLA public participation requirements.

The process for a proposed action and identification of potential impacts is typically initiated with a DOE environmental checklist prepared for review and approval. Information provided in the environmental checklist includes detailed information concerning the environmental aspects and potential sources of impact, including information on potential disturbance of a contaminated site. During the environmental checklist technical review, an appropriate specialist evaluates the information. The environmental checklist review and approval process ensures that applicable environmental requirements associated with the project have been identified and that the project will comply with all requirements.

An environmental checklist is developed for all proposed activities. Environmental evaluation requirements apply to activities conducted on behalf of DOE/RL at the Site by the maintenance and operations contractor, subcontractors, lessees, or any government entity (the U.S. Geological Survey). The environmental checklist evaluation would assess the proposed activity to identify any restrictions on disturbance of environmental media, well drilling, or management of waste or subsequent water-use restrictions related to aquifer contamination.

Work Control Process: All work at the Site is controlled through HNF-MP-003, *Integrated Environment Safety and Health Management System Plan*, which establishes a single, defined environment, safety, and health management system that integrates requirements into the work planning and execution processes to effectively protect workers, the public, and the environment. The integrated environment safety and health management system identifies a set of requirements that reflects DOE's commitment to a standards-based safety program and the safety concepts reflected by these requirements. The integrated

environment safety and health management system provides the mechanisms for increasing worker involvement in work planning including hazard identification and impact identification, analysis, and control; work execution; and feedback/improvement processes. Effective implementation of the integrated environment safety and health management system incorporates the best practices and supports the accomplishment of the Voluntary Protection Program, Enhanced Work Planning/Hanford Occupational Health Process, Responsible Care program of self-regulation, and other environment, safety, and health performance improvement initiatives.

Institutionally controlled CERCLA sites with potential radiological exposures require written authorization for personnel to enter and work within radiological areas in accordance with "Occupational Radiation Protection," "Radiological Areas" (10 CFR 835.501[d]). Records of these authorizations are mandated in accordance with 10 CFR 835.701(a) "General Provisions," to assist DOE's operating entities to comply with the requirements of 10 CFR 835 and DOE G 441.1-12, *Radiation Safety Training Guide for use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection*. This series of guidelines is structured to help radiation protection professionals develop the documented radiation protection program required by 10 CFR 835.101, "Radiation Protection Programs," and the supporting site- and facility-specific policies, programs, and procedures necessary to ensure compliance with related regulatory requirements. A DOE standard (DOE-STD-1098-99, *Radiological Control*) supplements DOE G 441.1-1B and serves as a secondary source or guidance for complying with 10 CFR 835.101.

Waste Information Data System: DOE maintains a tracking mechanism that identifies all waste site land areas that are under restriction or control in accordance with the institutional control requirement of CERCLA decision documents and as described in applicable work plans. The WIDS database, in combination with this plan and the Administrative Record, will initially be used to meet this requirement. In the future, a database that serves the stewardship needs of non-DOE entities by focusing on key stewardship data elements (institutional control information) may be made available to entities having jurisdiction.

Information on the location and nature of waste sites is contained in the WIDS database. WIDS identifies waste management units on the Site, their locations, waste types, and current status. Other descriptive information contained in WIDS includes size, extent and appearance, testing or sampling efforts, regulatory information, bibliographic references, images, change history, and data validation. The system is maintained by DOE in accordance with the WIDS change control system, which documents and traces additions, deletions, or other changes dealing with the status of waste management units. The long-term preservation of waste site information is addressed by RL-TPA-90-0001, and it will be a key part of the Long-Term Stewardship Program for the Site.

The Administrative Record which holds documents and information that are considered or relied on to arrive at a final decision for remedial action is publicly available on the Internet. The documents in the Administrative Record include, but are not limited to, proposed plans for IRAs, remedial design reports, and RODs. It can be located electronically at: http://www5.hanford.gov/arpir/.

Excavation Permits: Excavation permits are used by Site personnel to control access for subsurface work. The objectives of the excavation permitting process are as follows:

- Avoid unplanned disturbance or infiltration.
- Inform and protect workers regarding potential exposure to hazardous materials.
- Avoid the creation of potential pathways for the migration of hazardous materials.

The Site has a site-wide excavation permit that contractors are required to obtain before performing any excavation work, including well drilling. The work control process requires an excavation permit as part of the work-planning process. The excavation permit process is defined in the contract or procedures and contains the following features.

- Excavation permits generally follow the *Revised Code of Washington*.
- A review of the WIDS database is required to identify the proximity of existing waste sites.
- Cultural and biological resource surveys are required to comply with Section 106 of the *National Historic Preservation Act of 1966* and the *Endangered Species Act of 1973*.
- NEPA documentation requirements must be identified.
- The presence of any underground objects (utilities) must be identified.
- Excavation work is required to follow applicable health and safety requirements.

In addition to obtaining an excavation permit, wells must be registered with Ecology. Each prime contractor is responsible for ensuring that excavations are performed in accordance with excavation permit requirements. The following steps are required for excavation:

1. The excavation permit originator requests an excavation permit using the Site excavation permit process.
2. Radiological screening of the proposed work site is required.
3. The necessary reviews are performed, including the information in WIDS, the cultural and biological resources that may be present, applicable resource management plans, and applicable NEPA documents.
4. The permit must be logged and issued.
5. No less than 2 days and not more than 10 work days before excavation begins, the organization conducting the excavation must call the Emergency Notification Center for Excavation (1-800-424-5555) to allow outside electric, gas, sewer, telephone, and water companies to locate and explain any potential underground interferences.
6. Notification to the excavation coordinator is made when excavation work is completed.

Groundwater Use Management: DOE restricts well drilling and groundwater use in accordance with the institutional control requirements of CERCLA decision documents and as described in applicable work plans. Groundwater use on the Site is restricted, in accordance with EPA or Ecology, or as authorized in EPA-approved documents. Groundwater use also is controlled through excavation permits and the land use process.

Groundwater protection strategies include source control, remediation, and monitoring. An annual report is prepared and published each year documenting the results of groundwater monitoring for the previous year. The report summarizes groundwater monitoring results and provides an assessment of the effects of remediation or interim measures conducted under CERCLA. The report, along with OU-specific summaries, fulfills the reporting requirements of DOE Orders and the *Washington Administrative Code*.

Ongoing groundwater performance assessments and remediation are also reviewed and reported annually to identify trends in the condition of the groundwater and the potential implication of those trends to institutional controls (prohibition of groundwater use). The data from the report are considered in evaluating the effectiveness of the institutional controls and the need for changes to the controls.

If DOE transfers property with groundwater use restrictions to another entity, the appropriate use restriction will be attached to the real estate transaction to ensure that specific institutional controls will remain in place.

7.3.2.2 Access Controls

Access controls restrict entry or visually notify authorized personnel and public of the presence of contamination. At the Site, these controls include security, fences, surveillance, barriers, permanent markers, and warning signs. Warning signs are the predominant method of access control at the Site. They identify the location of CERCLA sites to any persons who may intentionally or inadvertently enter or disturb a site. Warning signs are posted in accordance with 10 CFR 835 at sites where residual contamination may pose a current or future risk to human health and the environment if excavated or otherwise disturbed. DOE generally uses two types of warning signs that, while not specifically designed as CERCLA notification signs, can serve the same purpose:

- No trespassing signs
- Notification signs for hazardous (including radiological control) and sensitive areas

A third type of sign may be used to identify Superfund sites (NPL sites), if necessary. Warning signs provide, as a minimum, information on the principal hazards at the site, the media of concern, a point of contact with phone number, and a warning not to disturb the area unless authorized. The potential hazard information is generalized (organics, inorganic, radionuclides, PCBs, asbestos, or ordinances) without identifying specific chemicals or radionuclides. The format of the signs is consistent throughout the site. Guidance on signage content and placement is provided in DOE/RL-2001-41.

7.3.2.3 Evaluation

Effectiveness: Institutional controls can assist in meeting RAOs by protecting human health from inadvertent exposure and protecting the environment by controlling land and groundwater use, until COC concentrations decline to PRGs through natural or active remediation processes. Given the large size of the COC plumes in the 200-UP-1 OU, these controls will span a very large area and need to be maintained for time frames of at least 150 years if no active remedial measures are taken. Potential impacts to human health and the environment associated with implementation of institutional controls are low. It is important to note the uncertainty associated with long-term management of the Hanford Site beyond the foreseeable future. Therefore, institutional controls are expected to have moderate effectiveness depending on which specific measure is being used.

Implementability: The technical and administrative feasibility of institutional controls is moderate to good, depending on which measure is proposed. Many of the controls have already been implemented under the interim ROD and ESD or can be readily modified to address the specific needs of the 200-UP-1 OU.

Relative Cost: Capital and O&M costs are expected to be low relative to other technologies.

Screening Result: Institutional controls are retained.

7.3.3 Monitored Natural Attenuation

MNA is a remediation technology that achieves contaminant toxicity, volume, concentration, mobility, volume, or bioavailability reduction through natural physical, chemical, or biological processes that occur without human intervention. MNA is evaluated in this section using guidance provided in EPA/540/R-99/009 and DOE, 1999, *Decision-Making Framework Guide for the Evaluation and Selection of Monitored Natural Attenuation Remedies at U.S. Department of Energy Sites*. Both guidance documents describe the functional requirements for application of MNA as a component of a broader alternative and present the results of a screening process to evaluate site-specific conditions against the applicable requirements.

For the COCs in the 200-UP-1 OU, the primary natural attenuation processes (Table 7-10) include sorption (uranium, I-129, trivalent chromium, and carbon tetrachloride), radioactive decay (tritium), biodegradation (nitrate, hexavalent chromium), hydrolysis (carbon tetrachloride), and dispersion/diffusion (all COCs).

Table 7-10. Key Natural Attenuation Processes for 200-UP-1 OU COCs

Natural Attenuation Process	Applicable COC	Key Factors
Sorption[1, 2]	Uranium	K_d = 0.4 mL/g
	I-129	K_d = 0.1 mL/g
	Trivalent Chromium	K_d > 1 mL/g
	Carbon Tetrachloride	0.00024 mL/g < K_d < 0.00032 mL/g
Radioactive Decay	Tritium	Half-life = 12.3 years
Biodegradation	Nitrate, Hexavalent Chromium	Requires anaerobic conditions (dissolved oxygen less than 0.5 mg/L). Field measurements indicate that this condition is not widespread in the monitored portions of the 200-UP-1 OU. However, localized zones are expected to be in some areas.
Hydrolysis [3]	Carbon Tetrachloride	Half-life = 100 years
Oxidation-Reduction-Precipitation	Uranium, Hexavalent Chromium	Uranium present in the +6 oxidation state may be reduced to the less mobile +4 oxidation state under anaerobic (reducing) conditions. Hexavalent chromium (+6) reduced to +3 oxidation state under anaerobic conditions.

Table 7-10. Key Natural Attenuation Processes for 200-UP-1 OU COCs

Natural Attenuation Process	Applicable COC	Key Factors
Dispersion/Diffusion	All COCs	Longitudinal dispersion = 50 m Lateral dispersion = 10 m Vertical dispersion = 0 m Diffusion: negligible Fate and transport modeling presented in Chapter 5 indicates that dispersion reduces COC concentrations to PRGs within a 15- to 120-year time frame (I-129 not included in this range).

Sources: DOE/RL-2007-28, *Feasibility Study Report for the 200-ZP-1 Groundwater Operable Unit*.

PNNL-13560, *Assessment of Carbon Tetrachloride Groundwater Transport in Support of the Hanford Carbon Tetrachloride Innovative Technology Demonstration Program*. Additional hydrolysis studies are underway per PNNL-18735, *Carbon Tetrachloride and Chloroform Attenuation Parameter Studies: Heterogeneous Hydrolytic Reactions*.

PNNL-16100, *Carbon Tetrachloride Partition Coefficients Measured by Aqueous Sorption to Hanford Sediments from Operable Units 200-UP-1 and 200-ZP-1*.

7.3.3.1 EPA Guidance

Natural attenuation processes are typically occurring at all sites but to varying degrees of effectiveness depending on the types and concentrations of contaminants and the physical, chemical, and biological characteristics of the soil and groundwater. Natural attenuation processes may reduce potential risks posed by contaminants in three ways:

1. Transformation of contaminants to less toxic forms through radioactive decay and destructive processes such as biodegradation or abiotic transformation.
2. Reduction of contaminant concentrations whereby potential exposure levels may be reduced.
3. Reduction of contaminant mobility and bioavailability through sorption onto the soil or rock matrix.

Following source control measures, natural attenuation may be sufficiently effective at some sites to achieve RAOs without the aid of other (active) remedial measures. Typically, however, MNA is used in conjunction with active remediation measures. For example, active remedial measures may be applied in areas where high contaminant concentrations occur, while MNA is used for low concentration areas. Moreover, MNA may used as a follow-up to active remedial measures.

Guidance in EPA/540/R-99/009 considers the following three factors to be the most important when considering MNA as part of a remedy:

- Factor 1: Are the contaminants likely to be effectively addressed by natural attenuation processes?
- Factor 2: Is the plume stable without increasing concentrations?
- Factor 3: Can the remediation occur in a reasonable time frame without any unacceptable human health or environmental risk?

With respect to Factor 1, MNA can effectively remediate tritium-contaminated groundwater because tritium has a relatively short half-life of 12 years. Contaminant fate and transport modeling presented in Chapter 5 shows that the tritium (as C-max) will attenuate within 50 years. As described in DOE/RL-2007-28, *Feasibility Study Report for 200-ZP-1 Groundwater Operable Unit*, the abiotic MNA process of hydrolysis is effective for carbon tetrachloride because no hazardous byproducts are formed. Other MNA processes including sorption, biodegradation, oxidation-reduction, and dispersion will reduce COC concentrations, especially in zones where current concentrations are close to the PRGs.

With respect to Factor 2, contaminant fate and transport simulations presented in Chapter 5 indicate that the tritium, nitrate, Tc-99, I-129, uranium, and chromium plumes have not met steady state conditions (declining concentrations and limited movement). Although the carbon tetrachloride plume behavior was not specifically simulated for this report, simulations presented in DOE/RL-2007-28 show that the 200-ZP-1 groundwater P&T remedy will result in significant contraction of the plume within 25 years. Additionally the carbon tetrachloride source located above 200-ZP-1 is being addressed by the 200-PW-1 OU soil vapor extraction system.

With respect to Factor 3, all COCs except I-129, nitrate, and uranium attenuate to the DWSs within 175 years based on C-max concentrations, and all COCs attenuate to their DWSs within 400 years using the 90th percentile (see Table 6-18). The modeling also indicates that 200-UP-1 OU COC plumes will remain on the Central Plateau, which lies a significant distance from potential points of human and ecological receptor exposure.

7.3.3.2 DOE Guidance

MNA may be applied as a remedial technology when site conditions can be defined as otherwise protective of human health and the environment. The following four functional requirements are identified for MNA to be retained as a remedial technology for 200-UP-1 OU groundwater:

1. The contamination condition does not currently present an actual risk to human or ecological receptors. There must be an expectation that exposure mitigation can and will be maintained throughout the MNA period.
2. The source of the observed groundwater contamination is no longer contributing to the plume. The source may have been previously controlled through an engineered remedy or naturally ceased to contribute to the problem. In some cases, a source control element (for example, localized P&T or selected in situ remedy) may be combined with the MNA alternative to ensure adequate control of secondary sources (such as residual mobile contamination in the vadose zone or high concentration plume segments in groundwater).
3. The target plume is static, retreating, or decreasing in concentration, or existing monitoring data confirm that attenuating processes are operating at the site.
4. Effective monitoring exists currently or can be implemented, and it will provide confirmation that the attenuation is proceeding as expected and that PRGs are achieved. MNA alternatives may also include contingent response options if monitoring indicates that attenuating processes are not sufficiently effective at plume control.

DOE guidance identifies a three-tiered approach to screening MNA alternatives (SAND99-0464, *Site Screening and Technical Guidance for Monitored Natural Attenuation at DOE Sites*), with requirements for favorable conditions to allow the screening to continue and, ultimately, for MNA to be developed or included in the scope of a remedial alternative. The three assessment tiers are as follows:

1. Scoping/Planning Phase (Tier I). In this phase, the functional requirements for MNA as applicable to a specific site, plume, or condition are identified and evaluated. Figure 7-3 presents a logic diagram for the Tier I assessment of MNA.
2. Alternative Evaluation/Selection Technical Analysis (Tier II). In Tier II analysis, the time frame for remediation by MNA is evaluated for compatibility with future land and groundwater use.
3. Alternative Evaluation/Selection Comparative Analysis (Tier III). In Tier III analysis, the MNA time frame for restoration is compared to other alternatives for reasonableness.

Evaluation and selection of MNA as part of a final remedy for groundwater contamination in the 200-UP-1 OU require rigorous analysis and thorough understanding of site-specific conditions.

Tier 1 Screening. The Tier I screening for MNA of a specific contaminant plume requires the most rigorous analysis and should, to the extent possible, be based on site-specific knowledge, understanding of site conditions, and evaluation of site-specific measurements and observations over a preceding time period. The following discussion provides a basis for analysis of groundwater plume conditions with respect to the four functional requirements for successful MNA.

Assess Current Exposures to Human and Ecological Receptors. Exposure mitigation is a primary requirement of any successful CERCLA response to environmental contamination. MNA implementation requires that there be no unacceptable actual exposure of human or ecological receptors to Site contaminants for the duration of the MNA remedy. In the Central Plateau, this means that plumes are well defined and that no actual exposures to contaminants in excess of risk-based action levels are occurring to groundwater users or ecological receptors (aquatic organisms in the Columbia River in groundwater discharge areas). For the 200-UP-1 OU, the groundwater contaminant plumes are generally well defined, and existing institutional controls (prohibitions against use of groundwater for a source of drinking water) prevent human exposure. The 200-UP-1 OU plumes occur within the unconfined aquifer beneath, and east of, the 200 West Area. These plumes do not extend to the groundwater discharge areas along the Columbia River to the east so that no ecological receptors are currently exposed to 200-UP-1 OU COCs or COPCs. Estimates of groundwater travel times indicate that the current institutional controls should remain effective at preventing exposure to human and ecological receptors for the foreseeable future. No additional actions to mitigate exposures are indicated for the plumes in the 200-UP-1 OU.

Control Source Contributions to the Groundwater Plumes. The second most important requirement for consideration of MNA is that continuing contribution of contaminants to the groundwater plumes is controlled. In the case of the 200-UP-1 OU, all known, nonpermitted, primary source discharges (that is, releases of process-related and sanitary wastes that were intentionally or inadvertently released to the ground) have stopped. Numerous historical liquid waste and waste water releases within the 200 West Area affected groundwater directly during their discharge periods. These same releases frequently resulted in secondary sources consisting of residual mobile contaminants within the underlying vadose zone that may continue to migrate downward. In situations where sufficient soil moisture remains in the vadose zone, residual vadose soil contaminants continue to drain through the soil column to affect the underlying groundwater. In addition to drainage of anthropogenic water in the vadose zone, some fraction of natural precipitation falling on the ground surface over the course of the year may enter the aquifer over time as recharge. In some areas, continuing vadose drainage is also associated with high concentration local groundwater plumes, presenting vadose- and groundwater-localized secondary sources.

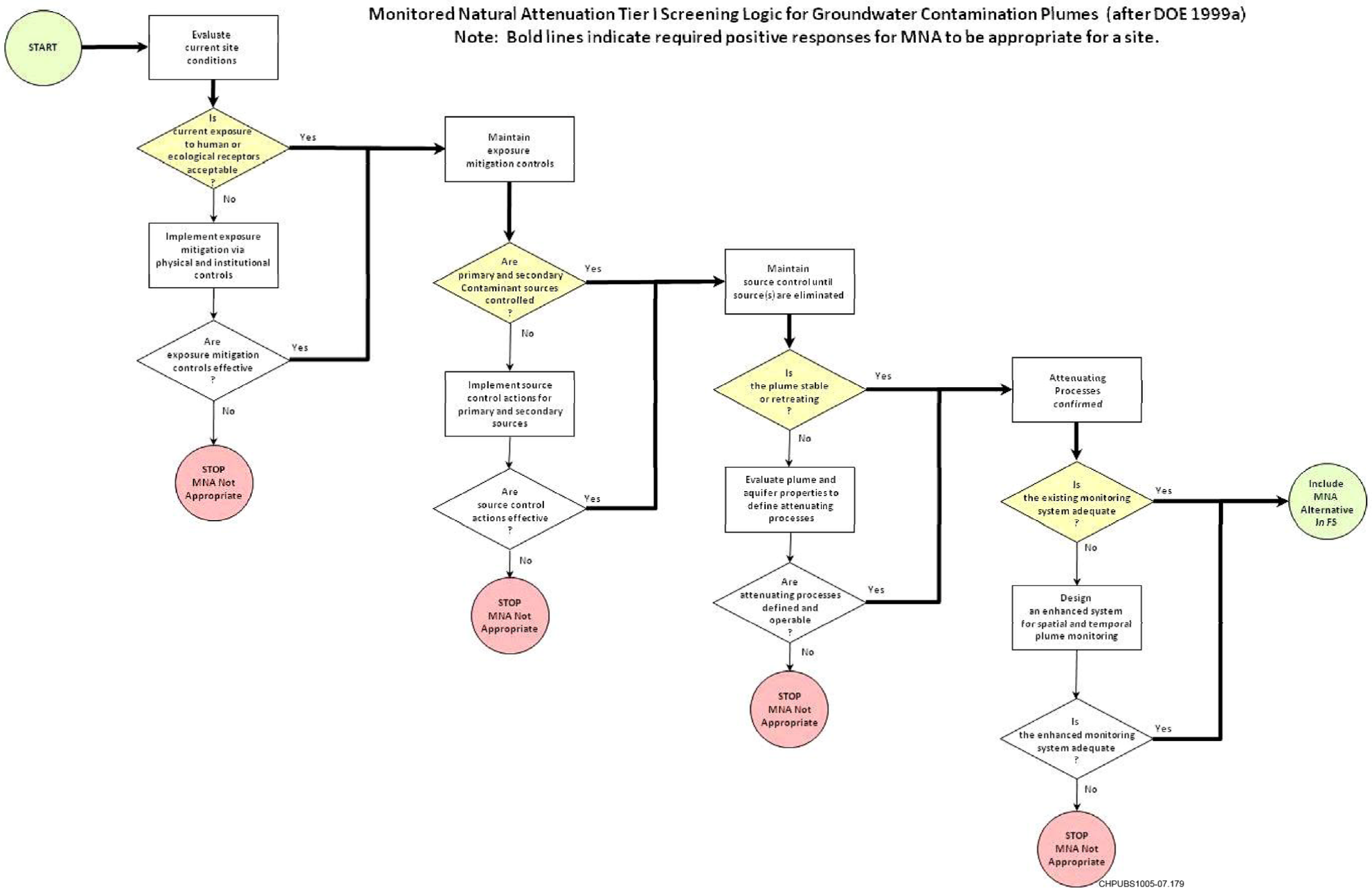

Figure 7-3. MNA Tier 1 Screening under DOE Guidance

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Conditions within the 200-UP-1 OU exhibit varying degrees of source control at this time. Some contaminant plumes (for example, the complex plumes immediately downgradient of WMA S-SX and WMA U) continue to receive contributions from vadose zone secondary sources. The plumes at WMA S-SX are the subject of IRA P&T systems to capture the high-concentration plumes in the general vicinity of the apparent release area. These localized P&T actions will remain in operation until they are replaced or modified by a final remedy. The developing plume at WMA U lies within the expected capture zone of the P&T system for the 200-ZP-1 OU. The uranium and Tc-99 plumes in the vicinity of U Plant include high-concentration plume segments that are the subject of a current IRA to address these groundwater secondary sources.

Control of vadose zone sources of groundwater contamination in the Hanford Central Plateau is being addressed through the CERCLA RI/FS process currently underway for the overlying source OUs. Protection of groundwater is one of the three primary objectives for source OUs (the other two are protection of human and ecological receptors). Residual vadose zone secondary sources are recognized but not addressed in the groundwater OU.

Figure 7-4 illustrates the logic for integration of secondary vadose sources into the source OUs. For the analysis of the 200-UP-1 OU, groundwater plume segments with contaminant concentrations equal to or greater than 10 times a PRG are considered to be secondary sources.

A group of large and dispersed contaminant plumes (nitrate, tritium, hexavalent chromium, and I-129) are east of the REDOX Plant area. These plumes exhibit their highest concentrations at locations downgradient from their apparent source areas (the REDOX and U Plant cribs). This condition indicates that source contributions to these plumes (that is, from primary source and secondary vadose sources) have diminished. Some of these plumes, however, exhibit high groundwater concentrations (for example, in excess of 10 times the PRG), and may be considered secondary sources that should be addressed through source control actions as part of a final remedial action alternative.

Demonstrate that Attenuating Processes Are Active. The presence and activity of attenuating processes within the affected aquifer system can be demonstrated by either of two methods: (1) monitoring history of the plume shows that the plume is stable or diminishing in size or maximum concentration, which indicate that source contributions are diminished, or attenuating processes are working within the plume; or (2) if the plume is not stable or shrinking, then empirical measurements and observations of aquifer or plume conditions confirm that attenuating processes are operable within the aquifer. Within the 200-UP-1 OU, a combination of observations and measurements demonstrate the activity of attenuating processes. In some instances, plumes and contaminant concentrations are diminishing based on the monitoring history. In other instances, observations and measurements of aquifer conditions (such as measurement of contaminant K_d) indicate that attenuating processes are at work within the system. Multiple attenuating processes may be effective on any one COC. The following processes are identified as functional within the 200-UP-1 OU:

1. Radioactive decay is confirmed for radioactive COCs. Tritium has a sufficiently short radioactive half-life (12.3 years) to support radioactive decay as a major attenuating element of an MNA alternative. Other radioactive COCs (I-129, Tc-99, and uranium) exhibit long half-lives and decay is not a major attenuating factor for those constituents.

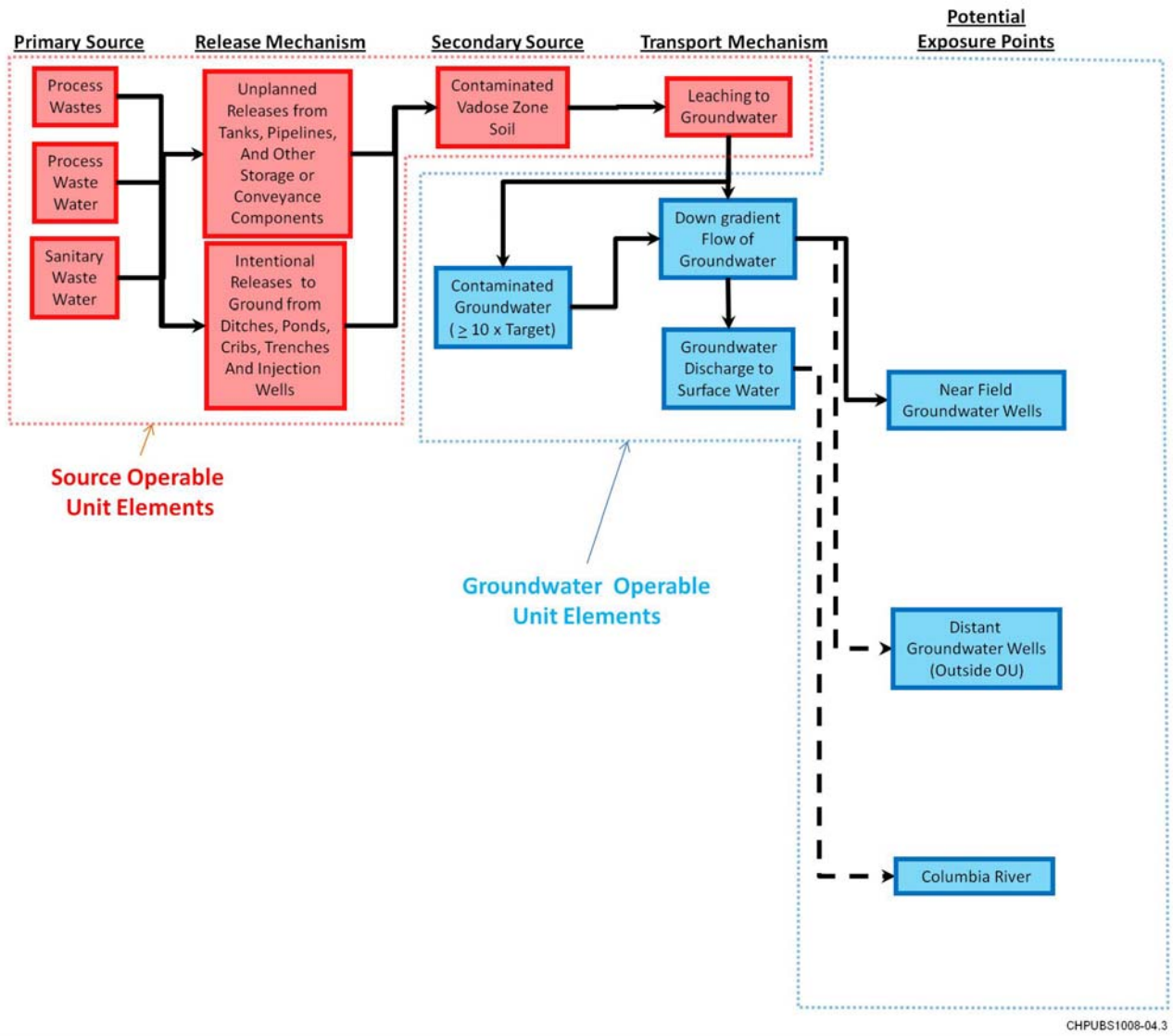

Figure 7-4. Integration of Secondary Vadose Sources

2. Sorption of constituents to the aquifer matrix reduces the relative groundwater concentration of contaminants that interact substantially with the matrix. The tendency of a constituent to sorb or bind to the aquifer matrix is generally described by its relative K_d. Constituents with higher K_d exhibit a stronger tendency to bind to the aquifer solid matrix that reduces the relative groundwater concentration. Alternatively, constituents that exhibit lower K_d exhibit less tendency to bind to aquifer solids and, therefore, do not exhibit concentration reduction through sorption to the aquifer matrix. Some constituents exhibit no tendency to sorb to aquifer solids, so sorption does not provide any meaningful attenuation for those constituents. COCs for the 200-UP-1 OU that exhibit meaningful attenuation from sorption include uranium ($K_d = 0.4$), I-129 ($K_d = 0.1$), and trivalent chromium ($K_d > 1$). This effect produces reduced migration velocity and reduced dissolved concentration within the aquifer. The 200-UP-1 OU contaminants that do not exhibit substantial sorption effects include tritium, Tc-99, nitrate, and hexavalent chromium, all of which have K_d values of 0.

3. Diffusion and dispersion within the aquifer are physical processes that reduce contaminant concentrations in groundwater over time and distance. Diffusion is a concentration-driven physical process that results in movement of dissolved constituents from areas of high concentrations to adjacent areas of low concentrations. Dispersion is a physical process that results in mixing dissolved constituents within the aquifer water as a result of variations in groundwater flow velocity along varying flow paths within the aquifer. This mixing results in reduction in contaminant concentrations over distance. Because the 200-UP-1 OU covers a relatively large area, and a large physical area of separation exists between the current plumes within the OU and locations of actual exposure to potential receptors, diffusion and dispersion can play a significant role as attenuating processes in an MNA alternative. Contaminant plumes migrating across the OU in the direction of groundwater flow (generally west to east) will be expected to exhibit substantial reduction in maximum concentrations as distance from the point of origin increases.

4. Biodegradation is a natural process whereby dissolved organic and inorganic chemicals in groundwater are transformed to other, less toxic or nontoxic compounds. Microorganisms that naturally inhabit the 200-UP-1 OU unconfined aquifer use these chemicals in oxidation-reduction reactions that generate energy for cell metabolism. Biodegradation processes can occur under aerobic (dissolved oxygen greater than 0.5 mg/L) or anaerobic (dissolved oxygen less than 0.5 mg/L) conditions. Anaerobic biodegradation is an important process for aliphatic (chlorinated organic solvents) hydrocarbons such as carbon tetrachloride and its breakdown products chloroform, methylene chloride, PCE, and TCE. Anaerobic biodegradation is also an important MNA process for nitrate and hexavalent chromium.

   a. Biodegradation of carbon tetrachloride occurs under anaerobic conditions in which chloride atoms are sequentially removed and replaced with hydrogen atoms, resulting in the formation of chloroform, methylene chloride, carbon dioxide, and chloride (DOE/RL-2007-28). Anaerobic biodegradation also requires the presence of a biodegradable organic carbon substrate, a condition lacking in most Hanford Site groundwater.

   b. Biodegradation of nitrate occurs through denitrification, in which the oxygen atoms (NO_3^-) in the nitrate molecule are removed by chemical reduction to produce nitrogen gas (N_2). Denitrification occurs under anaerobic conditions and in the presence of chemically reduced compounds such as organic carbon, ferrous iron, and sulfide minerals.

   c. Biodegradation of hexavalent chromium occurs through a chemical or biological mediated reduction process whereby hexavalent chromium is transformed into trivalent chromium, a relatively immobile and nontoxic form of chromium. The presence of dissolved organic carbon, ferrous iron, and sulfide enhances the process. Enhanced reduction of hexavalent chromium using an in situ redox manipulation technology, which mimics this natural process, is currently underway in 100-D.

   d. Although routine groundwater monitoring indicates that aerobic conditions are prominent within the 200-UP-1 OU unconfined aquifer, localized zones of anaerobic activity are present as revealed by recent depth-discrete sampling associated with 200-ZP-1 OU extraction well installation. As carbon tetrachloride, nitrate, and hexavalent chromium are transported into these anaerobic zones, biodegradation occurs. Future groundwater monitoring to be performed under the remedial action alternative to be selected in the 200-UP-1 OU ROD will develop additional information on these MNA processes so that their effectiveness can be determined in future 5-year review reports.

5. Abiotic degradation or hydrolysis is another important carbon tetrachloride MNA process in which chlorine atoms are sequentially removed, similar to the process of anaerobic biodegradation. Hydrolysis occurs under aerobic conditions. The hydrolysis half-life of carbon tetrachloride ranges from 36 to 290 years (PNNL-13560). The best estimates range from 41 to 100 years (PNNL-l3560).

Maintain Effective Monitoring. For application of MNA to groundwater contamination, effective monitoring must be maintained throughout the MNA period. Effective monitoring must provide representative three-dimensional spatial measurement and observation of aquifer conditions, as well as a representation of changes in aquifer conditions over time. Effective monitoring must be capable of demonstrating the desired change in contaminant concentration, continued activity of the attenuating process (if appropriate), and the continued required mitigation of exposures. Monitoring for MNA remedial alternatives should include monitoring at appropriate points of compliance and defined contingent responses if contaminant action level concentrations are exceeded at the compliance point.

The monitoring system for the 200-UP-1 OU would be designed and constructed as part of the final remedy and would use existing monitoring wells and newly constructed wells. In general, the existing monitor well network within the 200-UP-1 OU is not adequate for monitoring an MNA alternative for all affected plume areas. Additional monitoring wells are needed to monitor the full thickness of the shallow unconfined aquifer (to evaluate the expected vertical dispersion of contaminant plumes) and to establish clearly defined points of performance measurement in the downgradient direction. No unusual or unique requirements are indicated to monitor the applicable attenuating processes for COCs in the 200-UP-1 OU. Trigger conditions for points of performance measurement and associated contingent responses would need to be defined and implemented as part of an MNA alternative.

7.3.3.3 Evaluation

Effectiveness: MNA can reduce contaminant concentrations to PRGs through sorption, radioactive decay, biodegradation, abiotic degradation, and dispersion. MNA is best suited for addressing tritium and the low concentration portions of the Tc-99, nitrate, chromium, and carbon tetrachloride plumes in the 200-UP-1 OU, as demonstrated by the Tier 1 screening (Table 7-11) and the fate and transport modeling presented in Chapter 5 of this FS. MNA is rated poor for uranium and I-129 because of the persistence of these COCs in Hanford Site groundwater. Potential impacts to human health are low because there is very limited exposure to COCs, except during installation and sampling of monitoring wells. Impacts to the environment will persist for extended periods of time, but given the remote location of the 200-UP-1 OU, these effects are not likely to be adverse. Many of the natural attenuation processes (sorption, abiotic degradation, radioactive decay, and dispersion) are reliable and unaffected by external factors.

Implementability: The methods for sampling and evaluating MNA data are well understood, so no technical challenges are associated with implementing MNA; however, administrative challenges may exist because of the long time frames required before PRGs are achieved.

Relative Cost: The cost for implementing MNA is expected to be moderate compared to the implementation of other alternatives because of the long time frames involved.

Screening Result: MNA is retained for tritium, carbon tetrachloride, and the diffuse portion of the nitrate plume.

7.3.4 Containment

The two primary forms of containment are vertical-physical barriers (slurry walls, grout curtain, and sheet piling) and hydraulic barriers.

Table 7-11. Monitored Natural Attenuation Analysis Summary for 200-UP-1 OU COC Plumes

Plume/Plume Segment	COC	Exposure Control in Place?	Source Control in Place?	Attenuating Processes?	Effective Monitoring In Place?
U-Plant Zone	Tc-99	Yes[a]	No[b]	Yes[f]	Yes[i]
	Nitrate (high concentration)	Yes[a]	No[b]	Yes[f]	Yes[i]
	Carbon tetrachloride	Yes[a]	Yes[j]	Yes[k]	Yes[l]
	Hexavalent chromium	Yes[a]	Yes[e]	Yes[f]	Yes[i]
S-SX Zone	Tc-99	Yes[a]	Yes[c]	Yes[f]	Yes[i]
	Nitrate	Yes[a]	Yes[c]	Yes[f]	Yes[i]
	Carbon tetrachloride	Yes[a]	Yes[j]	Yes[k]	Yes[l]
	Hexavalent chromium	Yes[a]	Yes[e]	Yes[f]	Yes[i]
Northeast Nitrate Zone	Nitrate (diffuse)	Yes[a]	Yes[d]	Yes[f]	Yes[i]
	Tc-99	Yes[a]	Yes[d]	Yes[f]	Yes[i]
Southeast Chromium Zone	Hexavalent chromium	Yes[a]	Yes[e]	Yes[f]	Yes[i]
Central I-129 Zone	I-129	Yes[a]	Yes[e]	Yes[f,g]	Yes[i]
	Tritium	Yes	Yes	Yes	Yes

Table 7-11. Monitored Natural Attenuation Analysis Summary for 200-UP-1 OU COC Plumes

Plume/Plume Segment	COC	Exposure Control in Place?	Source Control in Place?	Attenuating Processes?	Effective Monitoring In Place?

a. Hanford Site-wide institutional controls prevent access to, and consumption of, contaminated groundwater within the 200-UP-1 OU.

b. Location-specific vadose source control not in place at all sources. Vadose zone secondary source falls within U-Plant Zone purview. Observed groundwater concentrations constitute a secondary source in groundwater (greater than 10 times the risk assessment guidance). High concentration groundwater plume areas are subject to IRA P&T system.

c. Location-specific vadose source control not in place at all sources. Vadose zone source falls within S-SX Zone purview. Observed groundwater concentrations constitute a secondary source in groundwater (greater than 10 times the risk assessment guidance). High concentration groundwater plume areas are subject to IRA P&T system.

d. Location-specific source control not defined at this time. Vadose zone source falls within Northeast Nitrate Zone purview. Observed groundwater concentrations constitute a secondary source in groundwater (greater than 10 times the risk assessment guidance for nitrate and Tc-99).

e. The dispersed plumes in the area east of the REDOX Plant exhibit apparent disconnection from release points. This indicates vadose sources have effectively stopped contributing to the plumes, and the plumes continue to migrate downgradient. Residual vadose zone secondary sources fall under the purview of the overlying source sites within the Southeast Chromium Zone and Central I-129 Zone.

f. Diffusion and dispersion contribute to attenuating processes. Alone, these two processes are not effective enough for retention of this technology for identified COCs.

g. Sorption to aquifer matrix (medium to high K_d) contributes to attenuating processes.

h. Radioactive decay (short half-life) contributes to attenuating processes.

i. Existing groundwater monitoring system generally provides adequate three-dimensional monitoring for most plumes, but gaps in the network will be addressed through installation of additional monitoring wells under final remedy implementation.

j. Carbon tetrachloride source control measures are described in the 200-ZP-1 OU ROD and DOE/RL-2008-78, *200 West Area 200-ZP-1 Pump-and-Treat Remedial Design/Remedial Action Work Plan*.

k. Carbon tetrachloride attenuation processes described in DOE/RL-2007-28, *Feasibility Study Report for the 200-ZP-1 Groundwater Operable Unit.*

l. Groundwater monitoring program described in DOE/RL-2009-115, *Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action.*

7.3.4.1 Vertical Physical Barriers

Vertical barriers would consist of installing slurry walls or jet-grout curtains that fully or partially enclose the 200-UP-1 OU contaminant plumes. A fully enclosing vertical barrier would imprison the plumes, thus preventing further migration. Natural attenuation processes within the barrier would reduce concentrations over time. A partially enclosing barrier would lengthen groundwater flow patterns to increase contaminant transport times. This would provide additional time for natural attenuation processes to reduce concentrations.

7.3.4.2 Evaluation

Effectiveness: A fully enclosing barrier could be very effective, depending on the continuity or integrity of the barrier. A poorly constructed barrier, or a barrier installed under challenging technical conditions, would be ineffective.

Implementability: Because the depth of construction is 137 m [450 ft]) or deeper, the barrier must be constructed using jet-grouting methods. Jet grouting has not been performed successfully to depths of greater than about 50 m (160 ft) at the scale required.

Cost: Very high.

Screening Result: Vertical barriers are rejected for all COCs as a result of the technical difficulty of their construction within the subsurface conditions at the 200-UP-1 OU. Furthermore, the depth of installation and long barrier lengths required to partially or fully enclose the dissolved plumes or plume hot spot areas would result in very high costs.

7.3.4.3 Hydraulic Containment

Hydraulic containment would consist of installing a network of groundwater extraction or injection wells along the leading edge of the largest and most persistent COC (uranium and I-129) plumes and pumping or injecting water at the minimum rate needed to prevent further migration. Containment can also be achieved by coupling extraction and injection wells to provide flow path control. This strategy is being used in the 200-ZP-1 OU to achieve hydraulic containment of the carbon tetrachloride plume. Because of its short radioactive half-life, the tritium plume would not be specifically addressed with hydraulic containment, although large portions would be captured or blocked using hydraulic containment.

Because the extraction or injection wells would be placed along the plume's leading edge, COC concentrations would initially be low in an extraction scheme but could increase over time. Extracted groundwater would require treatment, which could be performed at the existing 200 West Area groundwater treatment facility or a newly constructed treatment train, if additional treatment capacity is required. Treated groundwater would be returned to the aquifer through an array of injection wells. If an injection-only containment system were used, treatment would not be required.

7.3.4.4 Evaluation

Effectiveness: Hydraulic containment using groundwater extraction or injection wells is a well-developed technology and would be very effective in controlling plume mobility. This technology is well suited to the large volume of contaminated groundwater in the 200-UP-1 OU. COC treatment processes developed for the 200-ZP-1 groundwater P&T remedy are directly applicable to the 200-UP-1 OU COCs, and they are designed to reduce concentrations to the PRGs specified in the 200-ZP-1 OU ROD. Treatment of the I-129 in 200-UP-1 OU groundwater to a level of 1 pCi/L or less has not been demonstrated, so technology evaluation and treatability testing would be required during remedial design to determine what level of treatment can be achieved if containment via groundwater extraction were used; on the other hand,

hydraulic containment using injection wells would not require an aboveground treatment component. Potential impacts to human health and the environment associated with hydraulic containment would be low but would likely continue for an extended period of time. The NCP indicates a preference for containment (40 CFR 300.430[a][1][iii][b]) for waste that poses a low, long-term threat or where treatment is impracticable.

Implementability: Hydraulic containment using groundwater extraction or injection well technology is readily implemented using available equipment and resources. Extraction and injection well technology is used elsewhere at the Site under conditions comparable to those in the 200-UP-1 OU. While no immediate technical or administrative challenges are associated with this technology, a hydraulic containment system would need to operate for an extended period of time. Therefore, an O&M plan would need to account for this requirement using durable materials of construction.

Cost: Moderate, depending on the final design and complexity of the system, O&M requirements, and overall operating lifetime.

Screening Result: Hydraulic containment is retained, specifically for I-129, because of the large volume of contaminated groundwater in the 200-UP-1 OU. There is a preference in the NCP for containment of waste that poses a low long-term threat or where treatment is impracticable. Hydraulic containment using injection wells is preferred over extraction wells because there is no need for aboveground treatment.

7.3.5 Active Restoration

Active restoration by P&T uses many of the same elements as hydraulic containment but employs a more aggressive pumping strategy to reduce COC concentrations throughout the plume to PRGs within a desired time frame. More aggressive pumping is achieved with closely spaced wells pumping at higher rates. This, in turn, requires treatment systems with greater hydraulic capacities. Pumping is generally performed on a continuous schedule during the earlier and intermediate phases of the project. As the plume contracts and perimeter extraction wells are turned off, pumping may transition into a pulsed schedule if mass removal rates become desorption, diffusion, or solubility limited.

Active restoration using P&T within the 200-UP-1 OU would include an array of extraction wells placed within the footprint of the most persistent COC (uranium, Tc-99, and hexavalent chromium) plumes. Extracted groundwater would be pumped to the existing 200 West Area groundwater treatment facility, where it would be treated to remove uranium, Tc-99, hexavalent chromium, carbon tetrachloride, and nitrate, and COPCs that may be co-extracted (namely PCE, TCE, and chloroform). Treatment would be performed using the existing Train 1 or Train 2, or a new Train 3 would be installed within the available space, if additional mass loading or hydraulic capacity is required.

7.3.5.1 Evaluation

Effectiveness: Active restoration using groundwater P&T is a conventional technology and would be effective in controlling plume migration, removing contaminant mass, and reducing COC concentrations. This technology is well suited to the large volumes and depth of the contaminated groundwater in the 200-UP-1 OU. COC treatment processes developed for the 200-ZP-1 groundwater P&T remedy are reliable and will reduce concentrations to the proposed PRGs. Potential impacts to human health and the environment would be slightly higher than for hydraulic containment but could be effectively managed using existing Hanford Site procedures.

Implementability: Active restoration using P&T technology can be implemented using readily available equipment and resources. Because of the large size of the COC plumes, approximately 8 to 12 extraction wells are expected to be required, along with extensive infrastructure (piping and transfer buildings) to

convey the water from the 200-UP-1 OU to the 200 West Area groundwater treatment facility. While no immediate technical or administrative challenges are associated with this technology, the P&T system would likely need to operate for an extended period of time because of the large size of the COC plumes.

Cost: The overall cost for active restoration will be high depending on the final number of extraction and injection wells required, whether build out of a third treatment train in the 200 West Area groundwater treatment facility is required, and the estimated time frame required for pumping.

Screening Result: Active restoration for all COCs except tritium and I-129 is retained because of its flexibility and ability to address the volumes of contaminated groundwater in the 200-UP-1 OU. Active restoration for tritium and I-129 was not retained because no treatment technologies (see Section 7.2.1.5) are currently available to achieve the 20,000 pCi/L federal DWS for tritium and the 1 pCi/L federal DWS for I-129.

7.3.6 Passive Restoration

Passive restoration consists of actions that treat groundwater COCs in situ. Methods for in situ treatment of 200-UP-1 OU COCs include biological, and physical or chemical stabilization. Because of the large size of the COC plumes in the 200-UP-1 OU, passive treatment would be performed in a PRB. The treatment performed within the reactive portion of the PRB would be specific to each COC or group of COCs with similar requirements.

7.3.6.1 Biological – Carbon Tetrachloride, Hexavalent Chromium, Uranium, and Nitrate

Biological treatment would consist of injecting an organic substrate to reduce carbon tetrachloride, hexavalent chromium, uranium, and nitrate into less toxic compounds. For carbon tetrachloride, this reduction would include chloride ions and methane with some potential for formation of other toxic compounds such as chloroform. Hexavalent chromium and uranium would be reduced to their less oxidized forms, and nitrate would be reduced to nitrogen gas. Pilot testing would be required to determine the optimum substrate and dose necessary to ensure complete transformation. Different substrates may be required.

Because of the large size of the plumes, the substrate would be delivered in PRB configuration. The injections would likely have to be repeated over time to rejuvenate the barrier until all COCs exceeding PRGs have passed through the PRB.

7.3.6.2 Evaluation

Effectiveness: In situ biological treatment has a demonstrated effectiveness for destroying organic contaminants, redox sensitive metals, and nitrate. The technology requires direct-contact and must come into contact with the contaminant mass above the PRG for treatment to occur. This requirement generally requires overlapping and multiple treatment applications to ensure that all affected media come into contact with the substrate.

Implementability: While implementation of this technology is relatively straightforward, its use in a PRB application at depths of 91.4 m to 137.2 m (300 ft to 450 ft) would pose significant technical implementation challenges relative to construction of the PRB treatment zone and the PRB impermeable wings. Additionally, PRBs may need to be constructed at multiple locations to shorten the overall restoration time frame.

Cost: Very high because of the depth and required lengths of the PRBs.

Screening Result: The in situ biological treatment technology is not retained because of uncertainty on its effectiveness (pilot testing required), implementation challenges, and high cost.

7.3.6.3 ISCO—Nitrate

ISCO would consist of injecting a chemical oxidant into the treatment zone to oxidize contaminants as they enter and pass through the PRB. The injections would occur on a periodic basis and would be timed to coincide with a predetermined redox or other measureable in situ parameter. The injections would continue until all COCs exceeding PRGs have passed through the PRB.

7.3.6.4 Evaluation

Effectiveness: ISCO has a demonstrated effectiveness for destroying organic contaminants, but information on its application and effectiveness for inorganics and radionuclides is very limited. Therefore, it is assumed this technology is not effective for treatment of the latter. Additionally, ISCO is a direct-contact technology; the oxidant must come into contact with the contaminants for the treatment to occur. This requirement generally requires overlapping and multiple treatment applications to ensure that the surfaces area of all affected media come into contact with the oxidant.

Implementability: While implementation of the ISCO technology is straightforward, its use in a PRB application at depths of 91.4 m to 137.2 m (300 ft to 450 ft) would pose significant technical implementation challenges relative to construction of the PRB treatment zone and the PRB impermeable wings. Additionally, PRBs may need to be constructed at multiple locations to shorten the overall restoration time frame.

Cost: Very high because of the depth and required lengths of the PRBs.

Screening Result: The ISCO technology is not retained because its effectiveness in treating nitrate, metals (uranium), and radionuclides is unknown.

7.3.6.5 Stabilization – Permeable Reactive Barriers

The PRB technology is an interception technology designed to immobilize or treat contaminants as they enter a constructed-subsurface treatment zone. In general, contaminants are transported into the treatment (reactive) zone by the natural groundwater flow gradient and transformed into nontoxic compounds (biological or direct mineralization reactions), by adsorption of the contaminant onto the PRB media, or by immobilizing the contaminant through a chemical reaction. The PRB technology may be implemented as a funnel-and-gate system or an interception wall. Groundwater pumping wells may be placed downgradient from the PRB to help draw the contaminant plume through the reactive zone, which may decrease the PRB's required length.

The funnel-and-gate PRB uses impermeable (bentonite slurry) walls placed on either side to direct contaminated groundwater through a smaller permeable treatment zone (gate). An interception PRB wall is a continuous treatment zone that spans the full width of the contaminant plume's leading edge. The groundwater flow velocity controls the duration of the remediation effort and the design of the PRB. The PRB must be designed with a suitable thickness (or multiple walls in series) to provide enough residence time for reaction (destruction), adsorption, or precipitation of the contaminant at or below the PRG.

Several different media can be used for the PRB's treatment zone, including chemical oxidants (calcium polysulfide), zero-valent iron, biological media, chemical additions to control groundwater redox conditions, apatite, polyphosphate, and copper. To treat areas with overlapping COC plumes, it may be necessary to use a PRB with multiple treatment zones, or to place a series of PRBs, each designed to address a specific COC, within different areas of the plumes.

7.3.6.6 Evaluation

Effectiveness: PRBs are most effective for organic and conventional inorganic contaminants in shallow water-bearing zones. There has been very little PRB technology research and pilot testing for the 200-UP-1 OU COCs; therefore, there is uncertainty about how effective this technology would be. Additionally, the use of PRB technology for long-lived radionuclides may require long-term management of the PRB site until radioactive decay or other processes reduce concentrations to PRGs.

Implementability: The PRB technology would be very difficult to implement in most portions of the 200-UP-1 OU because of the depth of the COC plumes.

Cost: The overall cost for the PRB technology is expected to be high because of the depth of the construction and the required length.

Screening Result: The PRB technology is rejected for the COCs in the 200-UP-1 OU because of the depth of construction, size of the COC plumes, and uncertainty about the nature of the reactive media.

7.3.6.7 Stabilization – Chemical

Chemical stabilization involves injection of compounds that immobilize contaminants. Based on current information, chemical stabilization could be used to treat uranium, Tc-99, I-129, and potentially nitrate. Stabilization would not be applicable to tritium.

Polyphosphate—Uranium. The polyphosphate technology injects liquid polyphosphate to stabilize uranium. The polyphosphate is injected into groundwater at a slow, controlled rate. The presence of phosphate in groundwater, even in minor concentrations (10^{-8} M), promotes the formation of autunite-group minerals, which immobilize uranium. The use of a soluble long-chain polyphosphate reagent delays precipitation of the autunite, thereby mitigating plugging of the injection well and the aquifer in the vicinity of the injection point. By tailoring the polyphosphate chain, the hydrolysis reaction that releases the phosphate into the water can be engineered, and the uranium stabilization rate can be controlled.

Because autunite sequesters uranium in the oxidized form (U^{6+}), rather than forcing reduction to U^{4+}, the possibility of re-oxidation and subsequent re-mobilization is minimized. Extensive laboratory testing demonstrates very low solubility of autunite. In addition to autunite, excess phosphorous may result in apatite mineral formation, providing a secondary, long-term source for uranium immobilization. The polyphosphate technology may be deployed to treat uranium in groundwater and at the capillary fringe. The liquid form of the reagent facilitates application to and transport within the contaminated groundwater plume. Uranium transport studies in columns packed with contaminated sediment from the 300 Area indicate that a polyphosphate solution reduces the concentration of uranium in water to the 30 µg/L federal DWS. A polyphosphate injection would be considered an innovative treatment option.

Apatite—Uranium. Hydroxyapatite [$Ca_5(PO_4)_3OH$] has been found to be very effective in sequestering dissolved metals, including strontium and uranium. Injected or naturally occurring divalent metals react with dissolved phosphate to form a precipitate, which in turn immobilizes strontium and uranium. Apatite-forming minerals are injected using calcium citrate and phosphate solutions. The complexation of calcium and citrate delays the interaction of calcium and phosphate and subsequent formation of apatite until the citrate is degraded by microorganisms in the subsurface. Thus, apatite formation can occur over a greater radial distance from the injection well, depending on the subsurface hydrology and the microbial citrate degradation rate. This technology is currently being deployed to immobilize Sr-90 in the 100-N area. Injectable apatite would be considered an innovative treatment option.

Immobilization – Uranium and I-129. DOE's Savannah River National Laboratory recently initiated studies under DOE's Office of Environmental Management to identify methods for increasing sustainability of remediation addressing metal- and radionuclide-contaminated groundwater. One Savannah River National Laboratory study area is a 1 km^2 ($.39^2$ mi) metals and radionuclides waste site where a modified funnel-and-gate barrier system has operated since 2005 to treat groundwater containing Sr-90, uranium isotopes, I-129, Tc-99, and tritium. The groundwater is acidic (pH 3.2 to 4.0), a primary factor facilitating mobility of certain contaminants and associated risk drivers. In the current treatment strategy, alkaline solutions of pH 10 are injected periodically into the gates to neutralize groundwater and reduce mobility of some contaminants. The injection frequency is determined by monitoring pH in wells downgradient from the injection wells. When a trigger of pH 5.5 is reached, an alkaline solution is reinjected. In the 3 years of operation, injections were required approximately every 12 months at one gate and every 18 months at the second gate. The alkaline-enhanced funnel-and-gate system treats all contaminants by mixing the stratified plume at the barrier wall, as well as pH-sensitive contaminants such as Sr-90 and uranium isotopes. Early analytical data from downgradient wells indicate the system effectively reduces Sr-90, uranium isotopes, and tritium concentrations to below their respective federal DWSs.

Injection of reagents into the aquifer can cause iodide salts to precipitate, removing I-129 from groundwater. The addition of univalent copper [Cu(I)] could be effective in precipitation of copper iodide (WSRC-TR-2002-00571, *Potential In Situ Remediation of ^{129}I and ^{99}Tc in Groundwater Associated with the F-Area Seepage Basins [U]*). The fact that iodide forms insoluble salts with some metals suggests that precipitation may be a viable remediation strategy for I-129 at the 200-UP-1 OU. Univalent copper is the most promising metal for precipitation of I-129. Three of the four metals that could be used for this purpose have significant problems. Gold iodide is insoluble ($K_{sp} = 1.5 \times 10^{-14}$), but the cost of using gold would be prohibitive. Silver and mercury iodides are also insoluble ($K_{sp} = 8.1 \times 10^{-17}$ [AgI]) and 2.3×10^{-29} [HgI_2]), but both are considered hazardous metals and would not be appropriate for injection into an aquifer. Thus, univalent copper is the most promising counter ion for precipitation of iodide (3.5×10^{-12} [Cu(I)]).

Redox Manipulation – Nitrate and Uranium. Redox manipulation requires that an appropriate substrate and the necessary bacteria be present. Nitrate and uranium can be reduced under anaerobic conditions and converted to nonhazardous products (nitrate to nitrogen gas) or to insoluble chemical forms (uranium). The biomass that grows during anaerobic bioremediation may also increase the adsorption of other contaminants such as I-129, potentially enhanced through reduction of the iodine (Muramatsu et al., 2004, "Studies with Natural and Anthropogenic Iodine Isotopes: Iodine Distribution and Cycling in the Global Environment").

In situ anaerobic bioremediation could be implemented by distributing a long-duration substrate such as vegetable oil into the aquifer. Because the substrate is less accessible to the bacteria, it is not consumed as it is distributed and can provide a long-term food source once in place. The key property with this technology is the hydraulic conductivity of the aquifer. The radius of the treatment zone depends on how well the substrate can be injected into and distributed through the aquifer formation. A secondary property of interest is the length of time that the substrate lasts, which affects the frequency of regenerating the treatment zone. The radius of influence for long-duration substrate injection will be less than that for a soluble substrate.

7.3.6.8 Evaluation

Effectiveness: Many stabilization technologies have been evaluated primarily at the bench or field-scale only, so their effectiveness would need to be demonstrated under the conditions in the 200-UP-1 OU. As a result, there is uncertainty at this time as to whether this technology can achieve the PRGs for all of the COCs. Additionally, physical or chemical stabilization of uranium and long-lived radionuclides such as Tc-99 and I-129 would require long-term management of the reactive zone to prevent inadvertent intrusion.

Implementability: While implementation of the stabilization technology is relatively straightforward, its use in a PRB application at depths of 91.4 to 137.2 m (300 to 450 ft) would pose significant technical implementation challenges relative to construction of the PRB treatment zone and the PRB impermeable wings. Additionally, PRBs may have to be constructed at multiple locations to shorten the overall restoration timeframe.

Cost: Very high because of the depth and required lengths of the PRBs.

Screening Result: The PRB-stabilization technology is not retained because of uncertainty associated with overall treatment effectiveness, long-term management of treatment residuals in situ, and the high cost associated with installing PRBs in the 200-UP-1 OU.

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8 Development and Screening of Remedial Alternatives

The purpose of this FS and the overall remedy development process, is to develop and evaluate remedial alternatives that eliminate, reduce, or control risks to human health and the environment (40 CFR 300.430(a)(1)). The remedial alternatives developed in this chapter combine the remedial technologies and process options retained from the screening performed in Chapter 7 into a range of viable site specific remedial alternatives that achieve the RAOs.

Section 8.1 describes the criteria used for development of remedial alternatives. The remedial alternatives were developed to achieve the RAOs identified in Chapter 7 by considering the requirements identified in the NCP (40 CFR 300). Section 8.2 provides the rationale for alternatives development, a summary of common components to all 200-UP-1 alternatives, and a detailed description of each alternative. Section 8.2 also presents groundwater modeling results performed to demonstrate the time frames required for each alternative to reach the COC specific PRGs. Section 8.3 screens the remedial alternatives presented in Section 8.2 against the CERCLA evaluation criteria of effectiveness, implementability, and cost before being carried forward for detailed and comparative evaluation in Chapter 9.

8.1 Criteria for Development of Remedial Alternatives

As described in the NCP (40 CFR 300), the national goal of the remedy selection process is to select remedies that are: protective of human health and the environment, maintain protection over time, and minimize untreated waste. In 40 CFR 300.430(a)(1)(i) of the NCP, expectations are defined for developing remedial alternatives to achieve these goals.

The following criteria were considered in developing the remedial alternatives:

- Treatment should be used to address the principal threats posed by source materials wherever practical. 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.
- Engineering controls (containment) should be used for waste that pose a relatively low long-term threat or where treatment is impractical.
- A combination of methods, as appropriate, should be used to achieve protection of human health and the environment.
- ICs (restrictions on water use, security, fencing, and deed restrictions) should be used to supplement engineering controls as appropriate for short- and long-term management to prevent or limit exposure to hazardous substances or contaminated environmental media. The use of ICs should not be a substitute for active response measures as the sole remedy unless active measures are determined to not be practical.
- Innovative (nondemonstrated) technologies should be considered when such technologies offer the potential for comparable or superior treatment performance or implementability, fewer or lesser adverse impacts than other available demonstrated approaches, or lower costs for similar levels of performance than demonstrated technologies.
- Useable groundwater should be returned to beneficial use, wherever practical, within a time frame that is reasonable given the particular circumstances of the site. When restoration of groundwater to beneficial uses is not practical, EPA expects to prevent further migration of the plume, prevent exposure to the contaminated groundwater, and evaluate further risk reduction methods.

8.2 Development of Remedial Alternatives

This section describes the remedial alternatives developed for the 200-UP-1 OU. Section 8.2.1 provides an overview of the remedial alternatives. Section 8.2.2 presents remedial alternative components that are common to each of the alternatives. Section 8.2.3 presents the results of groundwater modeling conducted to support development of alternatives. Section 8.2.4 presents a detailed description of each of the remedial alternatives. These sections provide the basis for preliminary screening of alternatives in Section 8.3 and the detailed and comparative analysis presented in Chapter 9.

8.2.1 Overview of Remedial Alternatives

The remedial technologies and process options retained from the screening performed in Chapter 7 were combined to develop a range of viable remedial alternatives. Preliminary technical and functional requirements for the components of each alternative were identified based on RAOs and ARARs, as well as other considerations. Each remedial alternative was developed around the core remedial technologies of groundwater P&T and hydraulic containment, because these groundwater remediation technologies are robust and proven for the conditions present at the Hanford Site and specifically within 200-UP-1. ICs and MNA supplement the active restoration and containment general response actions(GRAs) of each alternative.

Table 8-1 provides a brief overview of the four 200-UP-1 OU alternatives, which encompass a range from no action through various degrees of active restoration using groundwater P&T. While each alternative relies upon common remedial technologies, they are distinguished by the COCs addressed by each technology, how aggressively these COCs are targeted by groundwater P&T, and the active restoration time frame predicted by the groundwater modeling presented in Section 8.2.3.

Each of the alternatives employing P&T require treatment of the extracted groundwater to comply with ARARs. Treatment will be performed at the 200 West groundwater treatment facility. Depending on the pumping rates employed under each alternative, modifications to the 200 West groundwater treatment facility may be required.

Table 8-2 provides the alternative development rationale for the individual remedial technologies and process options included in each remedial alternative and relates how each remedial technology addresses the three 200-UP-1 RAOs. It also includes the rationale for how the remedial technologies combine to address each COC. Table 8-3 gives a detailed summary of each remedial alternative by remedial technology/process option. It also provides an estimated time frame for each COC to reach their respective PRGs.

8.2.2 Common Components

Many of the remedial action alternatives developed for 200-UP-1 contain components that are common to one or more of the alternatives. To limit redundancy in the detailed description of alternatives presented in Section 8.2.4, the common components are described in the following subsections and are not repeated.

8.2.2.1 Institutional Controls

ICs are meant to supplement engineering controls during all phases of the cleanup and are a necessary component of all remedial alternatives, with the exception of the No Action Alternative.

Table 8-1. Overview of 200-UP-1 Remedial Alternatives

Remedial Components	No Action	Alternative 1—40 Years Active Remediation and MNA	Alternative 2—45 Years Active Remediation and MNA	Alternative 3—35 Years Active Remediation and MNA	Alternative 4—25 Years Active Remediation and MNA
Institutional Controls	The NCP (40 CFR 300.430(e)(6)) requires consideration of a No Action Alternative.	Maintain ICs for all COCs until PRGs are achieved.	Maintain ICs for all COCs until PRGs are achieved.	Maintain ICs for all COCs until PRGs are achieved.	Maintain ICs for all COCs until PRGs are achieved.
Groundwater P&T		P&T for Tc-99, uranium, carbon tetrachloride, and concentrated nitrate plume areas	P&T for Tc-99, uranium, carbon tetrachloride, chromium (total), and concentrated nitrate plume areas	Moderately aggressive P&T for Tc-99, uranium, carbon tetrachloride, chromium (total) and concentrated nitrate plume areas	Highly aggressive P&T for Tc-99, uranium, carbon tetrachloride, chromium (total), and all nitrate plume areas (concentrated and diffuse)
MNA	The NCP (40 CFR 300.430(e)(6)) requires consideration of a No Action Alternative.	Tritium, detached chromium, plume, diffuse parts of nitrate plume, and remaining parts of carbon tetrachloride plume	Tritium, diffuse parts of nitrate plume, and remaining parts of carbon tetrachloride plume	Tritium, diffuse parts of nitrate plume, and remaining parts of carbon tetrachloride plume	Tritium, and remaining parts of carbon tetrachloride plume
Hydraulic Containment*		I-129	I-129	I-129	I-129
Time to Reach PRGs**		40 Years	45 Years	35 Years	25 Years

Source: 40 CFR 300.430(e)(6), "National Oil and Hazardous Substances Pollution Contingency Plan," "Remedial Investigation/Feasibility Study and Selection of Remedy."

* The cleanup time frame for I-129 will be determined by the remedy selected at the completion of the technology evaluation.

** The time required to reach PRGs is shown for the COCs present within each remediation area except carbon tetrachloride..

EPA's *Institutional Controls: A Site Manager's Guide to Identifying, Evaluating and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups* (EPA 540-F-00-005) states that ICs:

- are non-engineered instruments such as administrative and/or legal controls that minimize the potential for human exposure to contamination by limiting land or resource use,
- are generally to be used in conjunction with, rather than in lieu of, engineering measures such as waste treatment or containment,
- can be used during all stages of the cleanup process to accomplish various cleanup related objectives, and,
- should be "layered" (i.e., use multiple ICs) or implemented in a series to provide overlapping assurances of protection from contamination.

ICs for the current Hanford Site CERCLA response actions are described in DOE/RL-2001-41. The plan describes how ICs are implemented and maintained, and serves as a reference for the selection of future IC's. Chapter 7 identifies the ICs that have been implemented at the Site, and describe how ICs are to be maintained for the future and will be subsequently revised to include ICs required by the 200-UP-1 ROD.

The 200-UP-1 Groundwater OU interim ROD (EPA/ROD/R10-97/048), as amended by 09-AMCP-0082, "Explanation of Significant Differences for the Interim Action Record of Decision for the 200-UP-1 Groundwater Operable Unit, Hanford Site, Benton County, Washington, February 2009," requires ICs during the interim action. DOE is responsible for implementing, maintaining, reporting on, and enforcing the ICs until the lead regulatory agency authorizes their removal. The current ICs provide a foundation from which to prevent exposure above risk based concentrations. The current ICs are:.

1. The DOE shall control access to 200-UP-1 OU Groundwater to prevent unacceptable exposure of humans to contaminants, except as otherwise authorized in lead regulatory agency approved documents.
2. Visitors entering any site areas of the 200-UP-1 OU will be required to be badged and escorted at all times.
3. No intrusive work shall be allowed in the 200-UP-1 OU unless the lead regulatory agency has approved the plan for such work and that plan is followed.
4. The DOE shall prohibit well drilling in the 200-UP-1 OU, except for monitoring, characterization, or remediation wells authorized in lead regulatory agency approved documents.
5. Groundwater use in the 200-UP-1 OU is prohibited, except for limited research purposes, monitoring, and treatment authorized in lead regulatory agency approved documents.
6. The DOE shall post and maintain warning signs along pipelines conveying untreated groundwater that caution site visitors and workers of potential hazards from the 200-UP-1 OU.
7. In the event of any unauthorized access (e.g. trespassing), DOE shall report such incidents to the Benton County Sheriff's Office for investigation and evaluation of possible prosecution.
8. Activities that would disrupt or lessen the performance of the P&T component of the remedy are to be prohibited.
9. The DOE shall prohibit activities that would damage the remedy components (e.g. extraction wells, piping, treatment plant, and monitoring wells).
10. The DOE will prevent the development and use of property above the 200-UP-1 OU for residential housing, elementary and secondary schools, childcare facilities, and playgrounds.
11. The DOE shall report on the effectiveness of ICs for the 200-UP-1 OU interim remedy in an annual report, or on an alternative reporting frequency specified by the lead regulatory agency. Such reporting may be for the 200-UP-1 OU alone or may be part of the Hanford Site wide report.

Table 8-2. 200-UP-1 OU Remedial Alternative Development Rationale

Alternative	Remedial Components	COCs Addressed	Remedial Action Objective Addressed		Rationale for Inclusion in Remedial Alternatives
			RAO No. 1	RAO No. 2	
			Return the 200-UP-1 OU groundwater to beneficial use as a potential drinking water source.	Apply ICs to prevent groundwater use until drinking water standards are achieved.	
No Action	No Action	Not Applicable			Required by 40 CFR 300.430(e)(6).
Alternative 1: 40 Years Active Remediation with MNA	ICs	All COCs		X	ICs meet the RAO 2 administrative controls that restrict access and limit land and groundwater use within the OU until PRGs are met. ICs are intended to supplement the engineering controls and other physical components of the remedial alternative (EPA-540-F-00-05). Site-wide IC requirements, as described in DOE-RL-2001-41, are applicable to the 200-UP-1 OU. The 200-UP-1 interim ROD (EPA/ROD/R10-97/048), as amended by 09-AMCP-0082 also required specific ICs during the interim action. The final ICs will be defined in the ROD.
	MNA	Tritium Nitrate (low concentration plume areas), chromium, Carbon tetrachloride	X		Natural attenuation includes reduction of toxicity, mobility, volume, concentration, and/or bioavailability through natural physical, chemical, or biological processes that occur without human intervention. These processes will assist in achieving RAOs 1. The monitoring component of the alternative verifies that the natural attenuation processes are occurring as anticipated and serves as a basis for determining whether PRGs have been met, or additional measures are needed. MNA is especially applicable for tritium, where a treatment technology is not available and it has a short half-life (12.3 years). Alternative 1 relies upon MNA to demonstrate the attainment of PRGs for tritium, chromium, the diffuse (low-concentration) nitrate plume areas, and residual areas of the carbon tetrachloride plume that are not co-extracted by the Tc-99 and uranium extraction wells.
	Groundwater P&T	Tc-99, Uranium, Nitrate (high concentration plume areas co-extracted with uranium), Carbon tetrachloride	X		The P&T component restores the Tc-99 and uranium plumes to PRGs to address RAO 1. The uranium P&T component also co-extracts the highest concentration areas of the nitrate plume and both P&T systems will remove portions of the carbon tetrachloride plume. Operation of the Tc-99 and uranium P&T components will contribute to achieving RAO 1but will require MNA as a supporting component of the remedy to reach PRGs for chromium, carbon tetrachloride and nitrate. The Tc-99 and uranium P&T components will continue for a period of 15 years and 40 years, respectively, to reduce concentrations to cleanup levels. Above ground treatment of extracted groundwater addresses RAOs 1 as a necessary component of the P&T system operation, which requires treatment to PRGs before injecting groundwater back into the aquifer. Alternative 1 assumes that treatment of 200-UP-1 groundwater will be accomplished at the 200 West groundwater treatment facility. Modifications to this facility will include addition of a uranium IX treatment train and a third Tc-99 IX treatment train.
	Hydraulic Containment	I-129	X		This component hydraulically contains the I-129 plume until a remedy is selected. Hydraulic containment as an engineering control is described in the NCP under 40 CFR 300.430(1)(1)(iii)(B). Hydraulic containment is intended to contain the plume present above DWSs within the aquifer to prevent further plume migration. Current technology is insufficient to treat groundwater to the 1 pCi/L DWS. The feasibility of treatment and level that can be achieved will be determined though a treatment technology evaluation.
Alternative 2: 45 Years Active Remediation with MNA	ICs	All COCs		X	Same as Alternative 1.
	MNA	Tritium, Nitrate (low-concentration plume areas), Carbon tetrachloride	X		Same as Alternative 1, with the exception that Alternative 2 does not rely on MNA to achieve the PRG for chromium which is addressed by P&T.
	Groundwater P&T	Tc-99, Uranium, Chromium, Nitrate (high concentration plume areas co-extracted with uranium), Carbon tetrachloride	X		The Tc-99 and uranium P&T components are the same as described for Alternative 1. This alternative adds active pumping for the chromium plumes. The P&T component restores the Tc-99, uranium, and chromium plumes to PRGs to address RAO 1. The uranium and Tc-99 P&T components also co-extracts the high-concentration areas of the nitrate plume and portions of the carbon tetrachloride plume that lie within the U Plant Area and WMA S-SX Area. P&T of the chromium plume will continue for a period of 45 years to reduce concentrations to the PRG. Above ground treatment of extracted groundwater is the same as described for Alternative 1.
	Hydraulic Containment	I-129			Same as Alternative 1.

Table 8-2. 200-UP-1 OU Remedial Alternative Development Rationale

Alternative	Remedial Components	COCs Addressed	Remedial Action Objective Addressed		Rationale for Inclusion in Remedial Alternatives
			RAO No. 1	RAO No. 2	
			Return the 200-UP-1 OU groundwater to beneficial use as a potential drinking water source.	Apply ICs to prevent groundwater use until drinking water standards are achieved.	
Alternative 3: 35 Years Active Remediation with MNA	ICs	All		X	Same as Alternative 1.
	MNA	Tritium, Nitrate, (low-concentration plume areas), Carbon tetrachloride	X		Same as Alternative 2.
	Groundwater P&T	Tc-99, Uranium, Chromium, Nitrate (high concentration plume areas co-extracted with uranium), Carbon tetrachloride	X		The P&T component restores the Tc-99, uranium, and chromium plumes to PRGs to address RAO 1. The uranium and Tc-99 P&T components also co-extracts the highest concentration areas of the nitrate plume and a portion of the carbon tetrachoride plume. The Tc-99 P&T component is the same as Alternative 1. The P&T components for the uranium and chromium plumes include an increased extraction rate compared to Alternative 2, and will continue for a period of 25 years to reduce concentrations to the PRGs. Above ground treatment of extracted groundwater is the same as described for Alternative 1, but requires the addition of a third biological process treatment train at the 200 West groundwater treatment facility.
	Hydraulic Containment	I-129			Same as Alternative 1.
Alternative 4: 25 Years Active Remediation with MNA	ICs	All		X	Same as Alternative 1.
	MNA	Tritium Carbon tetrachloride	X		Same as Alternative 1, with the exception that Alternative 4 does not rely on MNA to achieve the PRGs for chromium or nitrate, which are addressed by the P&T components for this alternative.
	Groundwater P&T	Tc-99, Uranium, Chromium, Nitrate (entire plume), Carbon tetrachloride	X		The P&T component restores the Tc-99, uranium, chromium, and nitrate plumes to PRGs to address RAO 1. The uranium P&T component also co-extracts the high-concentration areas of the nitrate plume that lie within the U Plant Area uranium plume, and Alternative 4 adds P&T of the diffuse (low-concentration) nitrate plume areas. The Tc-99 P&T component is the same as Alternative 1. The uranium and chromium P&T components are the same as Alternative 3. P&T of the nitrate plume will continue for a period of 20 years to reduce concentrations to the PRG. Carbon tetrachloride is addressed (in part) by the Tc-99 and uranium P&T systems, but MNA is required to treat the residual left after P&T is stopped. The groundwater treatment requirements for this alternative are the same as described for Alternative 3.
	Hydraulic Containment	I-129			Same as Alternative 1.

Sources: 09-AMCP-0082, "Explanation of Significant Differences for the Interim Action Record of Decision for the 200-UP-1 Groundwater Operable Unit, Hanford Site, Benton County, Washington, February 2009."

40 CFR 300.430(e)(6), "National Oil and Hazardous Substances Pollution Contingency Plan," "Remedial Investigation/Feasibility Study and Selection of Remedy."

DOE/RL-2001-41, *Site wide Institutional Controls Plan for Hanford CERCLA Response Actions*.

EPA 540-F-00-005, *Institutional Controls: A Site Manager's Guide to Identifying, Evaluating and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups*.

EPA/ROD/R10-97/048, *Interim Remedial Action Record of Decision for the 200-UP-1 Operable Unit, Hanford Site, Benton County, Washington*.

Table 8-3. Detailed Description of the 200-UP-1 OU Remedial Alternatives

Remedial Technologies	Process Options	Remediation Area/COCs Addressed	Alternative 1—40 Years Active Remediation and MNA	Alternative 2—45 Years Active Remediation and MNA	Alternative 3—35 Years Active Remediation and MNA	Alternative 4—25 Years Active Remediation and MNA
ICs	Entry Restrictions	All COCs	Site wide ICs implemented per DOE/RL-2001-41 with 200-UP-1 specific ICs adopted from the 200-UP-1 interim ROD (EPA/ROD/R10-97/048), as amended by 09-AMCP-0082.			
	Land and Groundwater Use management					
	Waste Site Information Management					
	Access Controls					
Estimated Groundwater Extraction and Injection Wells and Flow Rates						
Groundwater P&T[a,b,c]	Groundwater extraction using vertical wells Treated water discharge using vertical injection wells	***WMA S-SX Remediation Area*** -Tc-99 -Chromium -Nitrate -Carbon Tetrachloride	3 extraction wells operating at 300 L/min (80 gpm) total flow rate (Pumping Scenario #1).	3 extraction wells operating at 300 L/min (80 gpm) total flow rate (Pumping Scenario #1).	3 extraction wells operating at 300 L/min (80 gpm) total flow rate (Pumping Scenario #1).	3 extraction wells operating at 300 L/min (80 gpm) total flow rate (Pumping Scenario #1).
		U Plant Remediation Area -Uranium -Tc-99 -Nitrate -Carbon Tetrachloride	2 extraction and 2injection wells operating at 380 L/min (100 gpm) total flow rate (Pumping Scenario #2).	2 extraction and 2 injection wells operating at 380 L/min (100 gpm) total flow rate (Pumping Scenario #2).	2 extraction and 2 injection wells operating at 570 L/min (150 gpm) total flow rate (Pumping Scenario #3).	2 extraction and 2 injection wells operating at 570 L/min (150 gpm) total flow rate (Pumping Scenario #3).
		Northeast Nitrate Remediation Area -Nitrate -Tc-99	Not Applicable	Not Applicable	Not Applicable	1 to 2 extraction wells operating at 380 L/min (100 gpm) total flow rate (Pumping Scenario #2)
		Southeast Chromium Remediation Area -Chromium (total and hexavalent)	MNA for chromium (total and hexavalent) and tritium (Pumping Scenario #1)	2 extraction and 2 injection wells operating at 570 L/min (150 gpm) total flow rate (Pumping Scenario #3).	2 to 3 extraction and 2 to 3 injection wells operating at 760 L/min (200 gpm) total flow rate (Pumping Scenario #4).	2 to 3 extraction and 2 to 3 injection wells operating at 760 L/min (200 gpm) total flow rate (Pumping Scenario #4).
	Above ground treatment using 200 West Groundwater Treatment Facility	Groundwater Treatment – All Remediation Areas -Tc-99 -Chromium (total and hexavalent) -Nitrate -Uranium -Carbon Tetrachloride	Total Feed 680 L/min (180 gpm) Uses 200 West Groundwater Treatment Facility and adds 1 uranium and 1 Tc-99 treatment train.	Total Feed 1,250 L/min (330 gpm) Same treatment processes as Alternative 1.	Total Feed: 1,630 L/min (430 gpm) Same treatment processes as Alternative 1 and adds a third biological treatment process train.	Total Feed: 2,010 L/min (530 gpm) Same treatment processes as Alternative 3.
	Groundwater Monitoring[f]	Remedy Performance monitoring is included in the design of the overall remedy groundwater monitoring program.	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1
Hydraulic Containment[f]	Hydraulic Control Using Injection Wells	Central I-129 Remediation Area (no groundwater extraction)	3 injection wells operating at 570 L/min (150 gpm) total flow rate while technology evaluation is performed (Pumping Scenario #2).	3 injection wells operating at 570 L/min (150 gpm) total flow rate. Same as Alternative 1.	3 injection wells operating at 570 L/min (150 gpm) total flow rate. Same as Alternative 1.	3 injection wells operating at 570 L/min (150 gpm) total flow rate. Same as Alternative 1.
	Groundwater Monitoring[f]	Remedy performance monitoring is included in the design of the overall remedy groundwater monitoring program.	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1

Table 8-3. Detailed Description of the 200-UP-1 OU Remedial Alternatives

Remedial Technologies	Process Options	Remediation Area/COCs Addressed	Alternative 1—40 Years Active Remediation and MNA	Alternative 2—45 Years Active Remediation and MNA	Alternative 3—35 Years Active Remediation and MNA	Alternative 4—25 Years Active Remediation and MNA
MNA	Groundwater Monitoring[f]	Tritium Plume Area -Tritium (All alternatives)	Groundwater monitoring and reporting for all COPCs and COCs to document remedy progress. Alternative 1 relies on groundwater monitoring to document reduction of tritium, carbon tetrachloride, chromium, and the low-concentration areas of the nitrate plume to PRGs through natural attenuation.	Same groundwater monitoring program as Alternative 1. Alternative 2 relies on groundwater monitoring to document reduction of tritium, carbon tetrachloride, and the low-concentration nitrate plume areas to PRGs through natural attenuation. Alternative 2 does not rely upon MNA for attainment of the chromium PRG.	Same as Alternative 2.	Same groundwater monitoring program as Alternative 1. Alternative 4 relies on groundwater monitoring to document reduction of tritium and carbon tetrachloride to PRGs through natural attenuation. Alternative 4 does not rely upon MNA for attainment of the chromium or nitrate PRGs.
		Carbon Tetrachloride Plume -Carbon Tetrachloride (All alternatives)				
		Northeast Nitrate Remediation Area -Nitrate (Low-concentration plume area for Alternatives 1, and 3)				
		Southeast Chromium Remediation Area -Total and hexavalent chromium (Alternative 1 only)				
Estimated Time (years) to Reach PRGs						
Time to Reach PRGs[b]	All process options	WMA S-SX Remediation Area (Tc-99)	15	15	15	15
		U Plant Remediation Area (uranium)	40	40	25	25
		Northeast Nitrate Remediation Area (nitrate)	35	35	35	20
		Southeast Chromium Remediation Area (chromium	120	45	25	25
		Tritium Plume Area (Tritium)	25	25	25	25
		Central I-129 Remediation Area (I-129)	d	d	d	d
		Carbon Tetrachloride	125e	125e	125e	125e

Sources: 09-AMCP-0082, "Explanation of Significant Differences for the Interim Action Record of Decision for the 200-UP-1 Groundwater Operable Unit, Hanford Site, Benton County, Washington, February 2009."

DOE/RL-2001-41, *Site wide Institutional Controls Plan for Hanford CERCLA Response Actions*.

EPA/ROD/R10-97/048, *Interim Remedial Action Record of Decision for the 200-UP-1 Operable Unit, Hanford Site, Benton County, Washington*.

a. For Alternatives 1 through 4, groundwater pump-and-treat is assumed to continue until the 95th percentile exposure point concentration for each plume area is reduced below its respective PRG.

b. The time required to reach PRGs is shown for the COCs present within each remediation area.

c. All pumping rates and remedial action durations are estimated. Actual pumping rates and durations may vary.

d. The cleanup time frame for I-129 will be determined by the remedy selected at the completion of the technology evaluation.

e. Remediation of the carbon tetrachloride plume within the 200 West Area is being addressed as part of the 200-ZP-1 OU remedy. The selected remedy for the 200-ZP-1 OU defined in *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton County, Washington* (EPA, Ecology, and DOE, 2008) is P&T, MNA, flow-path control and institutional controls, and includes 25 years of P&T/flow-path control followed by 100 years of MNA to achieve groundwater PRGs with 125 years. 200-UP-1 OU P&T remedy components will also extract and treat carbon tetrachloride and contribute to a reduction in its overall cleanup time frame.

f. The MNA, groundwater P&T, and hydraulic containment process options all include groundwater monitoring. A single robust groundwater monitoring program is assumed for each alternative that fulfills the requirements of groundwater monitoring for each remedial process option.

g. The high concentration areas of the nitrate plume, co-located with the uranium plume near the U Plant, are co-extracted by the uranium P&T components in Alternatives 1 through 4.

12. Measures that are necessary to ensure continuation of ICs shall be taken before any lease or transfer of any land above the 200-UP-1 OU. DOE will provide notice to Ecology and EPA at least 6 months before any transfer or sale of 200-UP-1 OU or any land above the 200-UP-1 OU so that the lead regulatory agency can be involved in discussions to ensure that appropriate provisions are included in the transfer terms or conveyance documents to maintain effective ICs. If it is not possible for DOE to notify Ecology and EPA at least 6 months before any transfer or sale, DOE will notify Ecology and EPA as soon as possible, but no later than 60 days before the transfer or sale of any property subject to ICs. In addition to the land transfer notice and discussion provisions, DOE further agrees to provide Ecology and EPA with similar notice, within the same time frames, as to federal-to-federal transfer of property. DOE shall provide a copy of the executed deed or transfer assembly to Ecology and EPA.

The ICs specified above will be incorporated into the selected remedy, and will be maintained until the concentrations of hazardous substances in groundwater are at such levels to allow for unrestricted use and exposure and the lead regulatory agency authorizes the removal of restrictions. The ICs proposed under all of the remedial alternatives, except the No Action Alternative, would maintain the existing ICs restricting groundwater use until PRGs are achieved. The ICs described above are consistent with those in the 200-ZP-1 OU ROD.

As long as contaminants remain within the 200-UP-1 OU groundwater at concentrations that exceed proposed PRGs, a 5-year review is required by the NCP (40 CFR 300.430(f)(4)(ii)). The 5-year review will be conducted to evaluate the effectiveness of the existing institutional controls, to evaluate the need for continued institutional controls, or to consider a supplemental remedial action.

8.2.2.2 Incorporation of Current Interim Remedial Actions

Three 200-UP-1 interim actions, primarily targeting Tc-99 near WMA S-SX and uranium near U Plant, are being implemented under the requirements of the interim ROD (EPA/541/R-97/048), as amended by the ESD (Ecology, 2009b). These are:

- Two emerging Tc-99 plumes in the vicinity of WMA S-SX are being addressed by installing a three well, 300 L/min (80 gpm) extraction system. The extracted groundwater will be pumped through a new pipeline and transfer station to the 200 West treatment facility.
- An extraction system near U Plant constructed to extract uranium and Tc-99 contaminated groundwater. The extracted groundwater was sent to the Effluent Treatment Facility (ETF) for treatment.
- Quarterly sampling and purging of monitoring well 299-W23-19 located in the southern portion of WMA S-SX.

The U Plant P&T system was shut-down/stopped in 2012 since the remedial goals had been met for each contaminant (less than 10 times the DWS).

The extraction system described at WMA S-SX has been constructed, but has not begun operations. Figure 8-1 shows the conceptual layout for the WMA S-SX system, and the details are outlined in DOE/RL-97-36 (Rev. 3). This system is included as a component in each of the remedial alternatives. Quarterly sampling and purging of monitoring well 299-W23-19 will continue until the WMA S-SX extraction system becomes operational.

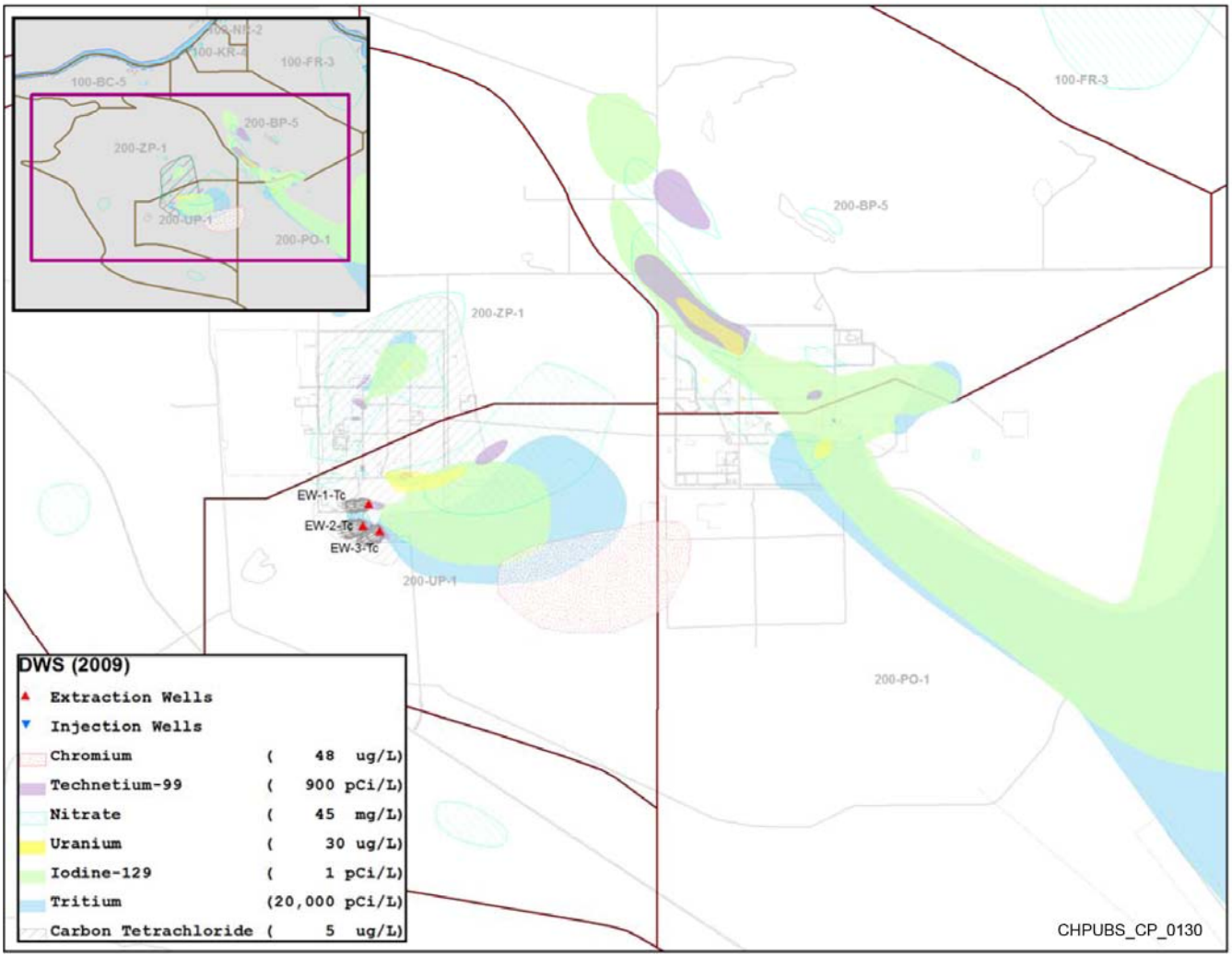

Figure 8-1. Conceptual Layout of Tc-99 Extraction Wells in the WMA S-SX Vicinity

8.2.2.3 Monitored Natural Attenuation

MNA relies on natural processes within the aquifer to achieve reductions in the toxicity, mobility, volume, concentration, and/or bioavailability of COCs. These natural processes include physical, chemical, and biological transformations that occur without human intervention. MNA requires information to show that attenuation is occurring, an understanding of site-specific and contaminant-specific attenuation mechanisms, and monitoring to demonstrate that natural attenuation is occurring as anticipated. MNA is considered appropriate for sites where RAOs can be achieved in a reasonable time frame compared to more active remedial alternatives.

MNA is a viable component for 200-UP-1 OU remedial alternatives, especially for tritium because of its short radioactive half-life (12.3 years) and because there is no groundwater treatment technology for this constituent. MNA for tritium and carbon tetrachloride are common components of each alternative except the No Action Alternative. Carbon tetrachloride will require the longest MNA timeframe which is estimated to be 125 years, consistent with the 200-ZP-1 OU ROD.

8.2.2.4 Groundwater Pump-and-Treat

Each of the alternatives, with the exception of the No Action Alternative, includes a groundwater P&T system. These systems consist of groundwater extraction well networks, transfer piping (with transfer pump stations), and use of the existing treatment facility in 200 West.

Extraction wells are designed to remove contaminants from the aquifer and to reduce or prevent further plume migration. Injection wells are used to inject treated water back into the aquifer to balance groundwater flow. The placement of injection wells near the plume margins or downgradient of the plume provides flow path (gradient) control to prevent migration and slow COC travel times. The above ground treatment system for all 200-UP-1 remedial alternatives is the 200 West Groundwater Treatment Facility, which includes various chemical, physical, and biological treatment technologies designed specifically to treat the COCs that are being addressed.

Extraction well design consider site-specific factors, such as the vertical contaminant distribution encountered within the aquifer during drilling, anticipated well yield, and the grain-size of the aquifer sediments. Based on the vertical contaminant distribution discussed in Section 4.2, the highest concentration of most contaminants occurs within the upper 20 to 30 m (66 to 98 ft) of the unconfined aquifer. Based on the current understanding of the nature and extent of contamination, it is anticipated that the extraction wells will be screened in the upper part of the aquifer with screen lengths of less than 30 m (98 ft). The extraction wells are assumed to be nominally 20 cm (8 in.) diameter.

Although injection well designs are also specific to their function (inject treated water to the aquifer or provide hydraulic flow path control), for the purpose of FS alternative development, the injection well design is assumed to be similar to the extraction well design. Injection wells for hydraulic containment of the I-129 plume will be extended to the base of the unconfined aquifer.

Groundwater extracted by P&T systems must be treated to appropriate standards before injection back into the aquifer. The 200 West Groundwater Treatment Facility is designed to treat the 200-ZP-1 OU COCs (carbon tetrachloride, chromium [total and hexavalent], nitrate, TCE, and Tc-99) (DOE/RL-2010-13, *200 West Area Groundwater Pump-and-Treat Remedial Design Report*), which are common to the 200-ZP-1 and 200-UP-1 OUs. Tritium is also present in the 200-ZP-1 OU, but it will not be actively treated. Although uranium is not a COC in the 200-ZP-1 OU, the treatment system design includes IX treatment of uranium that may be captured by the extraction wells (DOE/RL-2008-78, *200 West Area 200-ZP-1 Pump-and-Treat Remedial Design/Remedial Action Work Plan*). Capacity is also being designed into the system to treat uranium from the 200-UP-1 selected remedy. Floor space is reserved at the 200 West Groundwater Treatment Facility for a uranium IX (U IX) system to accomplish this objective.

The treatment facility is located south of the T Plant Area (Figure 8-2) and consists of two main processes. These include a separate radiological pretreatment area (Radiological or RAD Building) for groundwater containing Tc-99 and uranium, and the main 200 West Central Treatment Area (bio-process or bio-building) that contains the remainder of the biological, chemical, and physical unit processes. Figure 8-3 provides an overview of the 200 West Area Treatment Facility. Table 8-4 list the major unit processes, their process benefit, and targeted parameters. Figure 8-4 provides a block flow diagram depicting the groundwater extraction, treatment and injection flows for the t treatment facility before implementation of the 200-UP-1 remedy. The treatment facility design also allows for expansion of the system to include additional capabilities, as needed, to treat groundwater from the 200-UP-1 OU (DOE/RL-2010-13).

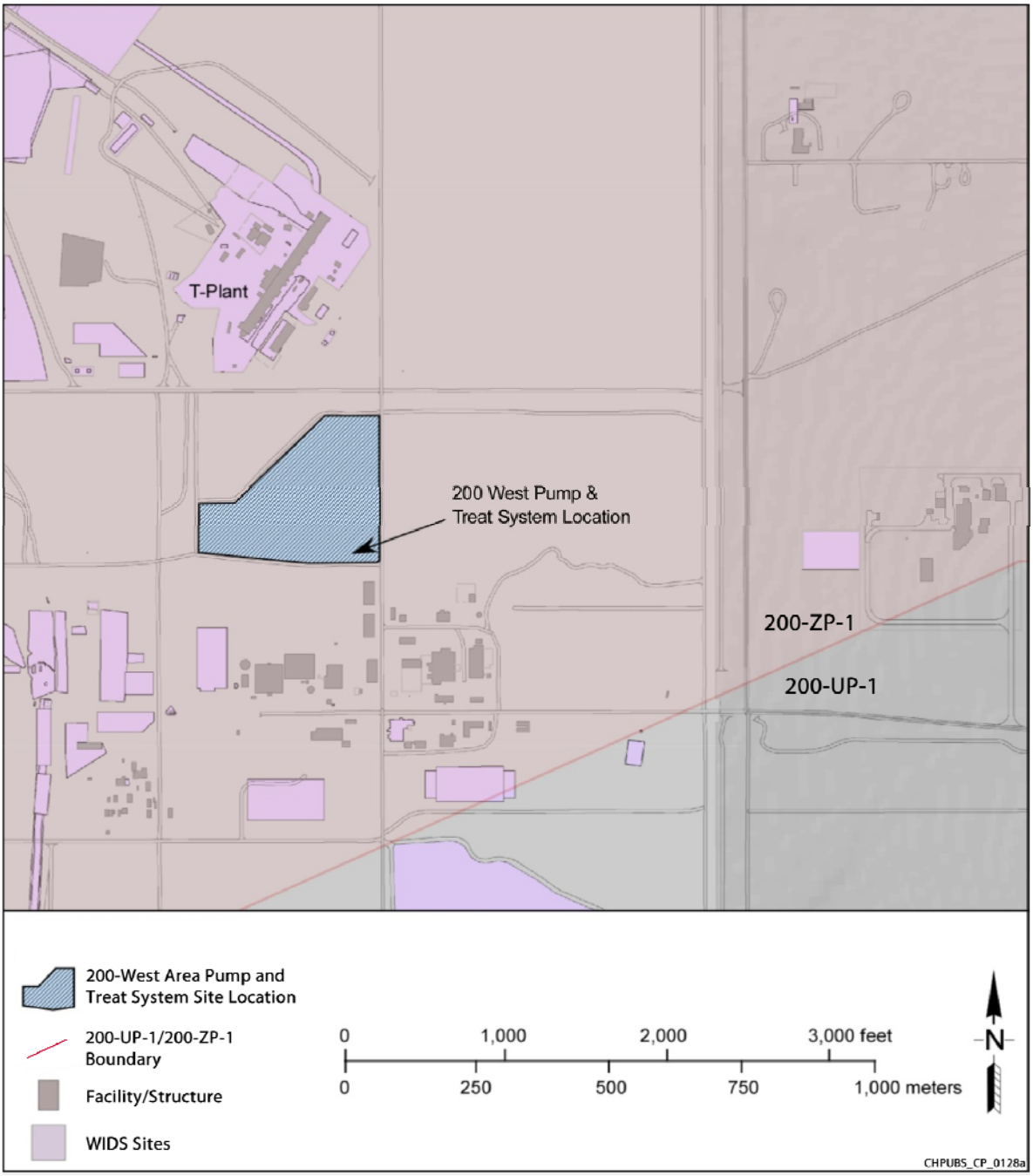

Figure 8-2. 200 West Groundwater Treatment Facility Location

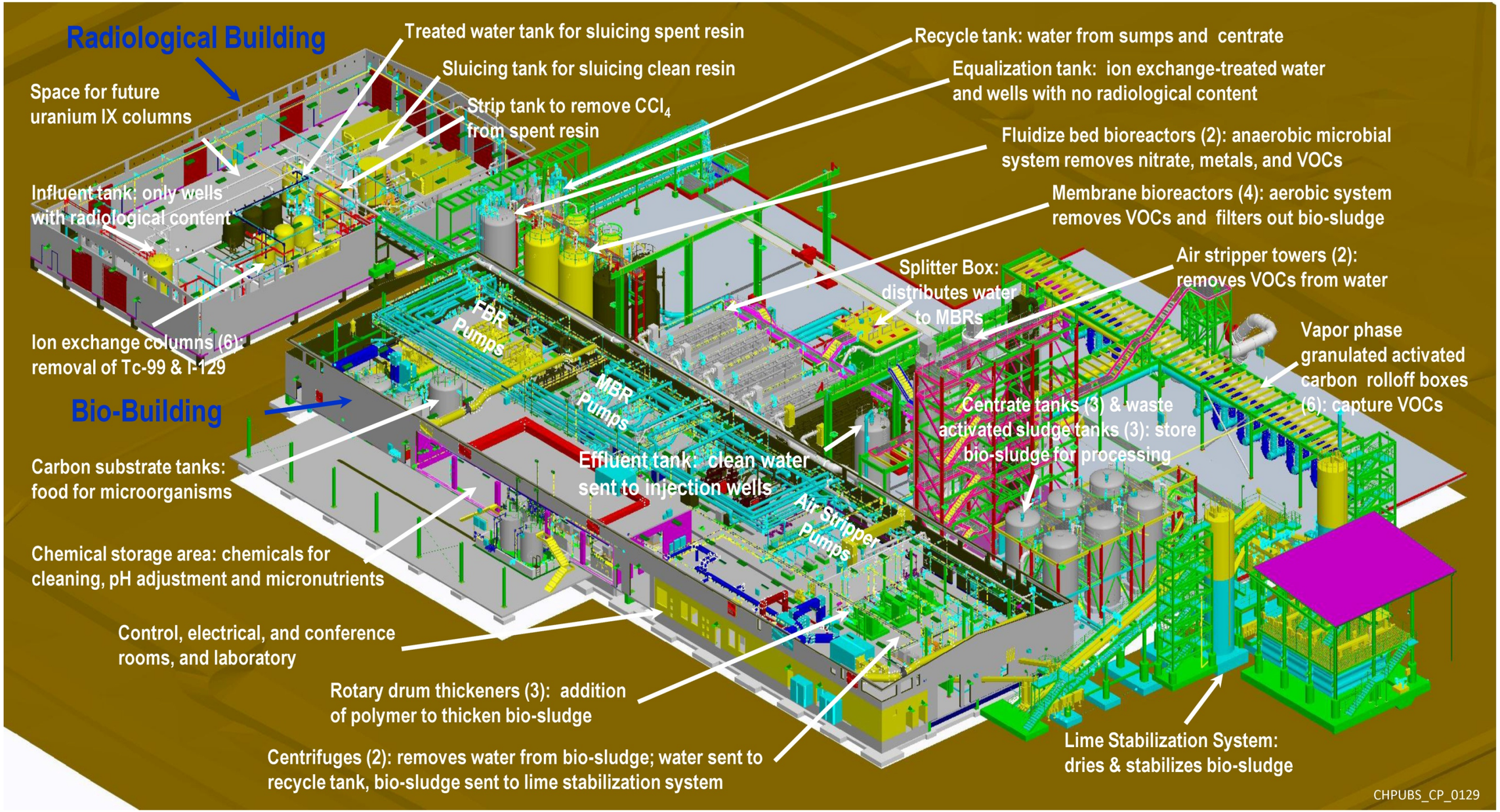

Figure 8-3. 200 West Groundwater Treatment Facility Overview

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Table 8-4. 200 West Groundwater Treatment Unit Processes

Unit Process	Process Benefit	Targeted Parameter
Ion Exchange	Removal of Tc-99, uranium, and I-129[a]	Tc-99 I-129 Uranium[b]
Anoxic/anaerobic Biodegradation	Removal of nitrate and carbon tetrachloride and conversion of hexavalent chromium to trivalent form	Nitrate Carbon tetrachloride Hexavalent chromium Trichloroethylene
Aerobic biodegradation	Degradation/removal of residual organic carbon substrate Removal of carbon tetrachloride and trichloroethylene	Biochemical Oxygen Demand (BOD) Carbon tetrachloride Trichloroethylene
Membrane filtration	Removal of particles, biomass, and precipitated trivalent chromium	Trivalent chromium Turbidity and BOD
Air stripping	Removal of volatile organic compounds (carbon tetrachloride and trichloroethylene)	Carbon tetrachloride Trichloroethylene
Sludge thickening	Thicken biological solids for dewatering process	Solids content
Sludge dewatering	Reduce water content to allow for landfill disposal	Water content
Lime treatment of dewatered sludge	Lyse micro-organism cells and kill biomass	Stabilized sludge for disposal
Treated water chemistry adjustment	Provide treated water stability	pH and alkalinity

a. Only partial removal of I-129 is anticipated with IX.

b. Uranium treatment is only required for groundwater from the 200-UP-1 OU.

The radiological process facility houses the Tc-99 IX pretreatment system and additional floor space reserved for a uranium IX (U IX) treatment system. The Tc-99 IX system consists of two parallel treatment trains capable of treating 1,320 L/min (350 gpm) each, with floor space reserved for a third identical train. The first two Tc-99 IX pretreatment trains include capacity to treat groundwater extracted from the WMA S-SX IRA, which will be incorporated into the 200-UP-1 selected remedy, along with selected 200-ZP-1 OU wells that contain high concentrations of Tc-99. Any additional 200-UP-1 flows requiring pretreatment for Tc-99 will require construction of the third treatment train. Construction of this third Tc-99 IX treatment train has been assumed for alternative development and cost estimating purposes for all 200-UP-1 remedial alternatives. The treatment facility design includes a U IX system; however, this system will not be constructed until needed for the 200-UP-1 remedy. All 200-UP-1 remedial alternatives assume construction of a U IX treatment train.

a. The 200 West Bio-Process Facility is constructed at 2,500 gpm maximum capacity with 350 gpm reserved for 200-UP-1 OU groundwater in trains 1 and 2. Flow from 200-ZP-1 extraction wells is assumed to be 1,720 gpm average/2,150 gpm maximum or less.

b. Average flows represent flow rates predicted by groundwater modeling. Maximum flows represent flow rates adjusted to account for 20 percent treatment system downtime.

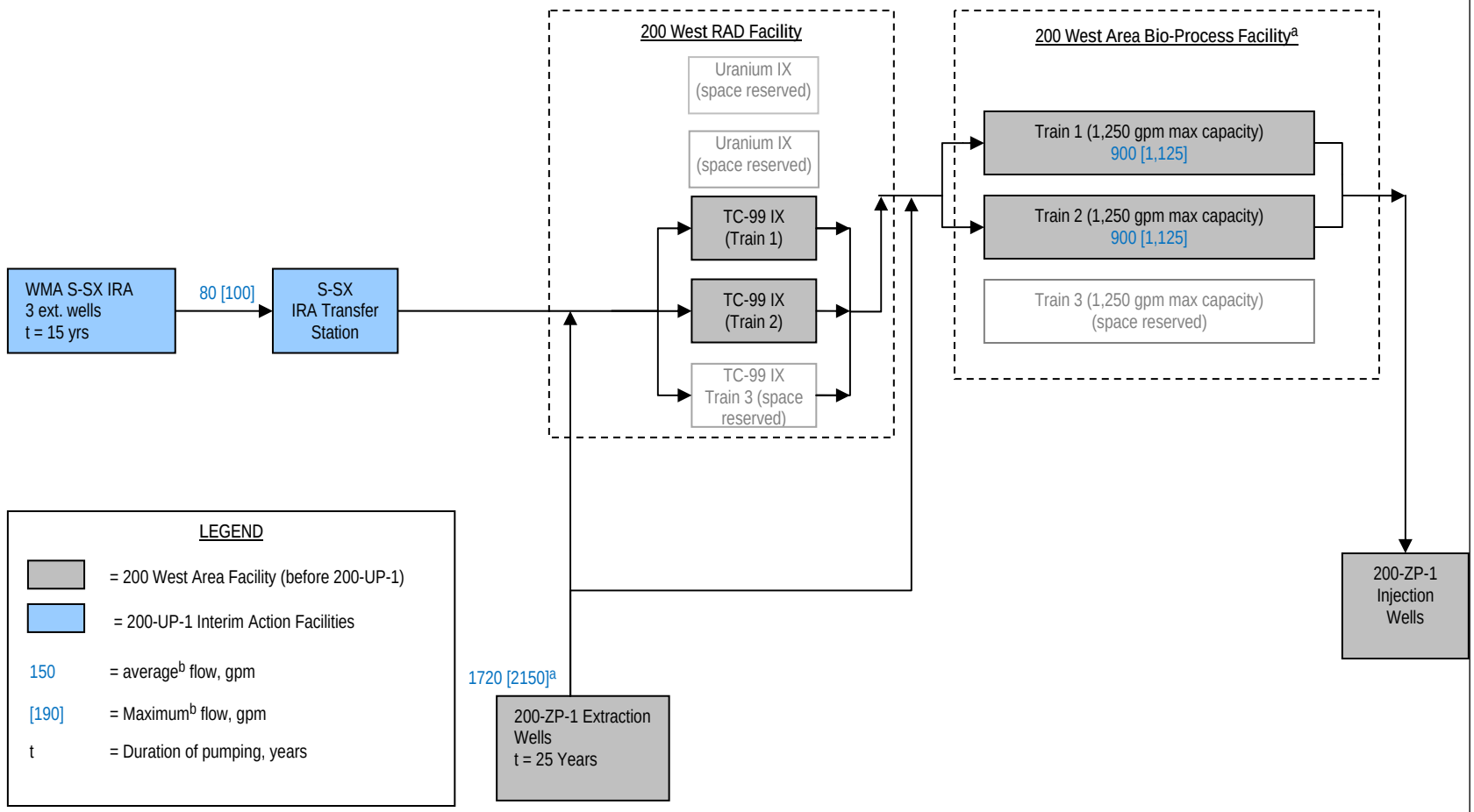


Figure 8-4. 200 West Groundwater Treatment Facility Block Flow Diagram

The FS alternatives are based on the assumption that flow rates up to 120 percent of the 1,320 L/min (350 gpm) flow capacity set aside for the 200-UP-1 OU could be accommodated at the 200 West Groundwater Treatment Facility without significant modification. Flows in excess of 120 percent of this amount will require installation of a third treatment train in the reserve space of the treatment facility. The remedial alternatives included in this FS are based on the assumption that the third treatment train will be constructed using the design presented in DOE/RL-2010-13. Addition of the third train, as designed, will increase the capacity of the treatment facility from a peak flow of 9,500 L/min (2,500 gpm) to 14,200 L/min (3,750 gpm).

The groundwater extraction flow rates under Alternatives 1 and 2 fall within the capacity set aside for the 200-UP-1 OU, and therefore, do not require any modifications to the treatment facility's biological process trains. The increased flow rates specified under Alternatives 3 and 4 exceed the available treatment capacity and, therefore, will require expansion to include an additional biological process treatment train. The treated effluent from the treatment facility will be returned to the aquifer through injection wells located within the 200-ZP-1 OU, with additional injection wells being installed as needed in the 200-UP-1 OU.

8.2.2.5 I-129 Hydraulic Containment

Hydraulic containment of the I-129 plume is a common component for Alternatives 1, 2, 3, and 4. Hydraulic containment of I-129 will be performed using three injection wells placed near the leading edge of the plume in the vicinity of the 1 pCi/L concentration isopleth. Treated water from the groundwater treatment facility will be injected into each of the three wells at an estimated flow rate of 190 L/min (50 gpm) per well. The total injection system flow rate is estimated at 570 L/min (150 gpm). Hydraulic containment of the I-129 plume will prevent further migration, thus stabilizing potential environment threats, until a determination on the feasibility of treatment can be completed. This treatment determination is a part of all alternatives.

8.2.2.6 I-129 Technology Evaluation

As described in Chapter 7, there currently is no available treatment technology that can remove I-129 from 200-UP-1 groundwater to a concentration of <1 pCi/L. Therefore, additional technology evaluation beyond that performed for this FS is needed. This common component, which is included in Alternatives 1, 2, 3, and 4, consists of conducting a technology evaluation and feasibility of treatment review to determine if a treatment option can be defined and implemented.Detailed information on the overall approach and schedule for the I-129 technology evaluation will be presented in the RD/RA Work Plan. Current technology is insufficient to reach the 1pCi/L DWS.

8.2.2.7 Carbon Tetrachloride Remediation

The P&T remedy components defined for the uranium and Tc-99 plumes in are located within the carbon tetrachloride plume footprint and operating the P&T systems in these areas will contribute to the removal of carbon tetrachloride mass. As such, the removal of carbon tetrachloride is a common component to each of the 200-UP-1 remedial alternatives.

A performance monitoring plan has been prepared to guide groundwater monitoring data collection activities associated with implementation of the 200-ZP-1 OU selected remedy (DOE/RL-2009-115). As illustrated in Figure 8-5, the 200-ZP-1OU monitoring network extends into the 200-UP-1 OU to incorporate the full extent of the 200 West carbon tetrachloride plume. The well network is designed to support plume geometry refinement and transport modeling to predict remedial system performance (i.e., 95 percent of the mass of COCs within 25 years and achieve PRGs within 125 years). The plan also

addresses the expectation that the design of the new 200-ZP-1 OU extraction, injection, and monitoring well field will continue to evolve as data are collected. (Section 1.3, page 1-7).

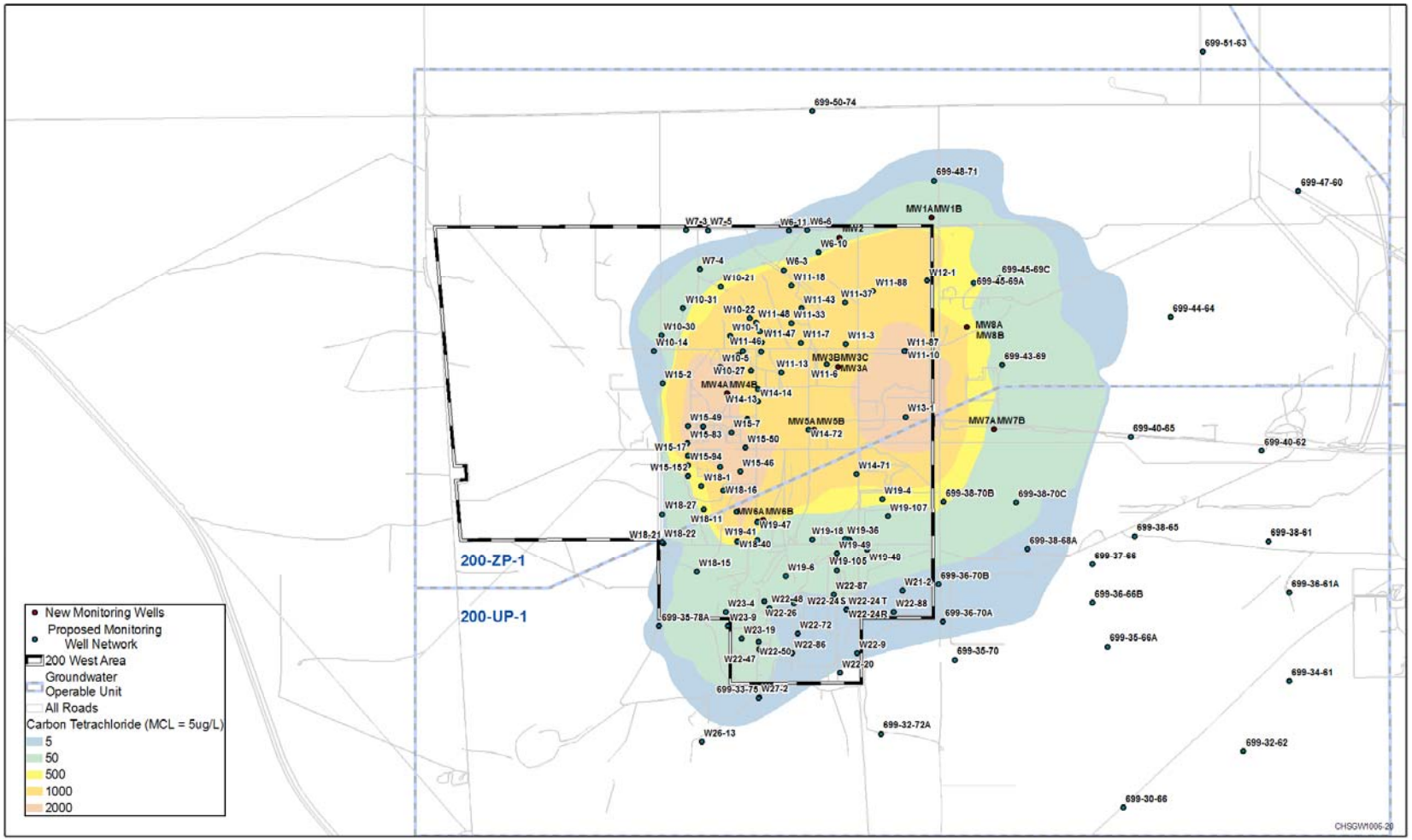
8.2.2.8 Remedy Performance Monitoring

Performance monitoring is conducted to evaluate the overall effectiveness of the selected remedy to attain the PRGs identified for the 200-UP-1 OU. The monitoring program included within the scope of each alternative (except the No Action Alternative) would address each of the components associated with the selected remedy. Detailed information on the performance monitoring program will be developed during the RD and included in an O&M Plan. Remedy performance monitoring applies to natural attenuation actions as well as active engineered remedies (groundwater P&T and hydraulic containment).

Performance monitoring of a P&T groundwater extraction well network would include groundwater sampling, water level measurement and flow measurements to evaluate contaminant mass removal and groundwater flow direction from the aquifer. Hydraulic monitoring would consist of measuring flow rates, total flow, and water levels for each extraction well. The injection well network would also be monitored for hydraulic performance. Water level measurements would be used to evaluate whether extraction and injection wells are operating within their design criteria. Monitoring would consist of analysis of extraction well discharge samples for COCs and a broader list of COPCs (if warranted).

Performance monitoring of the treatment system would include influent and effluent sampling to evaluate COC removal and treatment efficiency, and to compare effluent concentrations with PRGs. The design would include hydraulic monitoring of the treatment system. Hydraulic monitoring would consist of measuring flow rates and total flow at the treatment system influent. This monitoring, along with the contaminant concentrations of the influent and effluent water, would be used to determine the contaminant mass reduction from the treatment system. Monitoring would consist of treatment system influent and effluent sampling for COCs.

The performance monitoring well network would be used to evaluate remedy performance in the aquifer. The monitor well network developed for OU characterization activities includes 95 wells. Approximately 64 of these wells would form the basis for the performance monitoring network. However, characterization wells installed with the objective of defining the nature and extent of contamination may not be sufficient to evaluate the selected remedy. For FS remedial alternative development purposes, it is assumed that new monitor wells may be needed for each plume area in order to perform statistically significant calculations to validate that PRGs have been achieved. In total, 26 new groundwater extraction wells have been assumed for alternative development and cost estimating purposes to supplement the existing well network, and approximately 75 of those wells would be sampled per event.The frequency of remedy performance monitoring is anticipated to vary depending on the phase of remediation. For development of alternatives and cost estimating purposes, the frequency of monitoring is assumed to be semi-annual for the first five years of the remedy. After this initial period of semi-annual monitoring, the frequency of monitoring would be reduced to annual sampling events until PRGs are achieved. After the PRGs have been achieved, an additional five years of groundwater compliance monitoring would be performed with semi-annual sampling events to verify that cleanup goals have been met.



Source: DOE/RL-2009-115, *Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action*, Figure 3-1.

Figure 8-5. 200-ZP-1 OU Contaminant Monitoring Well Network

The performance monitoring well network is expected to include areas near vadose zone sources, contaminated groundwater zones of highest concentration and mobility, areas immediately downgradient of active waste sites, plume fringes or distal areas exhibiting low contaminant concentrations, and plume boundaries or other compliance boundaries. The design would include both hydraulic monitoring and groundwater sampling of the well network. Hydraulic monitoring would consist of measuring water levels at each monitor well to assess groundwater flow directions and evaluate groundwater capture by extraction wells and/or flow path control by injection wells. Groundwater sampling would consist of sampling monitor wells for COCs and COPCs. In addition to these parameters, site-specific parameters may be identified to better understand the ability of natural attenuation processes, given the aquifer conditions in the 200-UP-1 OU.

8.2.2.9 Operations and Maintenance

O&M of each remedial alternative (except the No Action Alternative) is required to ensure that the remedy achieves RAOs. O&M requirements are typically developed and presented in the O&M Plan, which summarizes the activities necessary to operate and maintain the remedy from completion of construction through decontamination and decommissioning of the remedy, after RAOs have been attained.

The scope of O&M activities varies by alternative. For example, O&M activities for the groundwater and MNA remedy components primarily include inspection, maintenance, and periodic replacement of monitor wells, whereas P&T components include routine and preventative maintenance programs as well as replacement of P&T system components at the end of their design life (typically 25 years). Alternatives with longer durations include multiple replacements of system components on a 25-year frequency.

Another component of O&M includes remedial process optimization. Remedial process optimization generally includes activities to improve a remedy's technical and/or cost effectiveness, or to make modifications to ensure RAOs are achieved. Typical remedial process optimization activities for P&T remedies include the following:

- Optimizing extraction and injection well numbers and placement and operation through observation or modeling
- Reducing flow rates at low-concentration wells so that flow rates at higher concentration wells can be increased
- Cycling extraction well flows to optimize or balance hydraulic and contaminant mass loading rate to the treatment system

Specific optimization steps will be determined after startup, once experience with the P&T system has been gained, and aquifer and plume response to pumping established.

8.2.3 Groundwater Modeling of Groundwater Extraction and Injection Pumping Scenarios

Each 200-UP-1 OU alternative relies upon the common remedial technologies of ICs, MNA, groundwater P&T, and hydraulic containment. Groundwater modeling is used to support the development of alternatives through evaluation of the effectiveness of a range of groundwater P&T scenarios, and demonstrating the effectiveness of the proposed hydraulic containment approach. Groundwater modeling provides an estimate of the cleanup time frame for each alternative through active restoration and MNA, and helps determine the time period that ICs will need to be maintained.

A series of seven pumping scenarios were developed and are presented in Appendix D (ECF-200UP1-10-0374) to understand the requirements needed for effective pumping, contaminant recovery, and hydraulic containment. The extent of the existing COC plumes in 200-UP-1 is shown in Figure 8-6. Given the separation in space and types of COCs to consider, the pumping scenarios were constructed from a set of components where each component addresses geographically distinct COC plumes. Each pumping scenario includes the following five areas that address the existing COC plumes (except that Pumping Scenario 1 includes only the first area):

- **WMA S-SX Remediation Area**—P&T to remediate the Tc-99, chromium, and nitrate in the vicinity of the WMA S-SX. The P&T consists of three extraction wells pumping at a rate of 300 L/min (80 GPM). These wells have already been constructed as part of the current interim action and have been incorporated into the remedial alternatives.
- **U Plant Remediation Area**—P&T to address uranium, Tc-99, and the high-concentration nitrate area near U Plant.
- **Northeast Nitrate Remediation Area**—P&T to address nitrate and Tc-99 in the diffuse nitrate plume located in the northeastern portion of the OU.
- **Southeast Chromium Remediation Area**—P&T to address the chromium plume in the southeastern portion of the OU.
- **I-129 Remediation Area—**Hydraulic containment of I-129 and tritium in the central portion of the 200-UP-1 OU.

Pumping Scenario 1 includes only the existing WMA S-SX Remediation Area. Pumping scenarios 2 through 7 assume that the WMA S-SX Remediation Area pumping rate it fixed at 300 L/min (80 gpm). Pumping scenarios 2 through 7 also vary the pumping rate for the U Plant Remediation Area, Northeast Nitrate Remediation Area, and Southeast Chromium Remediation Area. These remediation areas were developed using groundwater flow and contaminant transport modeling in an iterative trial-and-error approach, as described in Appendix D (ECF-200UP1-10-0374), to refine the components for these remediation areas. Pumping Scenarios 2 through 7 increase the pumping rate for the U Plant Remediation Area, Northeast Nitrate Remediation Area, and Southeast Chromium Remediation Area in evenly distributed 190 L/min (50 gpm) increments from a minimum of 380 L/min (100 gpm) to a maximum of 1,320 L/min (350 gpm) for each Remediation Area.

The I-129 Remediation Area represents a hydraulic containment strategy for the I-129 plume. A trial-and-error simulation with evaluation of hydraulic capture led to development of a three-injection-well design (no extraction) injecting a total 570 L/min (150 gpm) to achieve hydraulic containment of the I-129 plume. It is not necessary to further evaluate other pumping rates or well locations as this design is adequate to achieve hydraulic containment, and was treated as a fixed zone with fixed components in Pumping Scenarios 2 through 7.

The performance (i.e., predicted cleanup time frame) of each pumping scenario can be measured in terms of statistics based on the full extent of the modeled plume (maximum projected concentration [C-max] and 90th percentile concentration [C-90]) as well as by the 95th percentile upper confidence limit (95-UCL) computed from data collected at discrete wells in a monitoring well network which is the appropriate statistic for this purpose. Appendix D (ECF-200UP1-10-0374) describes the calculation of these statistics including the use of a hypothetical monitoring well network for the purpose of demonstrating performance evaluation.

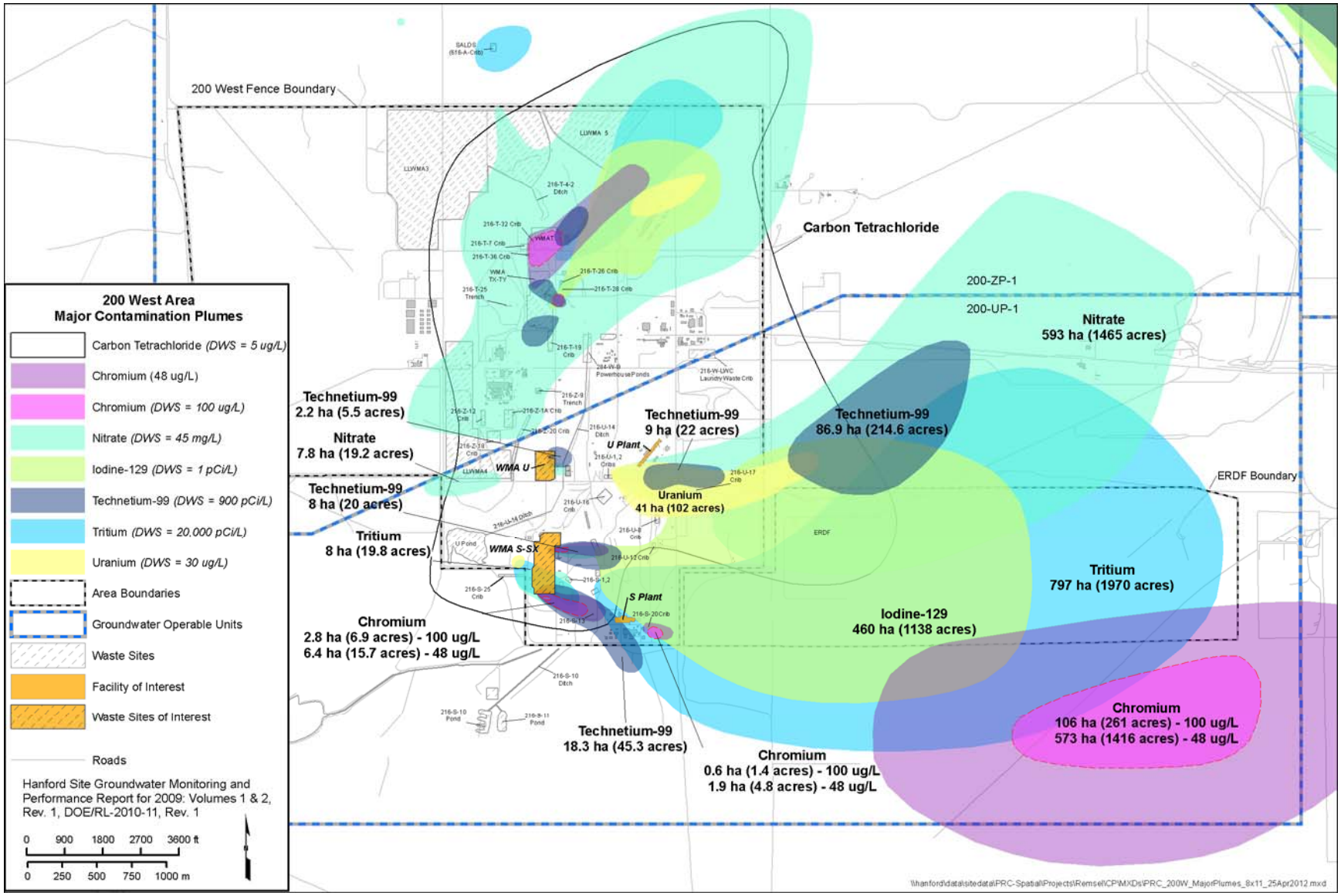


Figure 8-6. Initial Plumes of Contaminants of Concern in 200-UP-1 above Drinking Water Standards

Table 8-5 provides a summary of each of the pumping scenarios including the primary components of the pumping scenario, modeled extraction and injection flow rates, predicted cleanup time frames, ELCR, and HQ. Figure 8-7 provides a summary of the observation wells used for calculation of 95-UCL concentrations.

Each pumping scenario component was developed using an iterative, trial-and-error approach, in which the number, locations, pumping rate, and pumping duration of the extraction wells, both with and without injection wells, were considered with respect to COCs for each component that is part of each pumping scenario. Generally, a component of a pumping scenario consists of a distinctive geographic subarea and set of COCs that can be treated separately from other components of the pumping scenario. The process for the development of the pumping scenarios was:

1. Pumping Scenario 1 sets a lower bound for that is comprised of only one component – the existing interim P&T system at the WMA S-SX (this is the only pumping scenario that will not include all the other components).

2. Pumping Scenario 7 sets an upper bound that includes all components and uses a sufficient number of extraction and injection wells and pumping rates to achieve MCL for all COCs bounded by the water treatment capacity, with additional treatment train(s), available in the treatment facility.

3. Pumping Scenarios 2 through 6 establish a range of well numbers, pumping rates, and durations that provides an approximately even distribution of total groundwater treatment volumes between Pumping Scenarios 1 and 7.

The evaluation of the seven pumping scenarios provides a sensitivity analysis comparing the response of estimated cleanup time frames to a wide range of groundwater extraction rates. This analysis provides information needed to determine an optimal range of pumping rates to carry forward into remedial alternatives.

Figure 8-8 provides a graphical summary of the cleanup time frame response for increasing extraction flow rates for the U Plant Uranium Remediation Area, Southeast Chromium Remediation Area, and Northeast Nitrate Remediation Area. The figure illustrated the following key points:

1. **U Plant Remediation Area.** Increasing groundwater extraction and injection flow rates from 380 L/min (100 gpm) through 570 L/min (150 gpm) provide significant reductions in predicted cleanup time frame, with little further reduction above 570 L/min (150 gpm).

2. **Southeast Chromium Remediation Area.** A cleanup time frame of 120 years is predicted without implementation of groundwater P&T components. Increasing groundwater extraction and injection flow rates from 380 L/min (100 gpm) through 760 L/min (200 gpm) provide significant reductions in predicted cleanup time frame, with little further reduction above 760 L/min (200 gpm).

3. **Northeast Nitrate Remediation Area.** A cleanup time frame of 35 years is predicted without implementation of groundwater P&T components. The minimum extraction flow rates of 380 L/min (100 gpm) reduces the predicted cleanup time frame to approximately 20 years, with only a slight reduction to approximately 15 years at flow rates above 1,140 L/min (300 gpm). The minimum extraction rate of 380 L/min (100 gpm) is sufficient to achieve cleanup time frames commensurate with those of the other plume areas.

Based on the result of the pumping scenario evaluation, remedial alternatives have been developed on the basis of the time to reach PRGs. The following section presents the development of four remedial alternative. These alternatives are based on inclusion of the following pumping scenario components:

WMA S-SX Remediation Area—This component is included for all remedial alternatives (except No Action) with an extraction rate of 300 L/min (80 gpm) to remediate the COCs Tc-99, chromium, and nitrate in the vicinity of the WMA S-SX.

- **U Plant Remediation Area**—Pumping scenarios 2 (380 L/min [100 gpm]) and 3 (570 L/min [150 gpm]) will be included in remedial alternatives to remediate the COCs uranium, nitrate, and tritium in the vicinity of U Plant.
- **Northeast Nitrate Remediation Area**—Pumping scenario 2 (380 L/min [100 gpm]) will be included in remedial alternatives to remediate the COCs nitrate and tritium in the northeastern portion of the 200-UP-1 OU.
- **Southeast Chromium Remediation Area**—Pumping scenarios 3 (570 L/min [150 gpm]) and 4 (760 L/min [200 gpm]) will be included in remedial alternatives to remediate the COCs chromium and tritium in the southeastern portion of the 200-UP-1 OU.
- **Central I-129 Remediation Area**—This component will be included in all remedial alternatives (except No Action) with an injection rate of 570 L/min (150 gpm) to hydraulically contain I-129 tritium in the central portion of the 200-UP-1 OU.

8.2.4 Detailed Descriptions of Remedial Alternatives

The technologies retained in Chapter 7, the common components described in Section 8.2.2, and the pumping scenarios described in Section 8.2.3 provide the basis for development of each remedial alternative. The following subsections provide detailed discussion of the remedial technologies applied to each alternative.

8.2.4.1 No Action Alternative

The NCP (40 CFR 300.430(e)(6)) requires consideration of a No Action Alternative. The No Action Alternative serves as a baseline for evaluating other RA alternatives and is generally retained throughout the FS process. No action means that no further remediation would be implemented to alter the existing groundwater conditions.

8.2.4.2 Alternative 1—40 Years Active Remediation with MNA

Alternative 1 combines groundwater P&T at an estimated extraction rate of 680 L/min (180 gpm) for the Tc-99, uranium, and high-concentration nitrate plumes, with hydraulic containment of the I-129 plume at an estimated injection rate of 570 L/min (150 gpm), to reach PRGs within a 40 year time frame. MNA for the chromium plume, low-concentration nitrate plume areas, and tritium plume achieves PRGs within 120 years, 35 years, and 25 years respectively. A total duration of approximately 125 years (including active restoration and MNA) is required for carbon tetrachloride to reach the PRG. ICs prevent exposure and groundwater use until PRGs are achieved.

Alternative 1 includes the following remedy components implemented over the durations noted:

- ICs (125 years)
- Tc-99 P&T operation in the WMA S-SX area (15 years)—3 extraction wells operating at a total flow rate of 300 L/min (80 gpm)

Table 8-5. Summary of 200-UP-1 Groundwater Pumping Scenarios for Remedial Alternative Development

Remedial Technologies	Area/COCs Addressed	Pumping Scenario 1	Pumping Scenario 2	Pumping Scenario 3	Pumping Scenario 4	Pumping Scenario 5	Pumping Scenario 6	Pumping Scenario 7
Estimated Groundwater Extraction and Injection Wells and Flow Rates								
Groundwater P&T	WMA S-SX Remediation Area -Tc-99 -Chromium -Nitrate	3 extraction wells operating at 300 L/min (80 gpm) total flow rate	3 extraction wells operating at 300 L/min (80 gpm) total flow rate	3 extraction wells operating at 300 L/min (80 gpm) total flow rate	3 extraction wells operating at 300 L/min (80 gpm) total flow rate	3 extraction wells operating at 300 L/min (80 gpm) total flow rate	3 extraction wells operating at 300 L/min (80 gpm) total flow rate	3 extraction wells operating at 300 L/min (80 gpm) total flow rate
	U Plant Remediation Area -Uranium -Tc-99 -Nitrate	No Extraction	1 to 2 extraction and 1 injection wells operating at 380 L/min (100 gpm) total flow rate	2 extraction and 2 injection wells operating at 570 L/min (150 gpm) total flow rate	2 to 3 extraction and 2 to 3 injection wells operating at 760 L/min (200 gpm) total flow rate	3 extraction and 3 injection wells operating at 950 L/min (250 gpm) total flow rate	3 to 4 extraction and 3 to 4 injection wells operating at 1,140 L/min (300 gpm) total flow rate	4 to 5 extraction and 4 to 5 injection wells operating at 1,320 L/min (350 gpm) total flow rate
	Northeast Nitrate Remediation Area -Nitrate -Tc-99	No Extraction	1 to 2 extraction well operating at 380 L/min (100 gpm) total flow rate	1 to 2 extraction well[d] operating at 570 L/min (150 gpm) total flow rate	2 to 3 extraction and 2 to 3 injection wells operating at 760 L/min (200 gpm) total flow rate	3 extraction and 3 injection wells operating at 950 L/min (250 gpm)total flow rate	3 to 4 extraction and 3 to 4 injection wells operating at 1,140 L/min (300 gpm) total flow rate	4 to 5 extraction and 4 to 5 injection wells operating at 1,320 L/min (350 gpm) total flow rate
	Southeast Chromium Remediation Area -Chromium	No Extraction	1 to 2 extraction and 1 injection wells operating at 380 L/min (100 gpm) total flow rate	2 extraction and 2 injection wells operating at 570 L/min (150 gpm) total flow rate	2 to 3 extraction and 2 to 3 injection wells operating at 760 L/min (200 gpm) total flow rate	3 extraction and 3 injection wells operating at 950 L/min (250 gpm) total flow rate	3 to 4 extraction and 3 to 4 injection wells operating at 1,140 L/min (300 gpm) total flow rate	4 to 5 extraction and 4 to 5 injection wells operating at 1,320 L/min (350 gpm) total flow rate
Hydraulic Containment Only	Central I-129 Remediation Area -I-129 (no groundwater extraction) -tritium	No Extraction	3 injection wells operating at 570 L/min (150 gpm) total flow rate while treatability study is performed	3 injection wells operating at 570 L/min (150 gpm) total flow rate while treatability study is performed	3 injection wells operating at 570 L/min (150 gpm) total flow rate while treatability study is performed	3 injection wells operating at 570 L/min (150 gpm) total flow rate while treatability study is performed	3 injection wells operating at 570 L/min (150 gpm) total flow rate while treatability study is performed	3 injection wells operating at 570 L/min (150 gpm) total flow rate while treatability study is performed
Total Extraction Flow Rate		300 L/min (80 gpm)	1,440 L/min (380 gpm)	2,010 L/min (530 gpm)	2,570 L/min (680) gpm	3,140 L/min (830 gpm)	3,710 L/min (980 gpm)	4,280 L/min (1,130 gpm)
Estimated Time (years) to Reach PRGs (95th UCL)								
Time to Reach PRGs[c]	WMA S-SX Remediation Area (Tc-99)	15	15	15	15	15	15	15
	U Plant Remediation Area (uranium)	290	40	25	25	25	25	25
	Northeast Nitrate Remediation Area (nitrate)	35	20	20	20	20	15	15
	Southeast Chromium Remediation Area (chromium)	120	60	45	25	25	20	20
	Tritium Plume Area (tritium)	25	25	25	25	25	25	25
	Central I-129 Remediation Area I-129)	600	600	600	600	600	600	600

Table 8-5. Summary of 200-UP-1 Groundwater Pumping Scenarios for Remedial Alternative Development

Remedial Technologies	Area/COCs Addressed	Pumping Scenario 1	Pumping Scenario 2	Pumping Scenario 3	Pumping Scenario 4	Pumping Scenario 5	Pumping Scenario 6	Pumping Scenario 7
ELCR (HI) After 25 years - Initial ELCR=3.14E-04 - Initial HI=8.32								
ELCR and Hazard Quotient 25 years	WMA S-SX Remediation Area - ELCR	1.17E-05	1.19E-05	1.14E-05	1.37E-05	1.35E-05	1.40E-05	1.43E-05
	U Plant Remediation Area - HQ	5.15	1.05	0.46	0.49	0.43	0.41	0.38
	Northeast Nitrate Remediation Area - HQ	0.49	0.38	0.39	0.26	0.30	0.29	0.28
	Southeast Chromium Remediation Area - HQ	1.40	1.27	1.15	1.12	1.02	0.97	0.80
	200-UP-1 Total Area - ELCR (w/o I-129)	6.18E-05	6.19E-05	6.15E-05	6.37E-05	6.36E-05	6.40E-05	6.44E-05
	200-UP-1 Total Area - ELCR	6.83E-05	6.85E-05	6.80E-05	7.03E-05	7.02E-05	7.06E-05	7.09E-05
ELCR[f] (HI)[g] After 150 years - Initial ELCR=3.14E-04 - Initial HI=8.32								
ELCR and Hazard Quotient 150 years	WMA S-SX Remediation Area - ELCR	5.08E-06	4.39E-06	5.53E-06	4.67E-06	4.37E-06	5.58E-06	5.45E-06
	U Plant Remediation Area - HQ	2.27	0.32	0.20	0.20	0.21	0.15	0.14
	Northeast Nitrate Remediation Area - HQ	0.18	0.13	0.13	0.14	0.13	0.12	0.12
	Southeast Chromium Remediation Area - HQ	0.84	0.40	0.35	0.57	0.44	0.45	0.41
	200-UP-1 Total Area - ELCR (w/o I-129)	9.29E-06	8.60E-06	9.74E-06	8.88E-06	8.58E-06	9.79E-06	9.66E-06
	200-UP-1 Total Area - ELCR	1.74E-05	1.67E-05	1.78E-05	1.70E-05	1.67E-05	1.79E-05	1.77E-05

a. For Pumping Scenarios 2 through 7, pumping is assumed to continue until the exposure point concentration for each plume area is reduced below its respective PRG.
b. Pumping Scenario 1 includes the interim action pumping at the WMA S-SX Tc-99 plume.
c. Time to cleanup is shown for COCs within each remediation area and is based on 95th UCL calculations.
d. For Pumping Scenario 3, 50 GPM are used for the Nitrate hot spot near U Plant. Total pumping for uranium and nitrate is 300 gpm.
e. Threshold value for cumulative ELCR=1.0E-04, HI=1.0—Yellow background used to indicate areas below the threshold value(s).
f. ELCR is the calculated using the EPA tap water exposure scenario.
g. HQ (and HI) are calculated using the WAC 173-340-720, “Model Toxics Control Act—Cleanup,” “Groundwater Cleanup Standards,” noncarcinogen groundwater PRG.

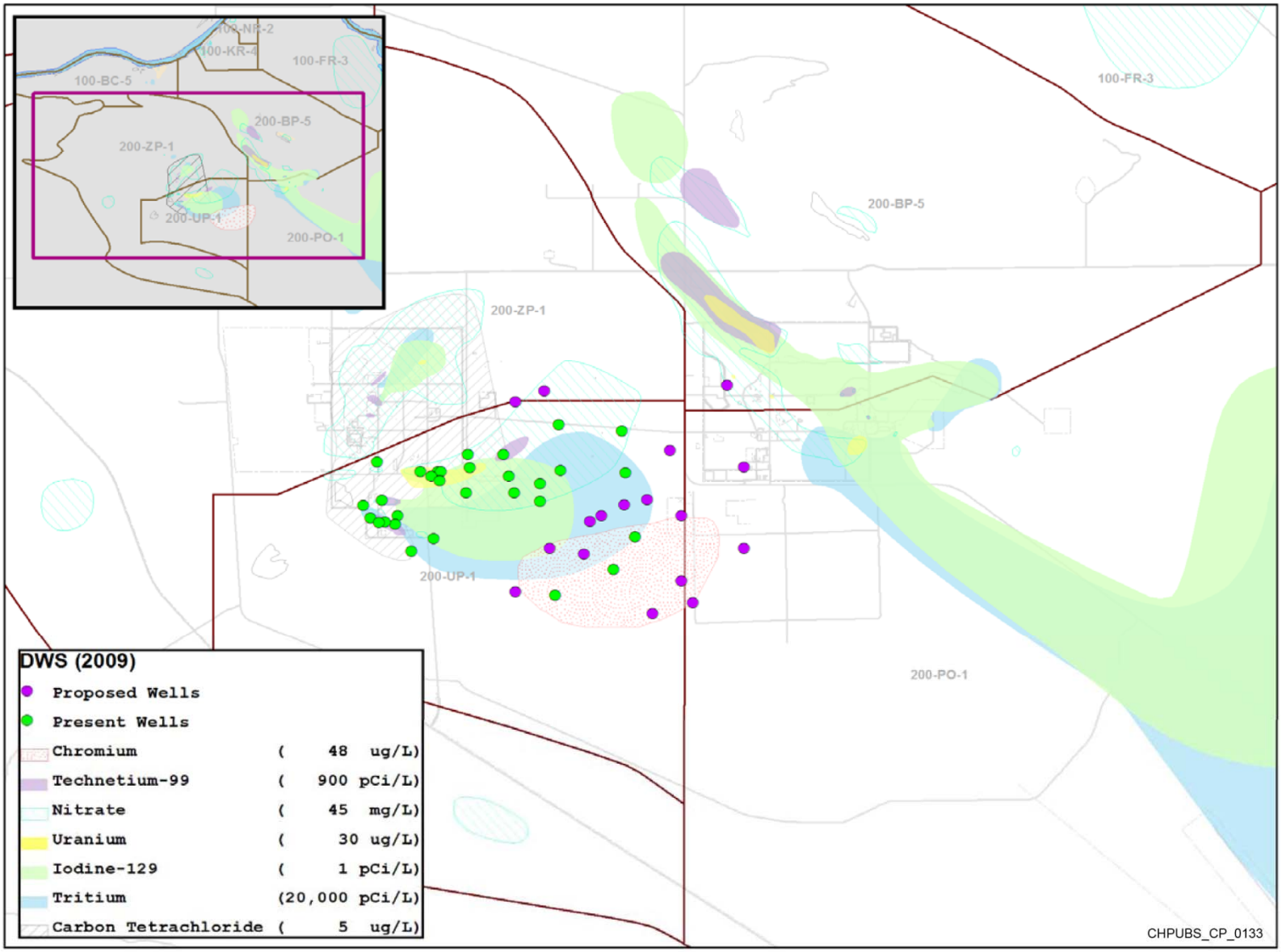


Figure 8-7. Observation Wells Used for 95-UCL Calculation

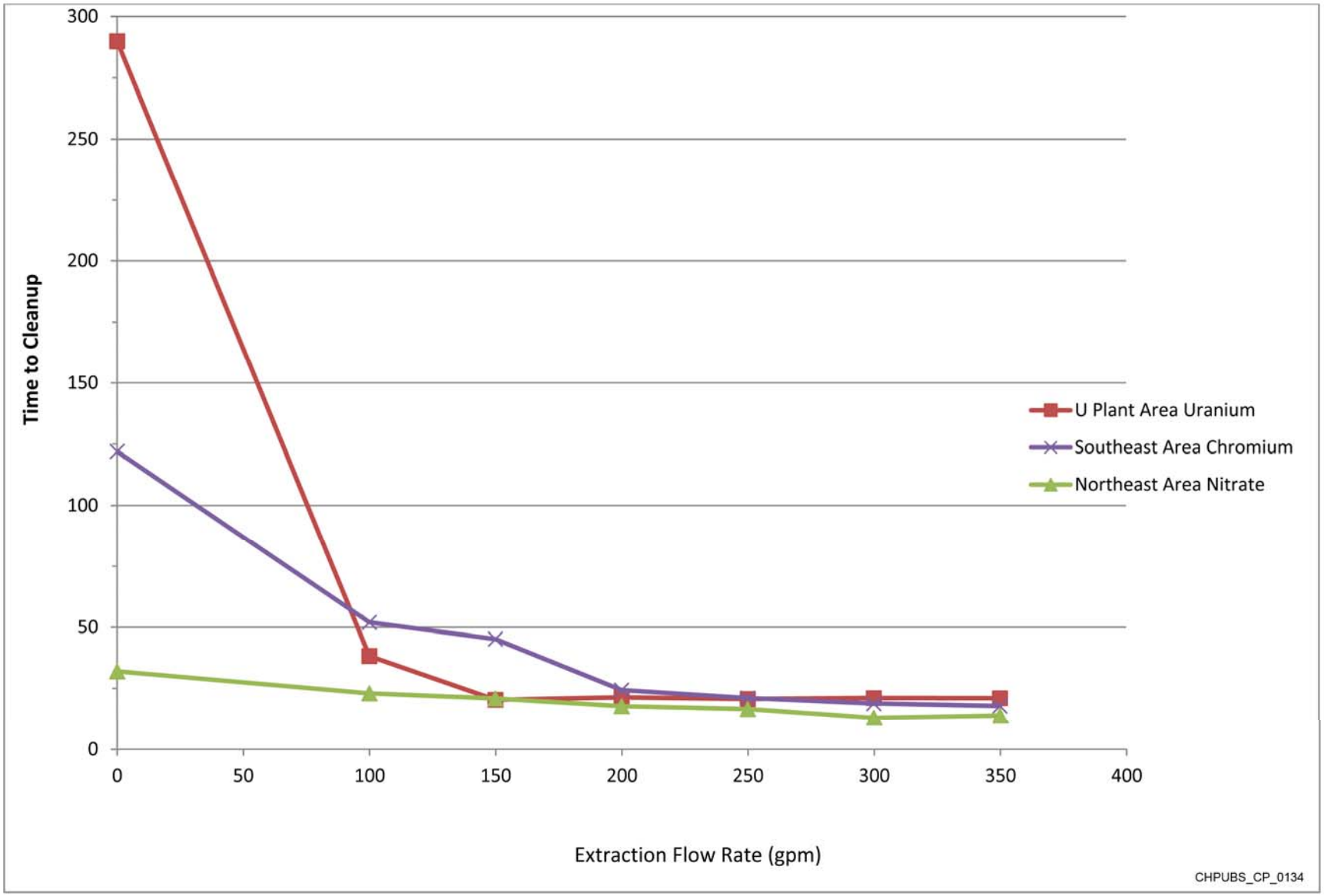


Figure 8-8. Time to Cleanup for Uranium, Chromium, and Nitrate Plumes for Increasing Pumping Rates

- P&T for the uranium plume and high-concentration nitrate plume area (40 years)—2 extraction wells and 2 injection wells operating at a total flow rate of 380 L/min (100 gpm)
- Hydraulic containment for the I-129 plume and technology evaluation for I-129 groundwater treatment methods—3 injection wells operating at a total flow rate of 570 L/min (150 gpm)
- Groundwater treatment for Tc-99 (15 years) and uranium (40 years) P&T components—modifications to the treatment facility include addition of a U IX treatment train and a third Tc-99 IX treatment train)
- Groundwater monitoring for the tritium plume MNA component (25 years)
- Groundwater monitoring for the low-concentration nitrate plume area MNA component (35 years)
- Groundwater monitoring for the chromium plume MNA component (120 years)
- Groundwater monitoring for the remaining portions of the carbon tetrachloride plume for the MNA component (up to 125 years)
- Groundwater compliance monitoring after PRGs are initially reached (5 year period after pumping ceases)

Figure 8-9 shows groundwater extraction and injection well locations for Alternative 2. Figure 8-10 shows a block flow diagram for this alternative. Figure 8-11 depicts the 15 year cleanup time frame for the for Tc-99 plume and 40 year cleanup time frame for the uranium plume, the 120 year cleanup time frame for the chromium plume, the 35 year cleanup time frame for the nitrate plume, and the 25 year MNA time frame for tritium based on 95th UCL concentration trends.

8.2.4.3 Alternative 2—45Years Active Remediation with MNA

Alternative 2 combines groundwater P&T at an estimated extraction rate of 1,250 L/min (330 gpm) for the Tc-99, uranium, high-concentration nitrate plume area, and chromium plume, with hydraulic containment of the I-129 plume at an estimated injection rate of 570 L/min (150 gpm), to reach PRGs within a 45 year time frame. MNA for the low-concentration nitrate plume area, and tritium plume achieve PRGs within 35 years, and 25 years respectively. A total duration of approximately 125 years (including active restoration and MNA) is required for carbon tetrachloride to reach the PRG. ICs prevent exposure and groundwater use until PRGs are achieved.

Alternative 2 includes the following remedy components implemented over the durations noted:

- ICs (125 years)
- Tc-99 P&T operation in the WMA S-SX area (300 L/min [80 gpm], 15 years)—Same as Alternative 1
- P&T for the uranium plume and high-concentration nitrate plume area (380 L/min [100 gpm], 40 years) – Same as Alternative 1.
- P&T for the chromium plume (45 years)—2 extraction wells and 2 injection wells operating at a total flow rate of 570 L/min (150 gpm).
- Hydraulic containment for the I-129 plume and technology evaluation for I-129 groundwater treatment methods (570 L/min [150 gpm])—Same as Alternative 1

- Groundwater treatment for Tc-99 (15 years), uranium (40 years), and chromium (45 years) P&T components. Modifications to the treatment facility include addition of a U IX treatment train and a third Tc-99 IX treatment train
- Groundwater monitoring for the tritium plume MNA component (25 years)—Same as Alternative 1
- Groundwater monitoring for the low-concentration nitrate plume area MNA component (35 years)—Same as Alternative 1
- Groundwater monitoring for the remaining portions of the carbon tetrachloride plume for the MNA component (up to 125 years)—Same as Alternative 1
- Groundwater compliance monitoring after PRGs are initially reached (5 year period after pumping ceases)

Figure 8-12 illustrates the extraction and injection well locations for Alternative 2, and Figure 8-13 presents a block diagram showing the treatment approach. Figure 8-14 depicts the 15 year cleanup time frame for the for Tc-99 plume, the 40 year cleanup time frame for the uranium plume, 35-year cleanup time frame for the nitrate plume, the 45 year cleanup time frame for the chromium plume, and the 25 year MNA time frame for tritium based on 95th UCL concentration trends.

8.2.4.4 Alternative 3—35 Years Active Remediation with MNA

Alternative 3 combines groundwater P&T at an estimated extraction rate of 1,250 L/min (430 gpm) for the Tc-99, uranium, high-concentration nitrate plume area, and chromium plumes, with hydraulic containment of the I-129 plume at an estimated injection rate of 570 L/min (150 gpm), to reach PRGs within a 25 year time frame. MNA for the low-concentration nitrate plume area, and tritium plume achieves PRGs within 35 years, and 25 years respectively. A total duration of approximately 125 years (including active restoration and MNA) is required for carbon tetrachloride to reach the PRG. ICs prevent exposure and groundwater use until PRGs are achieved.

Alternative 3 includes the following remedy components implemented over the durations noted:

- ICs (125 years)
- Tc-99 P&T operation in the WMA S-SX area (300 L/min [80 gpm], 15 years) – Same as Alternative 1
- P&T for the uranium plume and high-concentration nitrate plume area (25 years) –2 extraction wells and 2 injection wells operating at a total flow rate of 570 L/min (150 gpm)
- P&T for the Southeast Chromium Remediation Area chromium plume (25 years) – 2 extraction wells and 2 injection wells operating at a total flow rate of 760 L/min (200 gpm)
- Hydraulic containment for the I-129 plume and technology evaluation for I-129 groundwater treatment methods (570 L/min [150 gpm]) – Same as Alternative 1
- Groundwater treatment for Tc-99 (15 years), uranium (25 years), and chromium (25 years) P&T components (modifications to the treatment facility include addition of a U IX treatment train, a third Tc-99 IX treatment train, and a third biological process treatment train)
- Groundwater monitoring for the tritium plume MNA component (25 years) – Same as Alternative 1

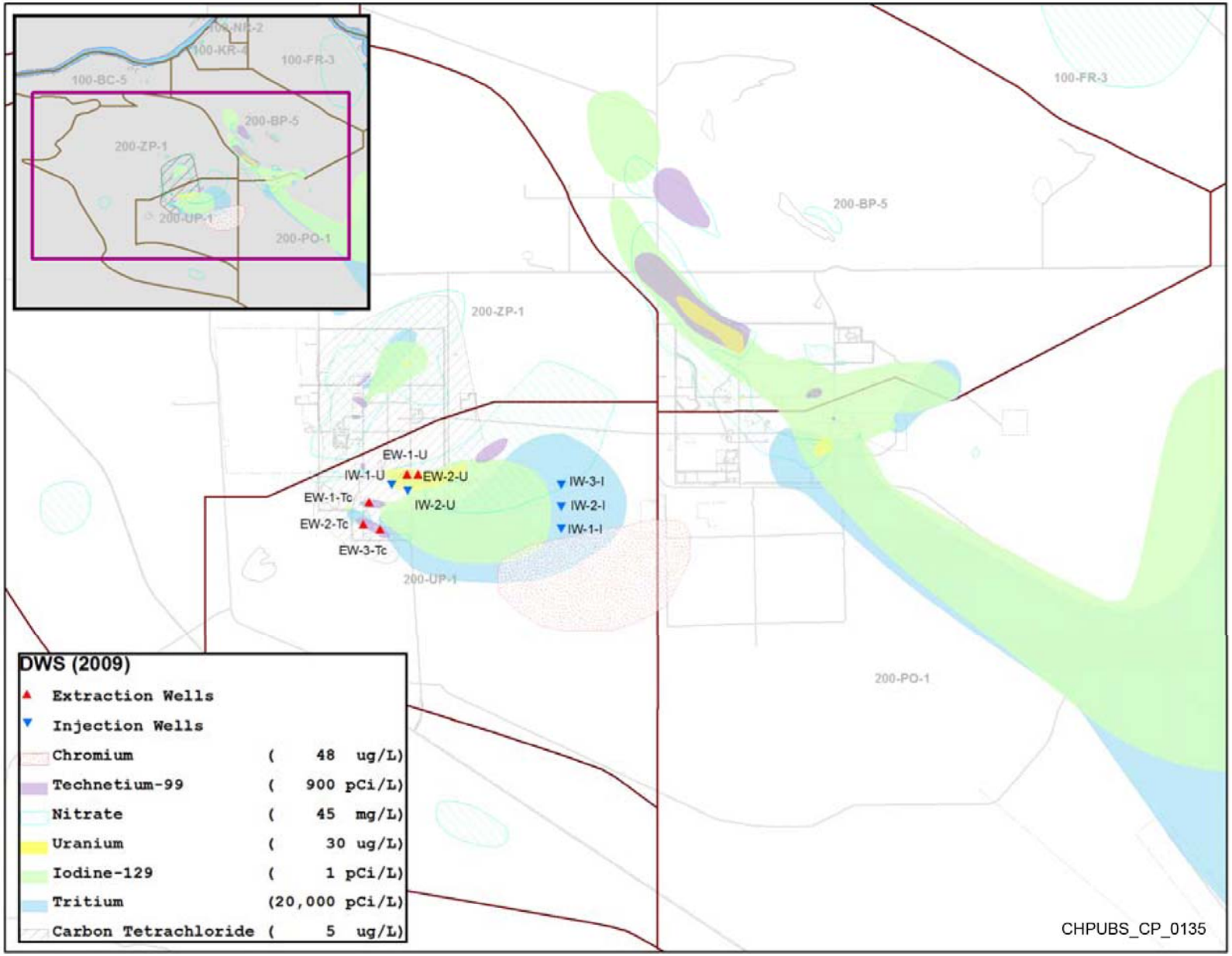


Figure 8-9. Alternative 1—Extraction and Injection Well Locations

a. The 200 West Bio-Process Facility is constructed at 2,500 gpm maximum capacity with 350 gpm reserved for 200-UP-1 OU groundwater in trains 1 and 2. Flow from 200-ZP-1 extraction wells is assumed to be 1,720 gpm average/2,150 gpm maximum or less.
b. Construction of one U IX train at 200 West Rad Facility is required. U IX effluent may be routed to Tc-99 IX trains as needed.
c. Construction of third Tc-99 IX train at 200 West Rad Facility is required.
d. Average flows represent flow rates predicted by groundwater modeling. Maximum flows represent flow rates adjusted to account for 20 percent treatment system downtime. Flow rates shown represent full scale and simultaneous operation of both 200-ZP-1 and 200-UP-1 systems.
e. Transfer pumps for extraction and injection wells may be commonly located within one or more separate pump station buildings. Extraction flows from each plume will remain segregated based on COCs present and treatment required.

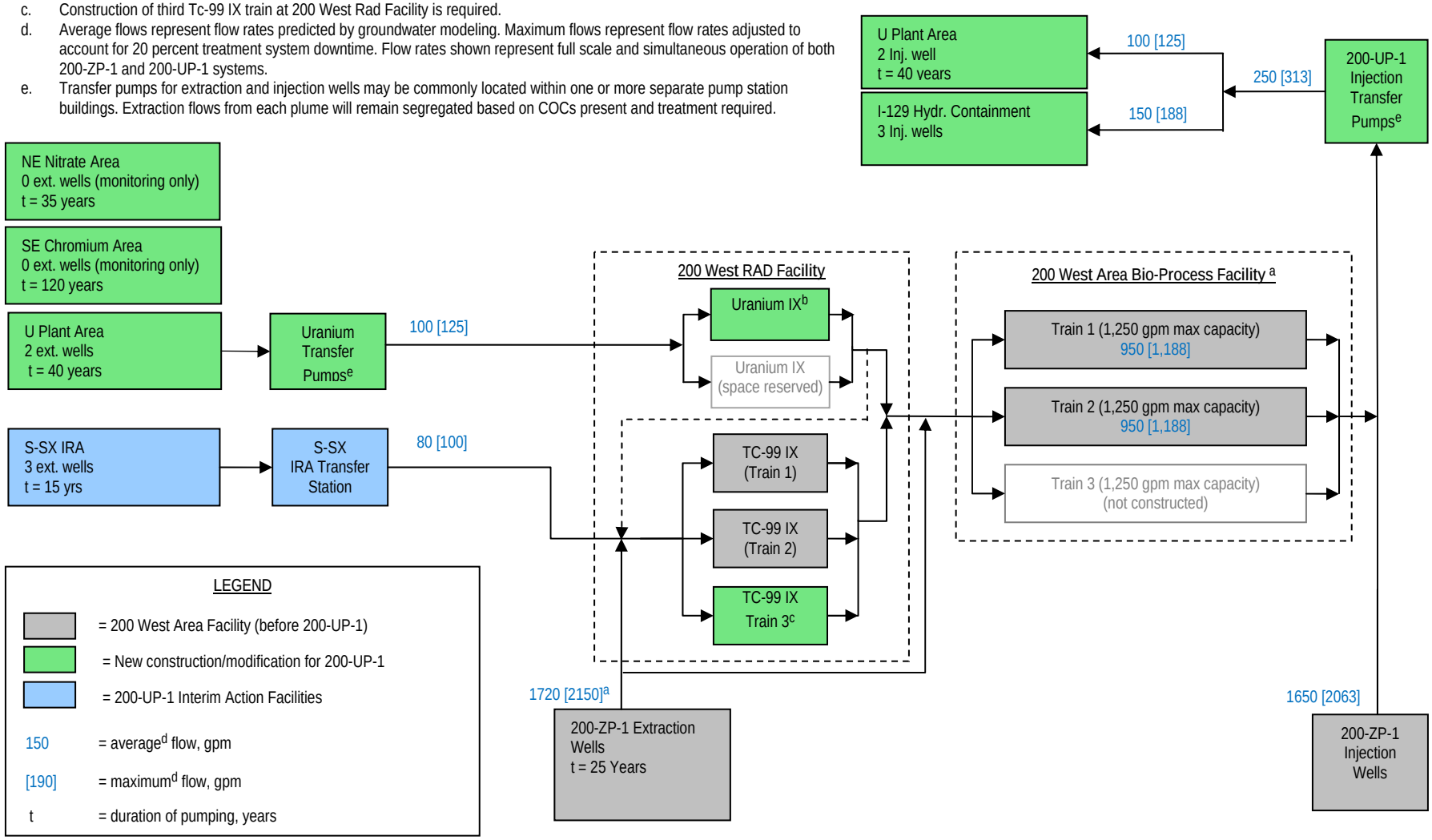


Figure 8-10. Alternative 1—Groundwater Extraction, Treatment, and Injection Block Flow Diagram

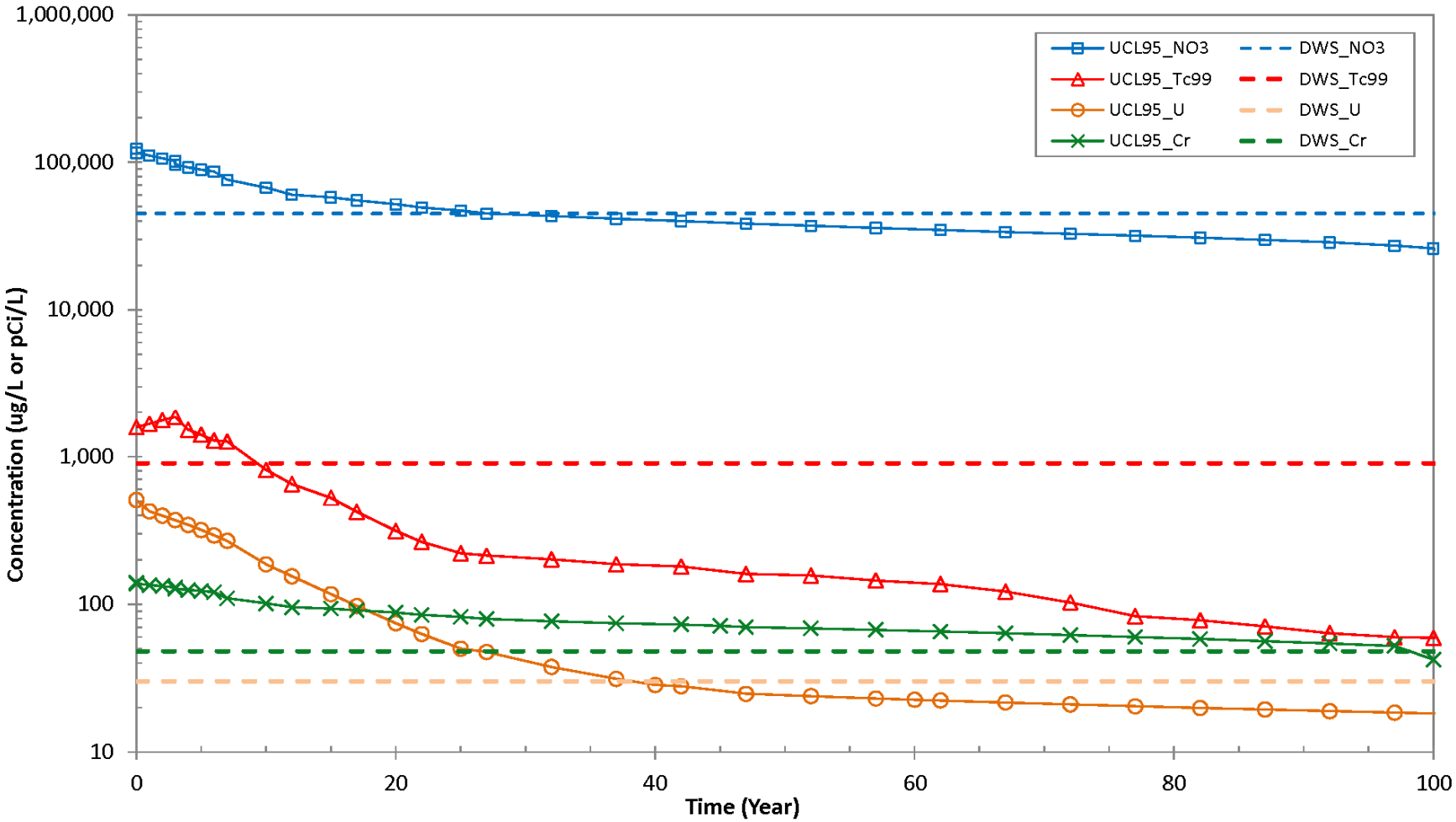


Figure 8-11. Estimated COC Cleanup Time Frames Based on 95th UCL Exposure Point Concentration Trends for Alternative 1

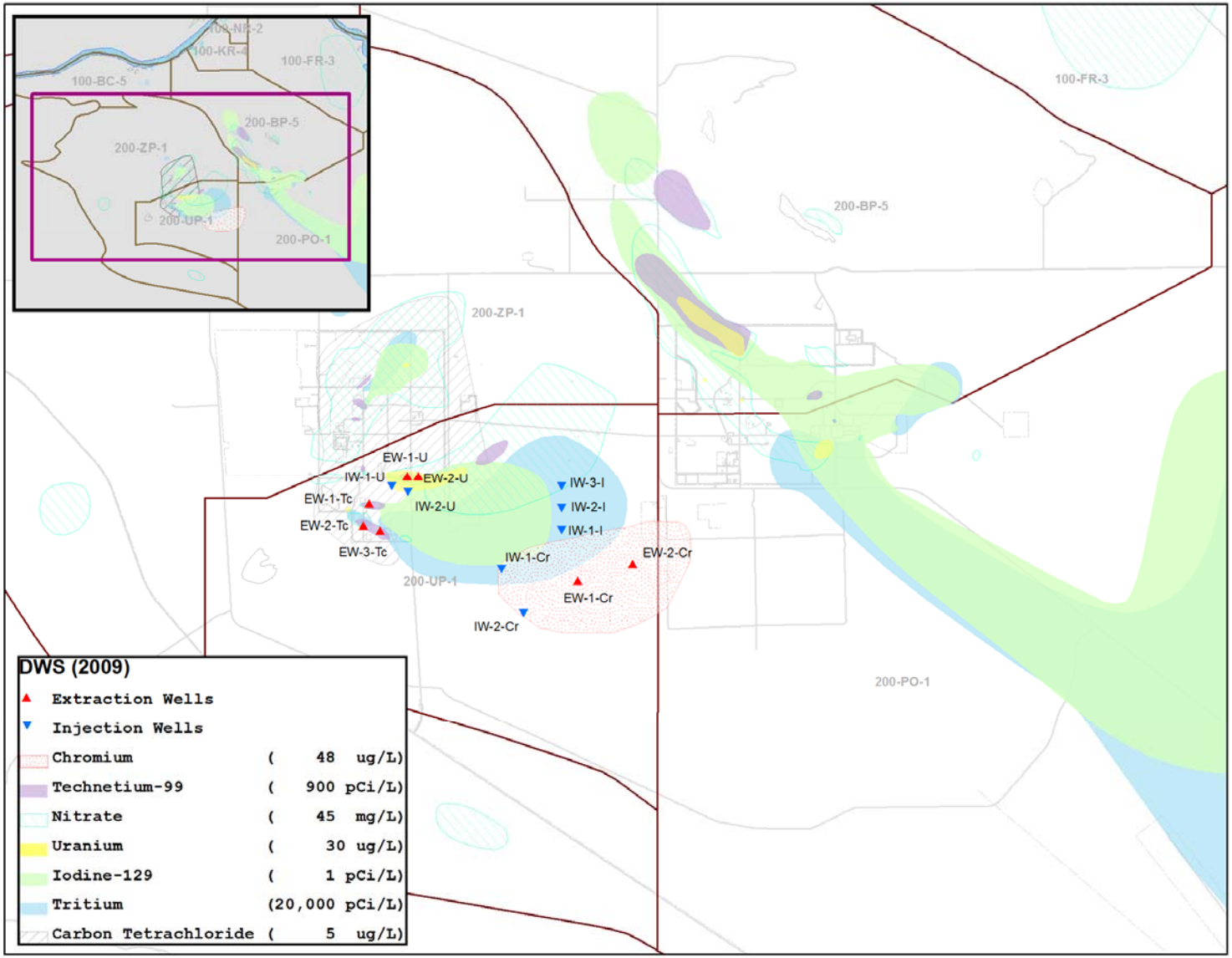


Figure 8-12. Alternative 2—Extraction and Injection Well Locations

a. The 200 West Bio-Process Facility is constructed at 2,500 gpm maximum capacity with 350 gpm reserved for 200-UP-1 OU groundwater in trains 1 and 2. Flow from 200-ZP-1 extraction wells is assumed to be 1,720 gpm average/2,150 gpm maximum or less.
b. Construction of one U IX train at 200 West Rad Facility is required. U IX effluent may be routed to Tc-99 IX trains as needed.
c. Construction of third Tc-99 IX train at 200 West Rad Facility is required.
d. Optimization of 200-UP-1 OU extraction well flows and optimization of 200 West Facility treatment capacity may be required to accommodate projected flows that exceed the 200 West Bio-Process Facility design capacity.
e. Average flows represent flow rates predicted by groundwater modeling. Maximum flows represent flow rates adjusted to account for 20 percent treatment system downtime. Flow rates shown represent full scale and simultaneous operation of both 200-ZP-1 and 200-UP-1 systems.
f. Transfer pumps for extraction and injection wells may be commonly located within one or more separate pump station buildings. Extraction flows from each plume will remain segregated based on COCs present and treatment required.

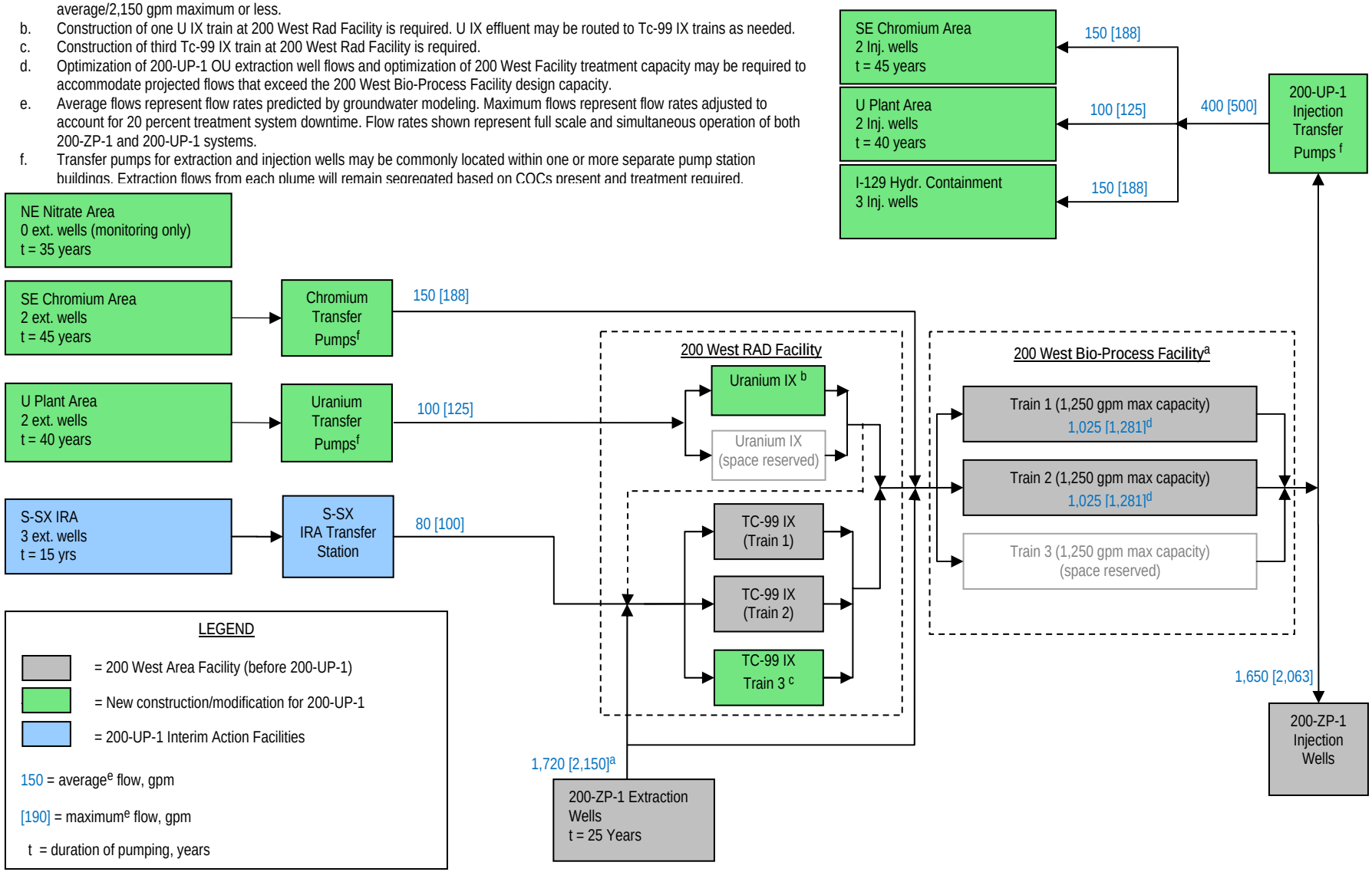


Figure 8-13. Alternative 2—Groundwater Extraction, Treatment, and Injection Block Flow Diagram

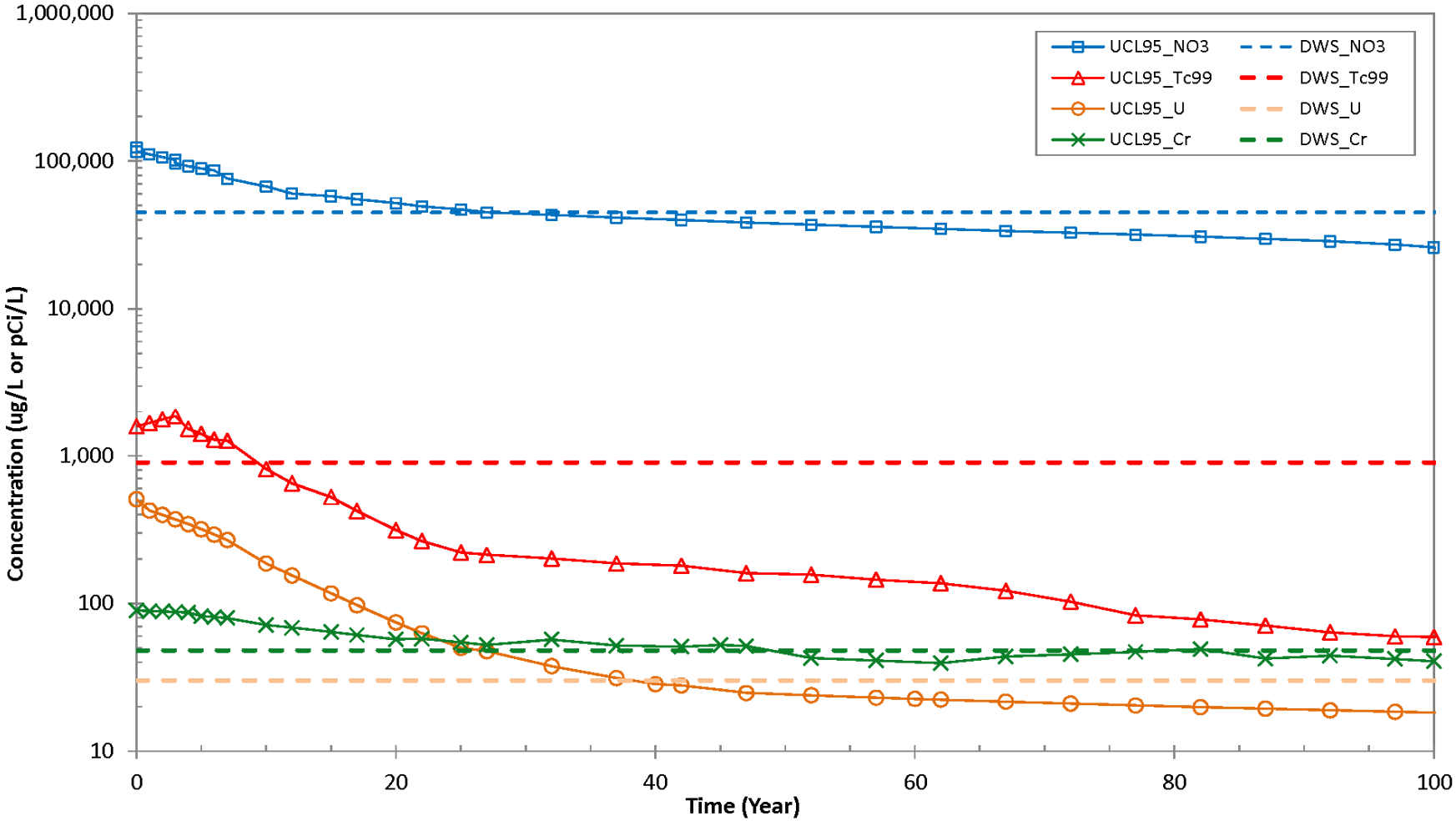


Figure 8-14. Estimated COC Cleanup Time Frames Based on 95th UCL Exposure Point Concentration Trends for Alternative 2

- Groundwater monitoring for the low-concentration nitrate plume area MNA component (35 years) – Same as Alternative 1
- Groundwater monitoring for the remaining portions of the carbon tetrachloride plume for the MNA component (up to 125 years) – Same as Alternative 1
- Groundwater compliance monitoring after PRGs are initially reached (5 year period)

Figure 8-15 illustrates the extraction and injection well locations for Alternative 3 and Figure 8-16 presents a block diagram showing the treatment approach. Figures 8-17 depicts the 15 year cleanup time frame for the for Tc-99 plume, the 35 year cleanup time frame for the nitrate plume, the 25 year cleanup time frames for the for uranium and chromium plumes, and the 25 year MNA time frame for the tritium plume based on 95th UCL concentration trends.

8.2.4.5 Alternative 4—25 Years Active Remediation with MNA

This alternative assumes that the additional flows and COC concentrations from 200-UP-1 OU groundwater can be accommodated at the treatment facility with the addition of the third biological process treatment train. The maximum flow rate of 2,030 L/min (540 gpm) for Alternative 3 exceeds the 1,320 L/min (350 gpm) treatment capacity reserved for 200-UP-1 OU groundwater in the first two treatment trains. Since this is above the 120 percent threshold assumed for FS alternatives, the third biological process treatment train has been included in this alternative for FS evaluation and cost estimation purposes. Flows are assumed to be spread equally among the three biological process trains for this alternative.

Alternative 4 combines P&T at an estimated extraction rate of 2,010 L/min (530 gpm) for the Tc-99, uranium, high-concentration nitrate area, chromium, and nitrate plumes, with hydraulic containment of the I-129 plume at an estimated injection rate of 570 L/min (150 gpm), to reach PRGs within a 25 year time frame. MNA for the tritium plume achieves the PRG 25 years. A total duration of approximately 125 years (including active restoration and MNA) is required for carbon tetrachloride to reach the PRG. ICs prevent exposure and groundwater use until PRGs are achieved.

Alternative 4 includes the following remedy components implemented over the durations noted:

- ICs (125 years)
- Tc-99 P&T operation in the WMA S-SX area (300 L/min [80 gpm], 15 years) – Same as Alternative 1
- P&T for the uranium plume and high-concentration nitrate plume area (570 L/min [150 gpm], 25 years) – Same as Alternative 3
- P&T for the chromium plume (760 L/min [200 gpm], 25 years) – Same as Alternative 3
- P&T for the low-concentration nitrate plume area (20 years) – 1 extraction well operating at 380 L/min (100 gpm)
- Hydraulic containment for the I-129 plume and technology evaluation for I-129 groundwater treatment methods (570 L/min [150 gpm]) – Same as Alternative 1
- Groundwater treatment for Tc-99 (15 years), uranium (25 years), chromium (25 years), and nitrate (20 years) P&T components. Modifications to the treatment facility include addition of a U IX treatment train, a third Tc-99 IX treatment train, and a third biological process treatment train
- Groundwater monitoring for the tritium plume MNA component (25 years) – Same as Alternative 1

- Groundwater monitoring for the remaining portions of the carbon tetrachloride plume for the MNA component (up to 125 years) – Same as Alternative 1
- Groundwater compliance monitoring after PRGs are initially reached (5 year period)

Figure 8-18 illustrates the extraction and injection well locations for Alternative 4, and Figure 8-19 presents a block diagram showing the treatment approach. Figure 8-20 depicts the 15 year cleanup time frame for the for Tc-99 plume, the 25 year cleanup time frames for the uranium and chromium plumes, the 20 year cleanup time frame for the nitrate plume, and the 25 year MNA time frame for tritium based on 95th UCL concentration trends.

This alternative assumes that the additional flows and COC concentrations from 200-UP-1 OU groundwater can be accommodated at the treatment facility with the addition of the third biological process treatment train. The maximum flow rate of 2,510 L/min (660 gpm) for Alternative 4 exceeds the 1,320 L/min (350 gpm) treatment capacity reserved for 200-UP-1 OU groundwater in the first two treatment trains. Since this is above the 120 percent threshold assumed for FS alternatives, the third treatment train has been included in this alternative for FS evaluation and cost estimation purposes. Flows are assumed to be spread equally among the three biological process trains for this alternative.

8.3 Remedial Alternatives Screening Evaluation

Each of the remedial alternatives developed in Section 8.2 were screened based on the EPA criteria of effectiveness, implementability, and cost before being carried forward for detailed and comparative evaluation (Chapter 9).

Effectiveness considers the ability of each remedial alternative to achieve RAOs and cleanup levels, implementability focuses on both the technical and administrative feasibility of implementing the alternative, and costs were evaluated in terms of net present value (NPV) and nondiscounted costs.

8.3.1 Effectiveness Screening Results

The groundwater modeling predicts the effectiveness of each alternative in achieving PRGs and the time frame necessary to do so. Based on these results, each of the alternatives has been designed to achieve RAOs. Alternatives 1 through 4 incorporate P&T for Tc-99 (WMA S-SX IRA) into the remedy and include hydraulic containment of the I-129 plumewhile a technology evaluation is performed to develop a viable I-129 groundwater treatment method. Since these remedy components are held constant, they do not impact the screening evaluation.

Alternatives 1 and 2 provide a uranium P&T component with an estimated cleanup time frame of 40 years. Alternatives 3 and 4 increase the uranium P&T flow rate to reduce the cleanup time frame to 25 years. Alternative 2 includes groundwater monitoring for the chromium plume, which reaches the PRG in an estimated 120 year time frame through MNA. Limited characterization data available for the chromium plume increase the uncertainty of model predicted cleanup time frames; therefore, the likelihood of achieving PRGs within the predicted time frame is lessened. Alternative 2 includes a groundwater P&T component for chromium estimated at 45 years, and Alternatives 3 and 4 utilize a more aggressive P&T component that reduces the cleanup time frame down to 25 years.

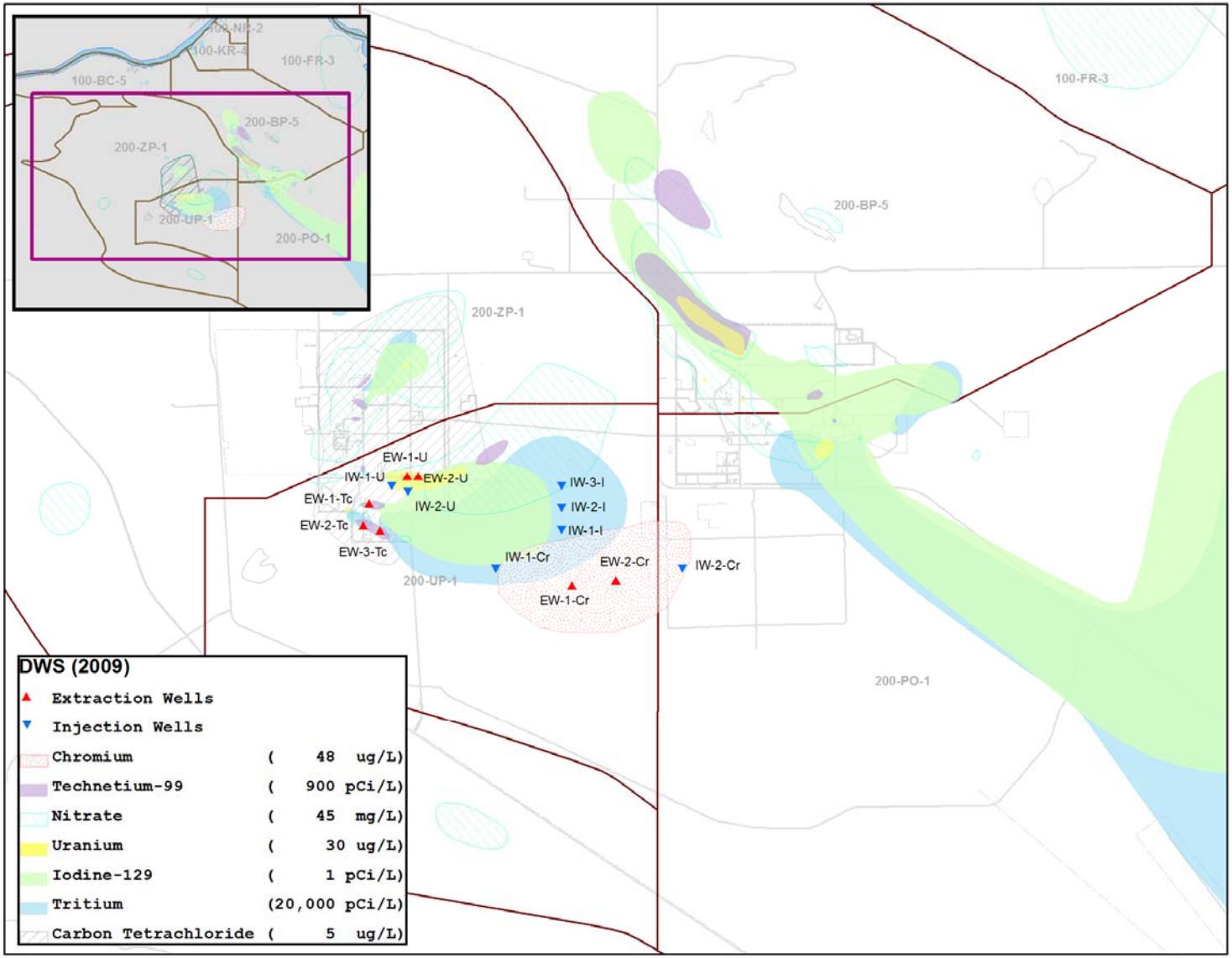


Figure 8-15. Alternative 3—Extraction and Injection Well Locations

a. The 200 West Bio-Process Facility is constructed at 2,500 gpm maximum capacity with 350 gpm reserved for 200-UP-1 OU groundwater in trains 1 and 2. Flow from 200-ZP-1 extraction wells is assumed to be 1,720 gpm average/2,150 gpm maximum or less.
b. Construction of one U IX train at 200 West Rad Facility is required. U IX effluent may be routed to Tc-99 IX trains as needed.
c. Construction of third Tc-99 IX train at 200 West Rad Facility is required.
d. Construction of third Bio-process treatment train is required. Flow is assumed to be split evenly between the 3 trains.
e. Average flows represent flow rate predicted by groundwater modeling. Maximum flows represent flow rates adjusted to account for 20 percent treatment system downtime. Flow rates shown represent full scale and simultaneous operation of both 200-ZP-1 and 200-UP-1 systems.
f. Transfer pumps for extraction and injection wells may be commonly located within one or more separate pump station buildings. Extraction flows from each plume will remain segregated based on COCs present and treatment required.

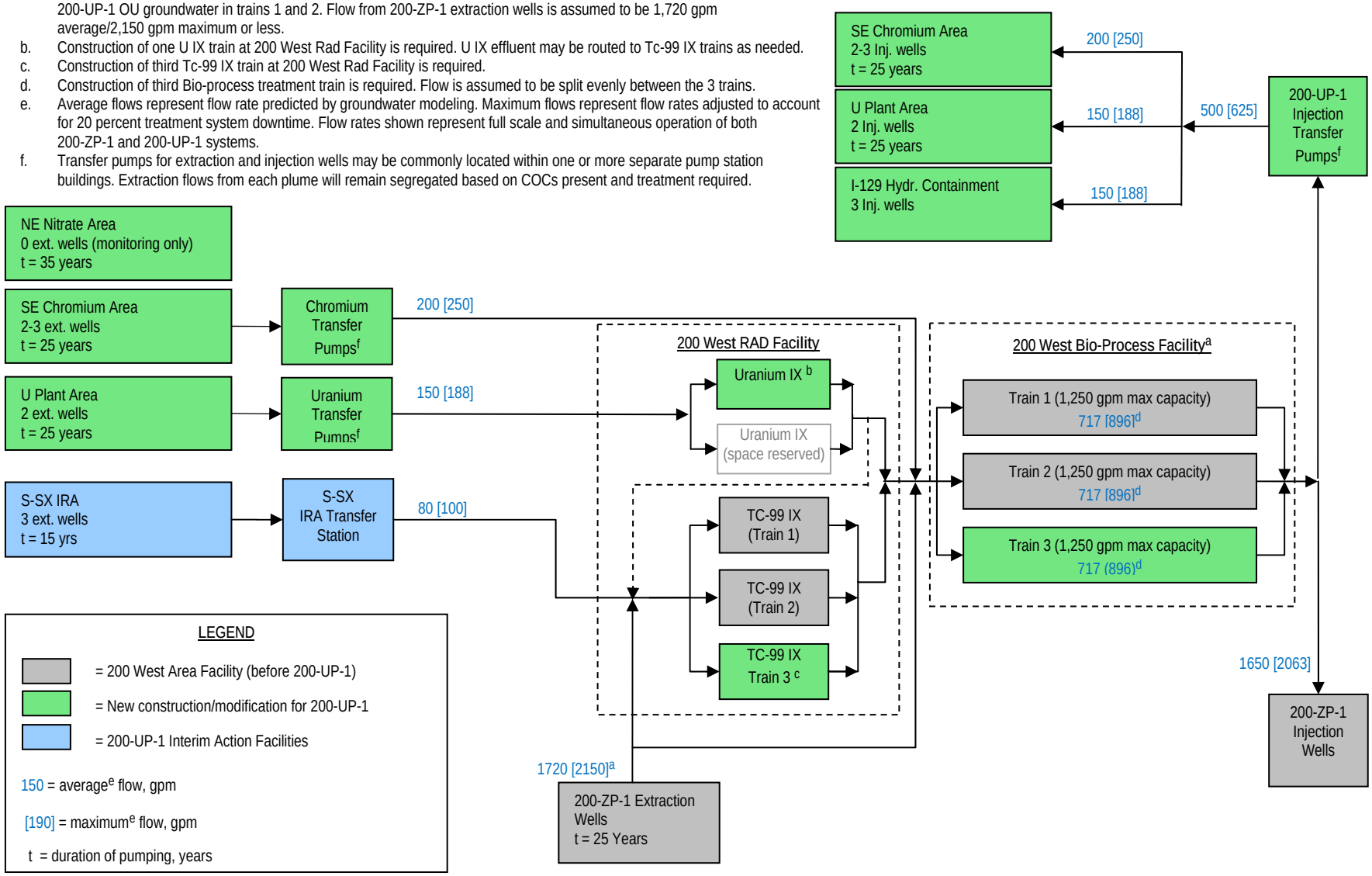


Figure 8-16. Alternative 3—Groundwater Extraction, Treatment and Injection Block Flow Diagram

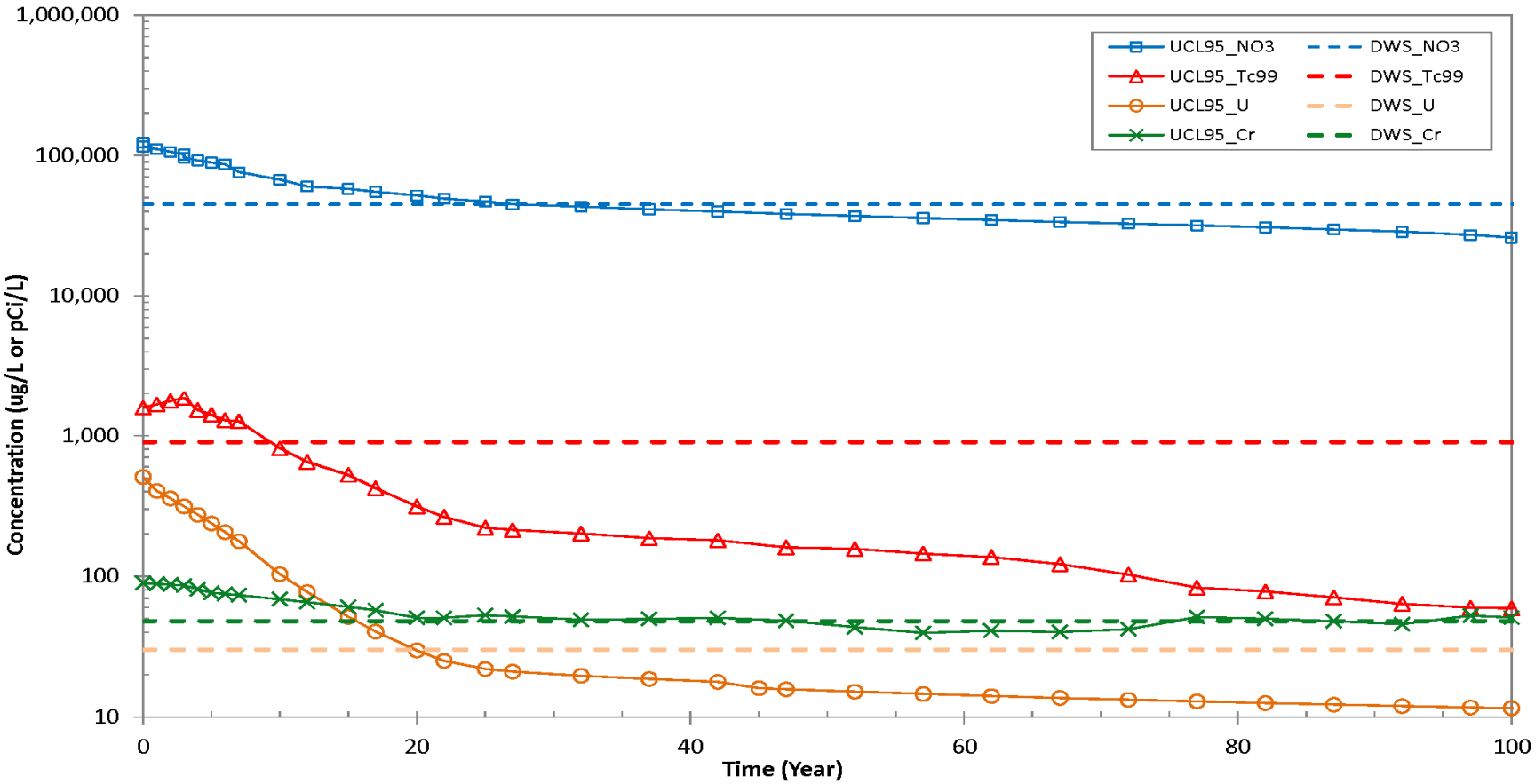


Figure 8-17. Estimated COC Cleanup Time Frames Based on 95th UCL Exposure Point Concentration Trends for Alternative 3

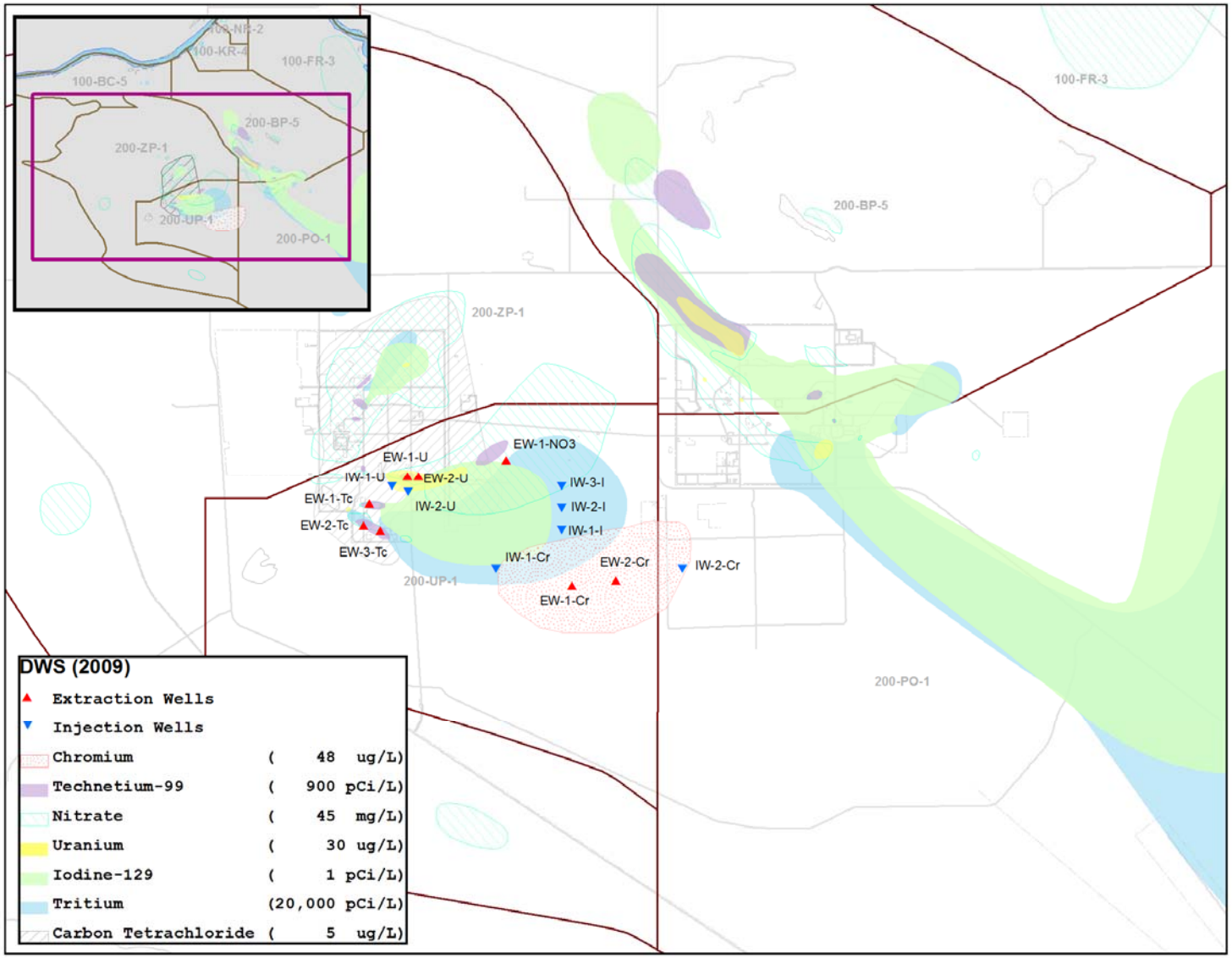


Figure 8-18. Alternative 4—Extraction and Injection Well Locations

a. The 200 West Bio-Process Facility is constructed at 2,500 gpm maximum capacity with 350 gpm reserved for 200-UP-1 OU groundwater in trains 1 and 2. Flow from 200-ZP-1 extraction wells assumed to be 1,720 gpm average/2,150 gpm maximum or less.
b. Construction of one U IX train at 200 West Rad Facility is required. U IX effluent may be routed to Tc-99 IX trains as needed.
c. Construction of third Tc-99 IX train at 200 West Rad Facility is required.
d. Construction of third Bio-process treatment train is required. Flow is assumed to be split evenly between the 3 trains.
e. Average flows represent flow rate predicted by groundwater modeling. Maximum flows represent flow rates adjusted to account for 20 percent treatment system downtime. Flow rates shown represent full scale and simultaneous operation of both 200-ZP-1 and 200-UP-1 systems.
f. Transfer pumps for extraction and injection wells may be commonly located within one or more separate pump station buildings. Extraction flows from each plume will remain segregated based on COCs present and treatment required.

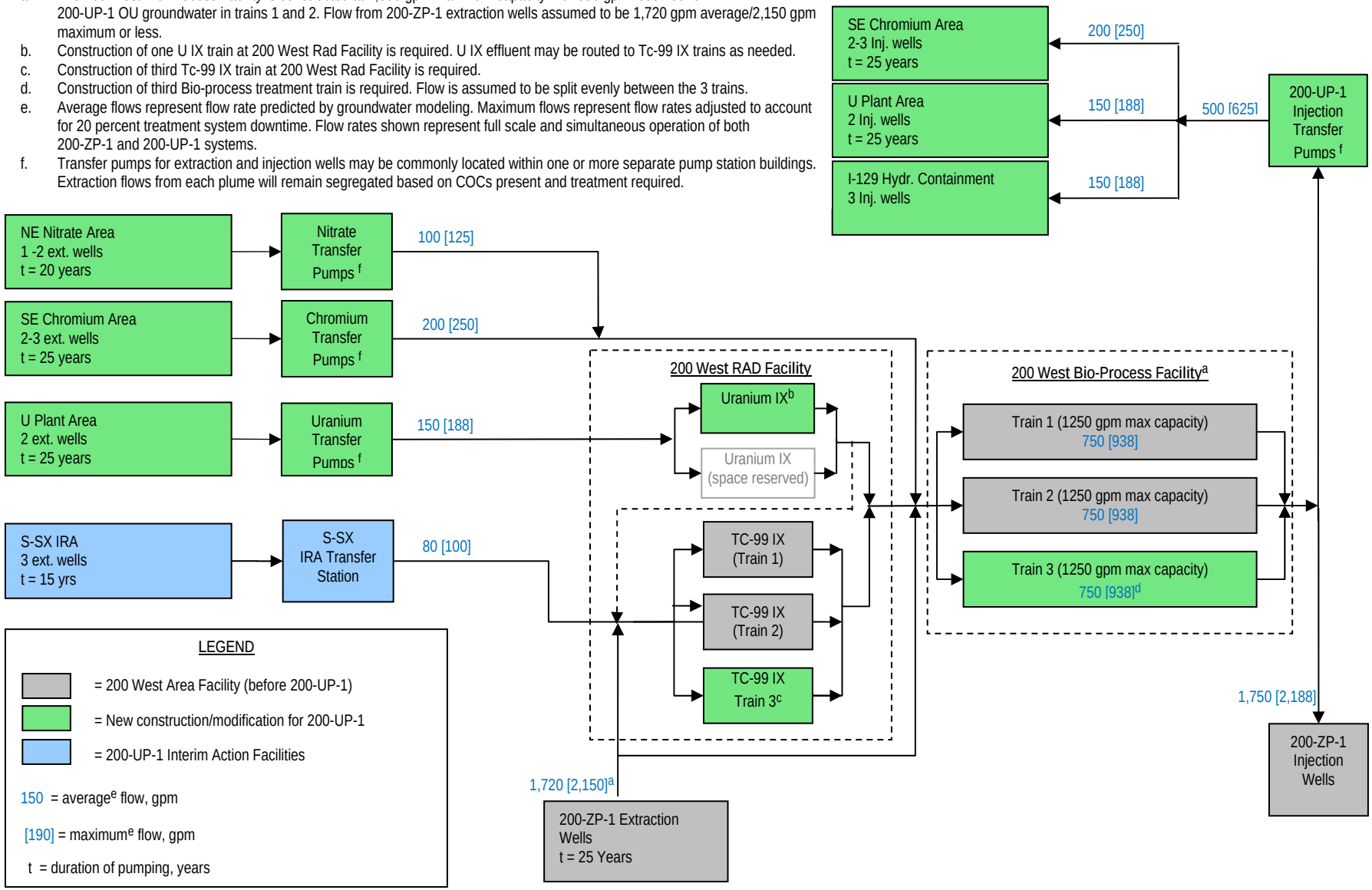


Figure 8-19. Alternative 4—Groundwater Extraction, Treatment and Injection Block Flow Diagram

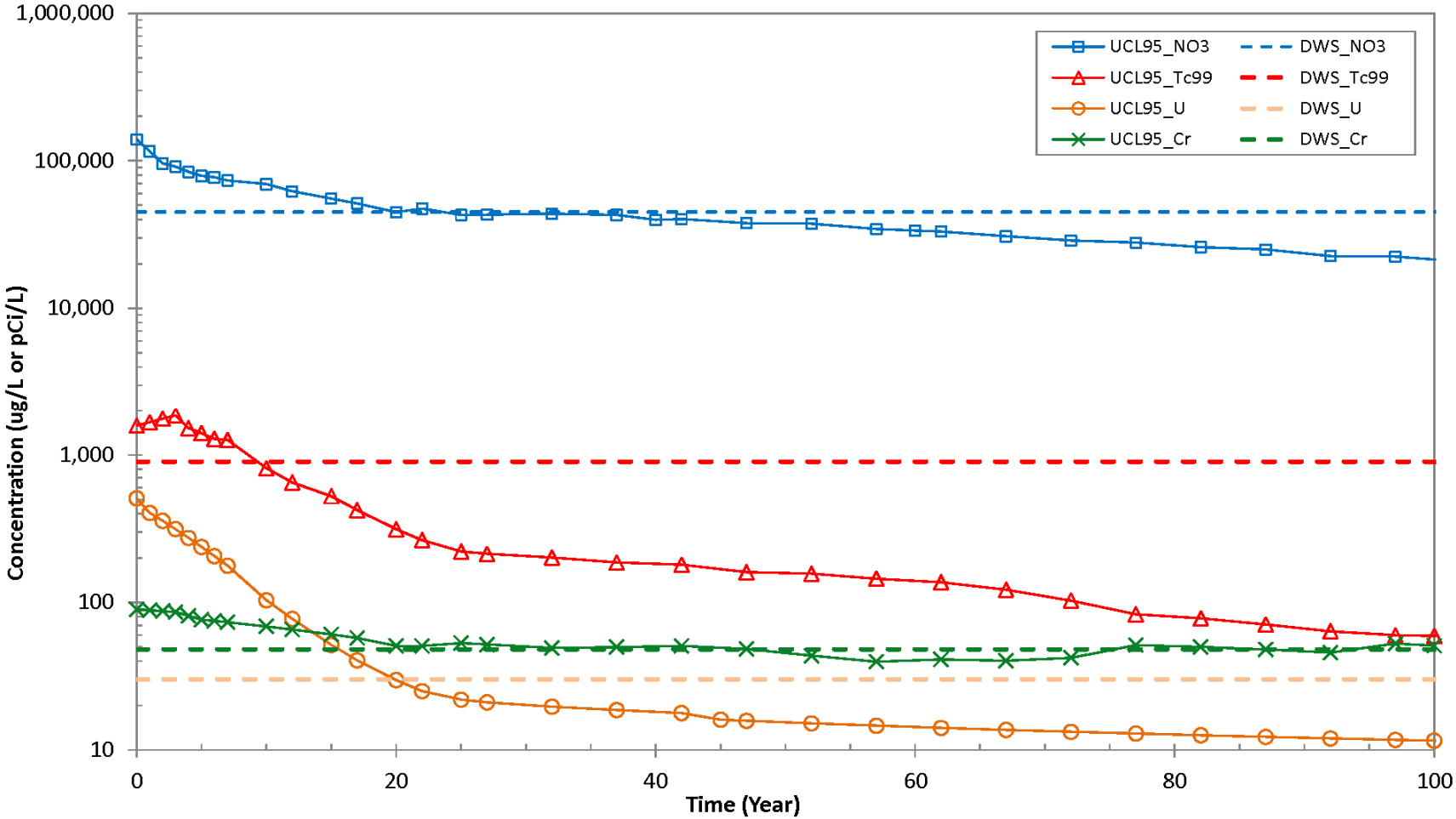


Figure 8-20. Estimated COC Cleanup Time Frames Based on 95th UCL Exposure Point Concentration Trends for Alternative 4

Alternatives 1 through 4 include a groundwater P&T component that co-extracts the high-concentration nitrate plume area within the uranium plume near U Plant. Alternatives 1 through 3 include only groundwater monitoring for the low-concentration nitrate plume area, which is estimated to reach PRGs within an estimated 35 years. Alternative 4 adds P&T for the low-concentration nitrate plume, which reduces the cleanup time frame to an estimated 20 years.

The overall effectiveness of Alternatives 1 through 4 are demonstrated by the following predicted time frames (with the exception of carbon tetrachloride) required to achieve PRGs:

- Alternative 1—120 years to achieve PRGs
- Alternative 2—45 years to achieve PRGs
- Alternative 3—35 years to achieve PRGs
- Alternative 4—25 years to achieve PRGs

The estimated time to reach the carbon tetrachloride PRG is approximately 125 years which includes the active restoration time frame and subsequent MNA period. This time period is consistent with the 200-ZP-1 ROD. Based on the anticipated effectiveness and duration for each alternative to achieve RAOs, Alternatives 2 through 4 will be retained for detailed and comparative analysis. Alternative 1 requires a significantly longer duration to achieve PRGs, compared to the remaining alternatives, with the least certainty that PRGs will be met within 150 years and, thus, will not be carried forward.

8.3.2 Implementability Screening

The remedial action alternatives were developed around robust and proven technologies such as groundwater P&T and hydraulic containment. Alternatives employing these technologies do not pose any significant technical or administrative challenges based on the hydrogeologic conditions and COCs present in the 200-UP-1 OU. The primary issue related to the implementability of these alternatives is the treatment of I-129. Currently, effective treatment technologies capable of treating I-129 to the 1 pCi/L DWS are not available. Each of the remedial alternatives provides a scenario where the I-129 plume is hydraulically contained until the results of the technology evaluation can be used to determine the feasibility of treatment.

No significant technical issues have been identified for implementation of Alternatives 2, 3, or 4 that warrant screening them out before detailed and comparative analysis. However, the long RA duration associated with Alternative 1 may make this alternative less implementable from an administrative standpoint (regulatory agency and public acceptance). Alternative 1 was also screened out on the basis of effectiveness. Therefore, Alternatives 2, 3, and 4 are carried forward on the basis of implementability.

8.3.3 Cost Screening

The estimated NPV and nondiscounted cost for the five alternatives are as follows:

- No Action—this alternative has a NPV and nondiscounted cost of $0.
- Alternative 1—NPV cost estimated at $243,497,000 and nondiscounted cost at $397,803,000.
- Alternative 2—NPV cost estimated at $304,043,000 and nondiscounted cost at $428,837,000.
- Alternative 3—NPV cost estimated at $319,083,000 and nondiscounted cost at $398,200,000.
- Alternative 4—NPV cost estimated at $342,180,000 and nondiscounted cost at $423,881,000.

The NPV cost range for the alternatives spans a broad range between $243,497,000 (Alternative 1) and $342,881,000 (Alternative 4). None of the alternatives are screened out on the basis of cost.

Chapter 9 provides detailed discussion and comparison of the capital, annual, and periodic costs for each alternative.

8.3.4 Remedial Alternative Screening Summary

Based on the preliminary screening of remedial alternatives performed on the basis of effectiveness, implementability, and cost, Alternative 1 was eliminated because of the uncertainty in achieving the cleanup level for chromium within a reasonable time frame due to the length of time predicted to reach the PRG (120 years) and the limited amount of characterization data available to define the chromium plume. Alternatives 2, 3, and 4 will be carried forward for detailed and comparative evaluation in Chapter 9 of this FS.

9 Detailed and Comparative Analysis of Alternatives

The purpose of the detailed and comparative analysis is to compare the alternatives and identify the key trade-offs among them. In this chapter, the remedial alternatives are analyzed against seven of the nine CERCLA evaluation criteria (40 CFR 300.430(e)(9)). The two remaining criteria; state acceptance and community acceptance are identified as modifying criteria and will be addressed following the public comment period on the Proposed Plan.

The public comment period will be held following issuance of the Proposed Plan, which identifies DOE and EPA's preferred alternative. Input received from the Tribal Nations and public during the public comment period may result in changes to the preferred alternative, or a new alternative may be defined and selected. Selection of the final alternative will occur in the ROD. DOE and EPA will respond to comments received in the responsiveness summary provided in the ROD. The nine CERCLA criteria are summarized in Section 9.1, and each of the remedial alternatives is analyzed individually and comparatively in Sections 9.2 and 9.3, respectively.

9.1 Description of CERCLA Evaluation Criteria

This section describes the nine CERCLA evaluation criteria upon which the detailed and comparative evaluation is based. The nine criteria are designed to enable the analysis of each alternative to be performed to address the statutory, technical, and policy considerations necessary to allow for selecting a final remedial alternative.

The CERCLA evaluation criteria include:

- *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
- *Modifying criteria:*
  - State acceptance
  - Community acceptance

9.1.1 Overall Protection of Human Health and the Environment

Remedial alternatives are analyzed to determine whether they can adequately protect human health and the environment, in both the short and long term. A remedial alternative is found to be "protective" by eliminating, reducing, or controlling exposures to the contaminants. Overall protection of human health and the environment draws on the assessments of the other evaluation criteria, as well, especially long-term effectiveness and permanence, and short-term effectiveness. For an alternative to pass the initial screening performed in Chapter 8, it would have to have meet this threshold criteria.

9.1.2 Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)

This criterion addresses whether an alternative will meet the identified federal and state requirements (ARARs) that are applicable, or relevant and appropriate, as described in Chapter 7 per CERCLA Section 121. The detailed analysis summarizes the ARARs and describes how the alternative meets those requirements.

If an alternative is not expected to achieve compliance with a given ARAR, a waiver may be granted per CERCLA (40 CFR 300.430(f)(1)(ii)(C)) under the following circumstances.

1. The alternative is an interim measure and will become part of a total remedial action that will attain ARARs at the remedy completion.
2. Compliance with the requirement will result in greater risk to human health and the environment than other alternatives.
3. Compliance with the requirement is technically impracticable from an engineering perspective.
4. The alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method or approach.
5. With respect to a state requirement, the state has not consistently applied, or demonstrated the intention to consistently apply the promulgated requirement in similar circumstances at other sites within the state.

9.1.3 Long-Term Effectiveness and Permanence

Long-term effectiveness and permanence assesses the anticipated ability of the alternatives to maintain reliable protection of human health and the environment at the protective level once the remedial goals are achieved. Alternatives are assessed for the long-term effectiveness and permanence they afford, along with the degree of certainty that the alternative will prove successful.

Factors that may be considered in this assessment include the following:

- The magnitude of residual risk from untreated waste or treatment residuals remaining at the conclusion of the remedial activities, including their volume, toxicity, and mobility.
- The adequacy, reliability, and durability of controls such as containment systems and ICs necessary to manage treatment residuals and untreated waste. For example, this factor addresses uncertainties in providing long-term protection of human health and the environment associated with land disposal of treatment residuals; the potential need to replace the technical components of an alternative such as a treatment system; and the potential exposure pathways and risks that would arise should the remedial action need replacement.

9.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

This criteria assesses the degree to which an alternative uses treatment or recycling to reduce toxicity, mobility, or volume including how treatment is used to address the principal threats. This evaluation relates to the statutory preference for selecting a remedial action that employs treatment to reduce the toxicity, mobility, or volume of hazardous substances. Factors that will be considered, as appropriate, include the following:

- Treatment or recycling processes that the alternative employs and the materials that they will treat.
- The amount of hazardous substance, pollutants, or contaminants that will be destroyed or recycled.

- The degree of expected reduction in toxicity, mobility, or volume of the waste because of the treatment or recycling and the specification of which reductions are occurring.
- The degree to which the treatment is irreversible.
- The type and quantity of residuals that will remain following treatment, taking into consideration their persistence, toxicity, mobility, and propensity to bioaccumulate.
- The degree to which treatment reduces the inherent hazards posed by the principal threats.

9.1.5 Short-term Effectiveness

This criteria assesses short-term effects that occur during implementation of the alternative including the following:

- Short-term risks that might be posed to the community.
- Potential risks or hazards to workers, and the effectiveness and reliability of protective measures.
- Potential environmental effects and the effectiveness and reliability of mitigative measures.
- Time until protection is achieved.

9.1.6 Implementability

This criteria assesses the ease or difficulty of implementing an alternative considering the following types of factors, as appropriate:

- Technical feasibility, including technical difficulties and unknowns associated with constructing and operating the technology, reliability of the technology, ease of undertaking additional remedial actions, and ability to monitor the effectiveness of the remedy.
- Administrative feasibility, including activities required to coordinate with other offices and agencies and the ability and time needed to obtain any necessary approvals and permits for offsite actions from other agencies.
- Availability of required materials and services.

9.1.7 Cost

The cost estimates are an order-of-magnitude level per CERCLA guidance. The cost estimates are based on a variety of information, including quotes from current Hanford site vendors and service providers, generic unit costs, conventional cost-estimating guides, and prior Hanford site experience for similar work tasks. The cost estimates were prepared based on the information available at the time the estimate was prepared, and are designed to assist with the evaluation of remedial alternatives. The basis for the costs are discussed in the support documentation contained in Appendix D (ECE-200UP1-10-00005, *Environmental Cost Estimate for the Remedial Action Alternatives Associated with 200-UP-1 Groundwater Remedial Investigation/Feasibility Study* and ECF-200UP1-10-0375, *Feasibility Study Cost Estimate Input Basis for the 200-UP-1 Groundwater Operable Unit*).

EPA cost estimate guidance (EPA 540-R-00-002, *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*) requires the development of two cost estimates for each alternative. A total non-discounted cost estimate, and a total discounted cost estimate also known as the present value estimate. The present value estimate is used by EPA to support decisions in the Superfund remedy-selection process; whereas the total non-discounted estimate is used for comparison purposes and demonstrates the impact of a discount rate on the total present-value cost and the relative amounts of future annual expenditures over the remedial action's duration. All costs estimate are based on year 2012

dollars. A discount rate of 2 percent was used to convert future annual O&M and periodic costs to present worth values, as specified in the EPA guidance.

Capital costs include those expenditures required to construct a remedial action. Both direct and indirect costs are considered in the development of cost estimates. Total O&M costs over the alternative's duration (which include operational labor, maintenance materials, labor, energy, and purchased services) have also been estimated.

9.2 Analysis of Individual Alternatives

This section evaluates each of the alternatives retained from the screening performed in Chapter 8 against the CERCLA threshold and balancing criteria as follows:

The CERCLA threshold and balancing criteria include:

- *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 alternatives assembled in Chapter 8 provide a range of options that address protection of human health and the environment over a range of time frames per the NCP (40 CFR 300.430(e)(4)). The preferred alternative will be further refined as necessary during the remedial design phase. The description of the alternatives and the analysis of each alternative with respect to the CERCLA criteria identified above reflect the fundamental components of the various alternative approaches being considered.

Each alternative is analyzed in the context that there is no continuing source from the vadose zone. Remedies implemented for the vadose zone OUs will be designed to protect groundwater resources.

As stated above, the modifying criteria of state acceptance and community acceptance will be formally assessed under the Proposed Plan and following receipt of public comments on the Proposed Plan. A summary of the individual analysis of alternatives with respect to the CERCLA threshold and balancing criteria is presented in Table 9-1.

Table 9-1. Detailed Analysis of Alternatives Summary for the 200-UP-1 OU

Criteria	No Action Alternative	Alternative 2 - 45 Years Active Remediation and MNA	Alternative 3 - 35 Years Active Remediation and MNA	Alternative 4 - 25 Years Active Remediation and MNA
Overall Protection of Human Health and the Environment				
Human Health Protection				
Direct contact	There is no risk because there are no current groundwater users.	Active treatment of Tc-99, uranium, chromium (total and hexavalent), carbon tetrachloride, and concentrated portion of nitrate plume through P&T reduces risk; ICs prevent exposure until active treatment and MNA achieves PRGs.	More aggressive active treatment for Tc-99, uranium, chromium (total and hexavalent), carbon tetrachloride, and concentrated portion of nitrate plume through P&T accelerates risk reduction; ICs prevent exposure until active remediation and MNA achieve PRGs.	Most aggressive form of active treatment for Tc-99, uranium, chromium (total and hexavalent), carbon tetrachloride, and nitrate plumes through P&T reduces risk within the shortest practicable time frame; ICs prevent exposure until active remediation and MNA achieve PRGs.
Groundwater ingestion for existing users				
Groundwater ingestion for future users	This alternatives does not protect future users because it contains no measures to eliminate, reduce, or control exposures or restore groundwater for future beneficial use.			
Environmental Protection	I-129 and chromium plumes migrate beyond the 200-UP-1 Groundwater OU boundary while the remaining COC plumes attenuate within the 200-UP-1 Groundwater OU.	Active treatment minimizes COC migration while reducing COC concentrations; hydraulic containment prevents further expansion of I-129 plume.	More aggressive form of active treatment accelerates COC concentration reductions, and minimizes COC migration; hydraulic containment prevents further expansion of I-129 plume.	Most aggressive form of active treatment accelerates COC concentration reductions within the shortest practicable time frame, minimizes COC migration; hydraulic containment prevents further expansion of I-129 plume.
Compliance with ARARs				
Chemical-specific	Does not comply with PRGs.	Complies with PRGs.	Complies with PRGs.	Complies with PRGs.
Location-specific	No location-specific ARARs were identified.	No location-specific ARARs were identified.	No location-specific ARARs were identified.	No location-specific ARARs were identified.
Action-specific	Would not invoke any action-specific ARARs because there will be no action.	Off gas from groundwater treatment operations would meet air discharge standards. COC concentrations in treated water would meet UIC requirements.	Off gas from groundwater treatment operations would meet air discharge standards. COC concentrations in treated water would meet UIC requirements.	Off gas from groundwater treatment operations would meet air discharge standards. COC concentrations in treated water would meet UIC requirements.
Other criteria and guidance	Does not comply with PRGs.	Complies with PRGs.	Complies with PRGs.	
Long-term Effectiveness and Permanence				
Magnitude of Residual Risk				
Direct contact	No reduction in risk	Active treatment of Tc-99, uranium, chromium (total and hexavalent), carbon tetrachloride, and concentrated portion of nitrate plume through P&T reduces risk; ICs prevent exposure until active treatment and MNA achieves PRGs.	More aggressive form of active treatment for Tc-99, uranium, chromium (total and hexavalent), carbon tetrachloride, and concentrated portion of nitrate plume through P&T accelerates risk reduction; ICs prevent exposure until active remediation and MNA achieve PRGs.	Most aggressive form of active treatment for Tc-99, uranium, chromium (carbon tetrachloride), and nitrate plumes through P&T reduces risk within the shortest practicable time frame; ICs prevent exposure until active remediation and MNA achieve PRGs.
Groundwater ingestion for existing users	No reduction in risk			
Groundwater ingestion for future users	No reduction in risk			
Adequacy and Reliability of Controls	Not reliable without any controls	Active treatment using P&T technology with disposal of treatment residuals at ERDF is a reliable means for removing and managing contaminant mass long-term. ICs are reliable tool for preventing exposure until PRGs achieved.	Active treatment using P&T technology is a reliable means for removing contaminant mass. ICs are reliable tool for preventing exposure until PRGs achieved.	Active treatment using P&T technology is a reliable means for removing contaminant mass. ICs are reliable tool for preventing exposure until PRGs achieved.
Need for 5-Year Review	Required until remedial goals are achieved.	Required until remedial goals are achieved.	Required until remedial goals are achieved.	Required until remedial goals are achieved.

Table 9-1. Detailed Analysis of Alternatives Summary for the 200-UP-1 OU

Criteria	No Action Alternative	Alternative 2 - 45 Years Active Remediation and MNA	Alternative 3 - 35 Years Active Remediation and MNA	Alternative 4 - 25 Years Active Remediation and MNA
Reduction of Toxicity, Mobility, or Volume through Treatment				
Treatment Process Used	None.	Extraction wells, ion exchange, biological, air stripping, granular activated carbon, injection wells.	Same as Alternative 2.	Same as Alternative 2.
Amount Destroyed or Treated	None.	Volume of groundwater treated and mass of contaminants removed is expected to be comparable between these two alternatives. Under Alternative 3 the treatment occurs within a shorter time frame.		Because this alternative includes a more aggressive nitrate P&T component, the volume of groundwater treatment and mass of contaminants removed is greatest under this alternative and comparable to Alternatives 2 and 3 for the remaining COCs.
Reduction of Toxicity, Mobility and Volume	None.	The contaminant mass above Federal and/or State drinking water standards will be removed for each contaminant with the exception of nitrate in the NE dilute portion of the plume.	Same as Alternative 2.	The contaminant mass above Federal and/or State drinking water standards will be removed for each contaminant.
Irreversible Treatment	None.	Technologies used for treatment of radionuclides, volatile organics, an inorganics are irreversible as is MNA component. IX and vapor phase granular activated carbon treatment media used in 200 West Groundwater Treatment Facility may be re-generated.	Same as Alternative 2.	Technologies used for treatment of radionuclides, volatile organics, an inorganics are irreversible as is MNA component. IX and vapor phase granular activated carbon treatment media used in 200 West Groundwater Treatment Facility may be re-generated.
Type and Quantity of Residuals Remaining After Treatment	No treatment.	Fraction of nitrate and carbon tetrachloride remaining after active treatment phase addressed through MNA.	Fraction of nitrate and carbon tetrachloride remaining after active treatment phase addressed through MNA.	Fraction of carbon tetrachloride remaining after active treatment phase addressed through MNA.
Statutory Preference For Treatment	Does not satisfy.	Satisfies	Satisfies	Satisfies
Short-term Effectiveness				
Community Protection	No increased risk to the community because no remedial action is performed.	Due to remote site location no increased risk to community during construction and system operation.		
Worker Protection	No increased risk to workers because no remedial action is performed.	Onsite workers will adhere to health and safety plan and personal protective equipment requirements during construction and operation to ensure protection.		
Environmental Impacts	Continues impact associated with existing conditions.	Vapor emissions during groundwater treatment operations will be monitored to ensure that standards are met. Groundwater monitoring during remedy implementation will provide information on plume migration and COC concentration trends.		
Time to Reach PRGs	Not applicable because no action is taken.	45 years for all COCs except 125 years of MNA for carbon tetrachloride.	35 years for all COCs except 125 years of MNA for carbon tetrachloride.	25 years for all COCs except 125 years of MNA for carbon tetrachloride.
Implementability				
Ability to Construct and Operate	No construction or operations costs.	P&T technology used widely at Hanford Site. A high level of construction, operation and optimization experience available for COC present in 200-UP-1 Groundwater OU. Hydraulic containment for I-129 is similar to flow-path control approach used in 200-ZP-1 Groundwater OU.		
Ease of Doing More Action if Needed	May need to go through the feasibility study and Record of Decision Process again if the No Action Alternative was selected.	Additional extraction and injection wells can be readily installed. Additional treatment capacity at 200 West Groundwater Treatment Facility available through optimization under Alternative 2 or expansion under Alternative 3 and Alternative 4.		
Ability to Monitor Effectiveness	No monitoring, which may result in inadvertent exposure to contaminated groundwater in the future.	Groundwater monitoring is the primary technology used for assessing P&T effectiveness. Monitoring an important component of each active treatment and MNA alternative.		

Table 9-1. Detailed Analysis of Alternatives Summary for the 200-UP-1 OU

Criteria	No Action Alternative	Alternative 2 - 45 Years Active Remediation and MNA	Alternative 3 - 35 Years Active Remediation and MNA	Alternative 4 - 25 Years Active Remediation and MNA
Ability to Obtain Approvals and Coordinate with Other Agencies	No approval necessary.	No issues expected.		
Availability of Services and Capacities	No services or capacities required.	Readily available.		
Availability of Equipment, Specialists, and Materials	None required.	Readily available.		
Availability of Technologies	None required.	Technologies readily available for all COCs except I-129. Technology research program for I-129 treatment is a component for each alternative.		
Cost				
Capital Cost	$0	$88,048,000	$131,346,000	$141,629,000
Average Annual O&M + Periodic Cost (non-discounted)	$0	$6,682,000	$6,509,000	$9,105,000
Total Present Value Cost	$0	$304,043,000	$319,083,000	$342,180,000

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The four alternatives retained from the preliminary screening performed in Chapter 8, Section 8.3, include:

- No Action Alternative
- Alternative 2 - 45 Years Active Remediation and MNA
- Alternative 3 - 35 Years Active Remediation and MNA
- Alternative 4 - 25 Years Active Remediation and MNA

Alternative 1- 40 Years Active Remediation and MNA was eliminated during the initial screening of alternatives presented in Chapter 8 due to uncertainty associated with its effectiveness to achieve PRGs for total chromium and hexavalent chromium. The individual evaluation of alternatives presented below is based on COC concentrations and mass inventory present in the 200-UP-1 OU through 2009.

9.2.1 No Action Alternative

A No Action Alternative is required under 40 CFR 340.430(e)(6), to provide a baseline for comparison against the other alternatives. This alternative assumes no further (no additional) remedial action would be taken. The existing P&T interim action at U Plant is now shutdown so this system would remain shut down. Since the interim action at WMA S-SX has been constructed and is scheduled to operate in 2012, it would remain operational until the final ROD is issued. If the No Action Alternative were selected, the WMA S-SX interim action would be shutdown. Selection of the No Action Alternative would not affect ongoing P&T operations in the 200-ZP-1 OU, which would continue in accordance with the requirements of the 200-ZP-1 Groundwater OU ROD (EPA, 2008) and DOE/RL-2008-78.

The 200-UP-1 OU interim action ROD and ESD required DOE to implement an array of ICs regarding land and groundwater use in the 200 Areas. These included: administrative measures to restrict drilling and groundwater use, and to have access controls (security, badges, fences, signage, excavation permits, and a Waste Information Data System (WIDS) to prevent inadvertent exposure. These ICs would be terminated under the No Action Alternative. Radioactive decay and contaminant attenuation along with other natural processes would be relied upon to reduce COC concentrations in groundwater over time. However, there would be no monitoring to track concentration changes or plume migration patterns. Long-term human health and environment risks would be comparable to those identified in the BRA.

9.2.1.1 Overall Protection of Human Health and the Environment

The No Action Alternative is not protective of human health or the environment because the ICs implemented under the interim ROD and ESD would be terminated; thus there would be no ICs in place to prevent exposure. COC concentrations expressed as 90th percentile values would remain above PRGs for up to 600 years.

9.2.1.2 Compliance with ARARs

The key ARAR (chemical-specific) for a current or future drinking water source are the federal DWS (40 CFR 141), Washington state DWS (WAC 173-340-200), and the Washington state MTCA groundwater cleanup levels (WAC 173-340-720). The No Action Alternative's ability to comply with ARARs includes the following:

- **Chemical-specific ARARs.** The No Action Alternative does not comply with chemical-specific (federal and/or state DWS or MTCA groundwater cleanup levels) ARARs for all COCs.

- **Location-specific ARARs.** There is no activity under the No Action Alternative, therefore this alternative complies with location-specific ARARs associated with preservation of archaeological

or historical data, protection of historic properties, and protection of Native American and archaeological sites.

- **Action-specific ARARs.** The No Action Alternative complies with the action-specific ARARs because there is no activity within the scope of this alternative.

Because the No Action Alternative does not protect human health and the environment, nor does it comply with chemical-specific ARARs, it cannot be selected. Therefore, the No Action Alternative was not retained nor further evaluated against the CERCLA balancing criteria.

9.2.2 Alternative 2—45 Years Active Remediation and MNA

Alternative 2 includes the following components:

- Active groundwater remediation using P&T for Tc-99, uranium, chromium (total and hexavalent), carbon tetrachloride, and the concentrated portion of the nitrate plume near U Plant for up to 45 years. Carbon tetrachloride would be co-extracted with Tc-99, uranium and nitrate.
- MNA and groundwater monitoring for tritium and carbon tetrachloride, and the diffuse portion of the nitrate plume that remains after 25 years of groundwater P&T system operation.
- Hydraulic containment for the I-129 plume.
- Maintenance of ICs for up to 125 years. This duration is based on the total remedial action time frame for carbon tetrachloride identified in DOE/RL-2007-28.

MNA and groundwater monitoring for tritium, carbon tetrachloride, and the diffuse nitrate, hydraulic containment for I-129, and maintenance of ICs for up to 125 years are common elements for Alternative 2, Alternative 3 and Alternative 4. The CERCLA threshold and balancing criteria analysis for these common elements is performed under Alternative 2, but is also applicable to Alternative 3 and Alternative 4.

9.2.2.1 Overall Protection of Human Health and the Environment

Alternative 2 protects human health and the environment through active treatment of the Tc-99, uranium, chromium (total and hexavalent), carbon tetrachloride, the concentrated nitrate plume. MNA is used to address tritium and the carbon tetrachloride that remains after active pumping, and the diffuse portion of the nitrate plume. ICs are maintained to prevent exposure until PRGs are achieved for all COCs. Alternative 2 reduces COC concentrations to PRGs, preventing expansion of the I-129 plume, and using groundwater monitoring to track COC concentration changes to ensure that the plume remains within the IC managed area.

9.2.2.2 Compliance with ARARs

Chemical-specific ARARs. Alternative 2 achieves PRGs within the aquifer for all COCs except I-129, which is being addressed through a hydraulic containment. Treatment of extracted groundwater containing Tc-99, uranium, chromium (total and hexavalent), nitrate, and carbon tetrachloride ensures compliance with re-injection ARARs. Although there is no specific treatment for tritium, the concentrations in the treated effluent will be less than the respective ARARs before re-injection because groundwater extraction does not occur within the concentrated portions of the tritium. I-129 is not targeted.

Location-specific ARARs. All new monitor and extraction/injection well installations and periodic groundwater monitoring activities would be conducted so as to minimize disturbance of the ground surface within the 200-UP-1 Groundwater OU boundary in accordance with cultural resource survey findings. All groundwater treatment would be performed using the 200 West Groundwater Treatment Facility. Therefore, this alternative complies with location-specific ARARs associated with preservation of archaeological or historical data, protection of historic properties, and protection of Native American and archaeological sites.

Action-specific ARARs. Alternative 2 complies with action-specific ARARs through worker protection programs, adherence to existing remediation waste management programs, and air emission requirements. Alternative 2 would comply with well decommissioning regulations during periodic well replacement events and at the conclusion of the remediation when all wells would be decommissioned in accordance with WAC 173-160 standards. All new treatment facility operations, waste management, and decommissioning practices under Alternative 2 would be performed in accordance with action-specific ARARs.

9.2.2.3 Long-Term Effectiveness and Permanence

This criterion relates to the health risks that remain from untreated contaminated groundwater and treatment residuals at the conclusion of remedial activities, and the adequacy and reliability of controls required to manage treatment residuals and untreated contaminated groundwater.

Magnitude of Residual Risk. Under Alternative 2, PRGs are achieved for each COC, therefore, the magnitude of residual risk present in the aquifer at the completion of the remediation will achieve chemical-specific ARARs and the acceptable risk level ensuring protection of future groundwater users.

Under this alternative, all 200 West Groundwater Treatment Facility treatment residuals are disposed at ERDF. Because EDRF has been specifically designed to provide for long-term management of hazardous materials, treatment residuals should not pose a risk to human health and the environment in the future. The ICs implemented under this alternative will prevent exposure to contaminated groundwater until PRGs are achieved.

Adequacy and Reliability of Controls. Under Alternative 2, existing ICs are used to protect against inadvertent exposure until PRGs are achieved. ICs perform well at the Hanford Site because the measures are comprehensive, with enough redundancy to ensure that protectiveness is maintained even if one measure fails. Placement of groundwater treatment residuals within ERDF provides a high level of assurance that treatment residuals are safely managed long-term.

9.2.2.4 Reduction of Toxicity, Mobility, and Volume Through Treatment

Alternative 2 achieves TMV reduction for Tc-99, uranium, chromium (total and hexavalent), carbon tetrachloride, and nitrate within the aquifer through extraction and above ground treatment until PRGs are met. Toxicity and volume reduction for tritium, carbon tetrachloride, and diffuse nitrate occur through MNA, while mobility reduction of the I-129 plume occurs through hydraulic containment.

9.2.2.5 Short-Term Effectiveness

This criterion addresses the effects of the alternative on the community, workers, and the environment during the construction and implementation phase, and the time frame required before PRGs are met. Under Alternative 2, there is no risk to the community due to the 200-UP-1 OU's remote location. Some short-term risks to construction workers may arise during well installation, groundwater transfer building construction, and treatment system O&M activities. However, this work would be performed by

experienced workers using well-established Hanford Site safe work processes and personal protective equipment (PPE).

Impacts to the environment associated with off gas emissions from the 200 West Groundwater Treatment Facility will be routinely monitored to ensure that action-specific ARARs are met. Periodic groundwater sampling performed to track P&T and MNA effectiveness will ensure that the environment is protected during remedy implementation.

The active remediation period for P&T activities is 45 years. Since MNA is also used to achieve PRGs, the total remediation period would require up to 35 years for nitrate and 125 years for carbon tetrachloride.

9.2.2.6 Implementability

Alternative 2 is readily implementable. The P&T technology is widely used at the Hanford Site, and therefore, the experience needed to construct, operate, optimize, and monitor the technology's effectiveness is readily available. Because Alternative 2 utilizes existing treatment capacity within the 200 West Groundwater Treatment Facility, no expansion is required. However, because excess treatment capacity is limited, more active flow management will be required. Many of the activities contained within this alternative, such as groundwater monitoring and data evaluation, and maintenance of ICs, are already performed on a routine basis at the Hanford Site. Additionally, many of the work processes used for design, construction, and operation of the 200-UP-1 interim actions and design of the 200-ZP-1 remedy would be used to implement Alternative 2.

9.2.2.7 Cost

The estimated total present valve cost for Alternative 2 is $304,043,000. This cost includes a capital cost of $88,048,000, and an average annual O&M/periodic cost of $6,682,000. The total non-discounted cost for Alternative 2, which includes all capital, O&M, and periodic costs, is estimated at $428,837,000.

9.2.3 Alternative 3—35 Years Active Remediation and MNA

Alternative 3 includes the following, plus the common elements described previously for Alternative 2:

- Active remediation using moderately aggressive P&T for Tc-99, uranium, chromium (total and hexavalent), and the concentrated portion of the nitrate plume areas for up to 25 years. Carbon tetrachloride is co-extracted with Tc-99, uranium and high concentration nitrate pumping wells.

Alternative 3 is similar to Alternative 2 with the primary difference being that higher groundwater pumping rates are used to address the uranium and chromium plumes. Under Alternative 3, the total pumping rate for the uranium plume is 150 gpm (versus 100 gpm under Alternative 2) and 200 gpm for the chromium (total and hexavalent) plume (versus 150 gpm under Alternative 2). The higher pumping rates enable the active remediation time frame to be 35 years (versus 45 years under Alternative 2). Under Alternative 3, a third treatment train will be installed within the 200 West Groundwater Treatment Facility to address the higher groundwater pumping rates.

9.2.3.1 Overall Protection of Human Health and the Environment

Alternative 3 protects human health and the environment through active treatment of the Tc-99, uranium, chromium (total and hexavalent), carbon tetrachloride, and high concentration portion of the nitrate plumes. MNA is used to address tritium and the carbon tetrachloride that remains after active pumping, and the diffuse portion of the nitrate plume. ICs are maintained to prevent exposure until PRGs are achieved. Alternative 3 reduces COC concentrations to PRGs, preventing expansion of the I-129 plume,

and use of groundwater monitoring to track COC concentration changes to ensure that the plume remains within the IC managed area.

9.2.3.2 Compliance with ARARs

Alternative 3 complies with ARARs as described for Alternative 2.

9.2.3.3 Long-Term Effectiveness and Permanence

This criterion relates to the health risks that remain from untreated contaminated groundwater and treatment residuals at the conclusion of remedial activities, and the adequacy and reliability of controls required to manage treatment residuals and untreated contaminated groundwater.

Magnitude of Residual Risk. Under Alternative 3, PRGs are achieved for each COC, therefore, the magnitude of residual risk present in the aquifer at the completion of the remediation will achieve chemical-specific ARARs and the acceptable risk level ensuring protection of future groundwater users.

Under this alternative, all 200 West Groundwater Treatment Facility treatment residuals are disposed at ERDF. Because EDRF has been specifically designed to provide for long-term management of hazardous materials, treatment residuals should not pose a risk to human health and the environment in the future. The ICs implemented under this alternative will prevent exposure to contaminated groundwater until PRGs are achieved.

Adequacy and Reliability of Controls. Under Alternative 3, existing ICs would be used to protect against inadvertent exposure until PRGs are achieved. ICs perform well at the Hanford Site because the measures are comprehensive, with enough redundancy to ensure that protectiveness is maintained even if one measure fails. Placement of groundwater treatment residuals within ERDF provides a high level of assurance that treatment residuals are safely managed long-term.

9.2.3.4 Reduction of Toxicity, Mobility, and Volume Through Treatment

Alternative 3 achieves TMV reduction for Tc-99, uranium, chromium, carbon tetrachloride and nitrate within the aquifer through extraction and above ground treatment until PRGs are met. Toxicity and volume reduction for tritium occur through MNA (radioactive decay), while mobility reduction of the I-129 plume occurs through hydraulic containment. Some additional toxicity and volume reduction of the carbon tetrachloride and the diffuse portion of the nitrate plume occurs through MNA.

9.2.3.5 Short-Term Effectiveness

This criterion addresses the effects of the alternative to the community, workers, and the environment during the construction and implementation phase, and the time frame required before PRGSs are met. Under Alternative 3, there is no risk to the community due to the 200-UP-1 Groundwater OU's remote location. Some short-term risks to construction workers may arise during well installation, transfer building construction, and treatment system O&M activities. However, this work would be performed by experienced workers using well-established Hanford Site safe work processes and PPE.

Impacts to the environment associated with off gas emissions from the 200 West Groundwater Treatment Facility will be routinely monitored to ensure that action-specific ARARs are met. Periodic groundwater sampling performed to track P&T and MNA effectiveness will ensure that the environment is protected during remedy implementation.

The P&T period is 25 years. Since MNA is also required to achieve PRGs, the total remediation period would require up to 35 years for nitrate and 125 years for carbon tetrachloride.

9.2.3.6 Implementability

Alternative 3 is readily implementable. The P&T technology is widely used at the Hanford Site, and therefore, the experience needed to construct, operate, expand, and monitor the technology's effectiveness is readily available. Alternative 3 utilizes expanded (third treatment train) treatment capacity within the 200 West Groundwater Treatment Facility. Many of the activities contained within this alternative, such as groundwater monitoring, data evaluation, and maintenance of ICs, are already being performed on a routine basis at the Hanford Site. Additionally, many of the work processes used for design, construction, and operation of the 200-UP-1 interim actions and design of the 200-ZP-1 remedy would be used to implement Alternative 3.

9.2.3.7 Cost

The estimated total present value cost for Alternative 3 is $319,083,000. This includes a capital cost of $131,346,000, and an average annual O&M/periodic cost of $6,509,000. The total non-discounted cost for Alternative 3, which includes all capital, O&M, and periodic costs is estimated at $398,200,000.

9.2.4 Alternative 4—25 Years Active Remediation and MNA

Alternative 4 includes the following, plus the common elements described previously for Alternative 2:

- Active remediation using highly aggressive P&T for the Tc-99, uranium, chromium (total and hexavalent), carbon tetrachloride, and nitrate plumes for up to 25 years.

Alternative 4 is similar to Alternative 3 with the primary difference being that Alternative 4 includes more aggressive pumping of the nitrate plume with up to two additional wells pumping at a total rate of 100 gpm. Expanded pumping of the nitrate plume reduces the remediation time frame for all COCs except carbon tetrachloride to 25 years. Under Alternative 4, a third treatment train would be installed within the 200 West Groundwater Treatment Facility to address the higher groundwater pumping rates.

9.2.4.1 Overall Protection of Human Health and the Environment

Alternative 4 protects human health and the environment through active treatment of most COCs with MNA for tritium and a portion of the carbon tetrachloride plume not addressed through P&T. ICs are maintained to prevent exposure until PRGs are achieved. Alternative 4 reduces COC concentrations to PRGs and prevents expansion of the I-129 plume.

9.2.4.2 Compliance with ARARs

Chemical-specific ARARs. Alternative 4 achieves PRGs within the aquifer for all COCs except I-129, which is being addressed through a hydraulic containment. Treatment of extracted groundwater containing Tc-99, uranium, chromium, nitrate, and co-extracted carbon tetrachloride ensures compliance with re-injection ARARs. Although there is no specific treatment for tritium and I-129, the concentrations in the treated effluent will be less than their respective re-injection ARARs.

Location-specific ARARs. All new monitor and extraction/injection well installations and periodic groundwater monitoring activities would be conducted so as to minimize disturbance of the ground surface within the 200-UP-1 Groundwater OU boundary in accordance with cultural resource survey findings. All groundwater treatment would be performed using the 200 West Groundwater Treatment Facility. Therefore, this alternative complies with location-specific ARARs associated with preservation of archaeological or historical data, protection of historic properties, and protection of Native American and archaeological sites.

Action-specific ARARs. Alternative 4 complies with action-specific ARARs through worker protection programs, adherence to existing remediation waste management programs, and air emission requirements. Alternative 4 would comply with well decommissioning regulations during periodic well replacement events and at the conclusion of the RA when all wells would be decommissioned in accordance with WAC 173-160 standards. All new treatment facility operation, waste management, and decommissioning practices under Alternative 4 would be performed in accordance with action-specific ARARs.

9.2.4.3 Long-Term Effectiveness and Permanence

This criterion relates to the health risks that remain from untreated contaminated groundwater and treatment residuals at the conclusion of remedial activities, and the adequacy and reliability of controls required to manage treatment residuals and untreated contaminated groundwater.

Magnitude of Residual Risk. Under Alternative 4, PRGs are achieved for each COC, therefore, the magnitude of residual risk present in the aquifer at the completion of the RA will achieve chemical-specific ARARs and the acceptable risk level ensuring protection of future groundwater users. Because a majority of the treatment is accomplished using P&T, there is less reliance on MNA and groundwater monitoring, and therefore, greater certainty that the magnitude of residual risk under Alternative 4 will be less than the acceptable risk threshold.

Under this alternative, all 200 West Groundwater Treatment Facility treatment residuals are disposed at ERDF. Because EDRF has been specifically designed to provide for long-term management of hazardous materials, treatment residuals should not pose a risk to human health and the environment in the future. The ICs implemented under this alternative will prevent exposure to contaminated groundwater until PRGs are achieved.

Adequacy and Reliability of Controls. Under Alternative 4, existing ICs are used to protect against inadvertent exposure until PRGs are achieved. ICs perform well at the Hanford Site because the measures are comprehensive, with enough redundancy to ensure that protectiveness is maintained even if one measure fails. Placement of groundwater treatment residuals within ERDF provides a high level of assurance that treatment residuals are safely managed long-term.

9.2.4.4 Reduction of Toxicity, Mobility, and Volume Through Treatment

Alternative 4 achieves TMV reduction for Tc-99, uranium, chromium, nitrate, and carbon tetrachloride within the aquifer through extraction and above ground treatment. Toxicity and volume reduction for tritium occur through MNA (radioactive decay), while mobility reduction of the I-129 plume occurs through hydraulic containment. Some toxicity and volume reduction of the carbon tetrachloride plume occurs through MNA after the active pumping period.

9.2.4.5 Short-Term Effectiveness

This criterion addresses the effects of the alternative to the community, workers, and the environment during the construction and implementation phase, and the time frame required before PRGs are met. Under Alternative 4, there is no risk to the community due to the 200-UP-1 Groundwater OU's remote location. Some short-term risks to RA construction workers may arise during well installation, transfer building construction, and treatment system O&M activities. However, this work would be performed by experienced workers using well-established Hanford safe work processes and PPE.

Impacts to the environment associated with off gas emissions from the 200 West Groundwater Treatment Facility will be routinely monitored to ensure that action-specific ARARs are met. Periodic groundwater sampling performed to track P&T and MNA effectiveness will ensure that the environment is protected during remedy implementation.

The active remediation period for P&T is 25 years. Since MNA is also required to achieve PRGs for carbon tetrachloride, the total remediation period would require up to 125 years.

9.2.4.6 Implementability

Alternative 4 is readily implementable. The P&T technology is widely used at the Hanford Site, and therefore, the experience needed to construct, operate, expand, and monitor the technology's effectiveness is readily available. Alternative 4 utilizes expanded (third treatment train) treatment capacity within the Treatment Facility. Many of the activities contained within this alternative, such as groundwater monitoring, data evaluation, and maintenance of ICs, are already being performed on a routine basis at the Hanford Site. Additionally, many of the work processes used for design, construction, and operation of the 200-UP-1 Groundwater OU IRAs and design of the 200-ZP-1 Groundwater OU remedy would be used to implement Alternative 4.

9.2.4.7 Cost

The estimated total present value cost for Alternative 4 is $342,180,000. This includes a capital cost of $141,629,000 and an annual average O&M/periodic cost of $9,105,000. The total non-discounted cost for Alternative 4, which includes all capital, O&M, and periodic costs, is estimated at $423,881,000.

9.3 Comparative Analysis of Remedial Alternatives

The remedial alternatives analyzed in Section 9.2 are compared in this section. The comparative analysis identifies the relative advantages and disadvantages of each alternative in the context of the CERCLA evaluation criteria so the key trade-offs may be identified and balanced. The comparative analysis provides a measure of the relative performance of the alternatives against each evaluation criterion. Table 9-2 summarizes the comparative evaluation.

9.3.1 Overall Protection of Human Health and the Environment

All of the alternatives, except the No Action Alternative, protect human health by preventing exposure to contaminated groundwater through the use of ICs until PRGs are achieved both now and in the future.

Alternative 4 is expected to provide a higher level of protection for human health and the environment because Tc-99, uranium, chromium, nitrate and carbon tetrachloride contaminated groundwater are removed from the aquifer using aggressive P&T. Alternatives 3 and 2 also provide a high level of protection for human health and the environment, however, under these two alternatives extraction along with MNA and groundwater monitoring are used to address the diffuse nitrate and carbon tetrachloride plumes. Under all three alternatives tritium is addressed through MNA while the I-129 plume is hydraulically contained while a treatment technology is performed.

The No Action alternative provides the lowest level of protection for human health and the environment because there are no provisions under this alternative to prevent exposure or plume migration.

9.3.1.1 Compliance with ARARs

All of the alternatives, except the No Action Alternative, comply with chemical-specific ARARs in the defined aquifer attainment areas within time frames that decrease from 45 years under Alternative 2, to 35 years under Alternative 3, to 25 years under Alternative 4 for all COCs except carbon tetrachloride and I-129. Compliance with the chemical-specific ARAR for carbon tetrachloride requires up to 125 years for all three alternatives. Iodine will undergo a technology evaluation and will be hydraulically.Each of the alternatives would comply with action- and location-specific ARARs if RA activities are conducted in accordance with existing Hanford Site work processes.

Table 9-2. Comparative Evaluation of Alternatives Summary for the 200-UP-1 Groundwater OU

Alternative	Threshold Criteria		Balancing Criteria				
	1. Overall Protection of Human Health and the Environment?	**2. Compliance with ARARs***	**1. Long-Term Effectiveness and Permanence**	**2. Reduction of Toxicity, Mobility, and Volume Through Treatment**	**3. Short-Term Effectiveness**	**4. Implementability**	**5. Present Worth Cost (Million $)**
No Action Alternative	No	No	Not evaluated. This alternative does not meet threshold criteria for protection of human health and the environment, therefore, it cannot be selected.				$0
Alternative 2— 45 Years Active Remediation and MNA	Yes	Yes	Good. Some levels of residual risk associated with chromium and uranium may remain at end of 45 yr remedial action time frame if actual remedy performance is less than the modeling simulations. ICs can be maintained and extended as necessary to protect against inadvertent exposure until PRGs are achieved. Treatment residuals transported to secure facility for long-term management.	Moderate. P&T and MNA reduce TMV for Tc-99, uranium and chromium. Tritium toxicity reduction occurs through MNA. I-129 mobility reduced through hydraulic containment until final remedy selected. Nitrate toxicity is reduced through plume dispersion, however, no mobility or significant volume reduction are expected. Immobilized treatment residuals transported to secure facility for permanent disposal.	Good. Nominal short-term risks to workers during extraction and injection well installation, during routine treatment facility O&M, and during periodic groundwater sampling events. Risks minimized through HSP and PPE. No adverse risks to community, due to the Site's remote location. Carbon tetrachloride requires 125 year of MNA to reach PRGs	Moderate. Implemented with standard construction equipment and methods, and use of existing treatment facility capacity. Limited capacity requires additional flow balancing to ensure that the existing treatment system components operate within design parameters.	$304
Alternative 3— 35 Years Active Remediation and MNA	Yes	Yes	Good. Some levels of residual risk associated with nitrate may remain at end of 35 yr remedial action time frame if actual concentration trends and plume behavior differ from model simulations. ICs can be maintained and extended as necessary to protect against inadvertent exposure until PRGs are achieved. Treatment residuals transported to secure facility for long-term management.	Moderate. TMV reduction is accelerated over Alternative 2 with more aggressive pumping rates for uranium and chromium. Tc-99 TMV reduction comparable to Alternative 2. Tritium toxicity reduction occurs through MNA. I-129 mobility reduced through hydraulic containment until final remedy selected. Nitrate toxicity is reduced through plume dispersion, however, no mobility or significant volume reduction are expected. Immobilized treatment residuals transported to secure facility for permanent disposal.	Good. Nominal short-term risks to workers during extraction and injection well installation, during routine treatment facility O&M, and during periodic groundwater sampling events. Risks minimized through HSP and PPE. No adverse risks to community, due to the Site's remote location. Carbon tetrachloride requires 125 year of MNA to reach PRGs	Good. Readily implemented with standard construction equipment and methods. Allows design, construction and operation of a third treatment train at treatment facility which adds additional hydraulic capacity. Additional capacity improves operational flexibility to operate under a broader range of flow conditions and contaminant loading.	$319
Alternative 4— 25 Years Active Remediation and MNA	Yes.	Yes	Good. Potential for residual risk under this alternative is low as active remediation methods are used to address all COCs. Treatment residuals transported to secure facility for long-term management.	Good. TMV reduction is accelerated over Alternative 3 with more aggressive pumping rates for uranium and chromium, and implementation of P&T for nitrate. Tc-99 TMV reduction comparable to Alternative 2 and Alternative 3. Tritium toxicity reduction occurs through MNA. I-129 mobility reduced through hydraulic containment until final remedy selected.	Good. Nominal short-term risks to workers during extraction and injection well installation, during routine treatment facility O&M, and during periodic groundwater sampling events. Risks minimized through HSP and PPE. No adverse risks to community, due to the Site's remote location. Carbon tetrachloride requires 125 year of MNA to reach PRGs	Moderate. Readily implemented with standard construction equipment and methods. Requires design, construction and operation of a third treatment train at treatment facility. Addition of active nitrate remediation increases alternative's complexity and overall O&M burden.	$342

* Iodine will undergo a technology evaluation and will be hydraulically contained.

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9.3.1.2 Long-Term Effectiveness and Permanence

Alternatives 2, 3 and 4 provide good and comparable levels of long-term effectiveness and permanence because the volume of contaminated groundwater that is treated is similar for the Tc-99, uranium, chromium, carbon tetrachloride plumes while Alternative 4 is superior with respect to nitrate. All three alternatives provide comparable levels of long-term effectiveness and permanence for I-129 and tritium because the remedial alternative components addressing these two COCs are the same.

9.3.1.3 Reduction of Toxicity, Mobility, and Volume Through Treatment

Alternative 4 provides the highest degree of TMV reduction for the Tc-99, uranium, nitrate, chromium, carbon tetrachloride and nitrate plumes because a majority of the COC mass is removed from the aquifer using P&T with treatment residuals immobilized and disposed at a secure long-term management facility (ERDF). Alternative 3 has comparable levels of TMV reduction to Alternative 4 for all COCs except nitrate. Although the total volume of groundwater pumped and treated is similar amongst the three alternatives, Alternative 2 has less early uranium and chromium TMV reduction because it employs lower pumping rates. All three alternatives have comparable levels of TMV reduction for Tc-99, I-129 and tritium because the approach for addressing these three COCs is the same.

9.3.1.4 Short-Term Effectiveness

Alternatives 2, 3, and 4 provide similar levels of short-term effectiveness relative to protection of the community because the 200-UP-1 Groundwater OU is located in a remote portion of the Hanford Site where community exposure would not occur.

With respect to protection of workers, all work associated with these alternatives can be performed safely with minimal risk to workers and the environment by conducting the work per existing Site work safe work processes. However, as the scope of a remedial alternative grows, the potential for worker risk increases. Therefore, Alternative 2 would pose the least short-term risk to workers followed by Alternative 3 and Alternative 4, respectively.

At 25 years, Alternative 4 has the shortest active remediation time frame followed by Alternative 3 at 35 years, and Alternative 2 at 45 years. However, under all three alternatives, up to 125 years is required for MNA to address the carbon tetrachloride plume remaining after pumping. Therefore, each of the alternatives is ranked similarly.

9.3.1.5 Implementability

All three alternatives are readily implemented using existing Hanford Site safe work procedures. However, as the scope of an alternative grows, the degree of difficulty associated with its implementation increases. Alternative 4 is expected to pose the greatest implementation challenge because of the increased O&M associated with operation of the biological treatment process required to treat the larger volumes of nitrate contaminated groundwater resulting from operation of the nitrate extraction wells. Although Alternative 2 does not require expansion of the 200 West Groundwater Treatment Facility, whereas Alternatives 3 and 4 do, Alternative 2 will require remedial process optimization to ensure that pumping and treatment throughput rates can be maintained over the active remediation time period. Therefore, Alternative 2 was judged to be more difficult to implement than Alternative 3 and comparable to Alternative 4.

9.3.1.6 Cost – Total Present Worth

Alternative 2 at a total NPV cost (Table 9-3) of $304 million has the lowest cost followed by Alternative 3 at $319 million NPV, and Alternative 4 at $342 million NPV. The total present value costs for Alternatives 2, 3, and 4 does not include an allowance for modification of the I-129 hydraulic

containment remedy to implement the findings of the treatment technology evaluation. The present value cost represents the dollars that would need to be set aside today, at the defined interest rate, to ensure that funds would be available in the future as they are needed to perform the remedial alternative.

The cost estimates were developed in accordance with EPA/540/R-00/002. The RACER™ cost estimating software (AECOM, 2010, *Overview of the Remedial Action Cost Engineering Requirements (RACER™) System*) was used in conjunction with Microsoft Excel (MS Excel)™ software to develop the cost estimate for each of the RA alternatives. Key assumptions associated with development of the costs are summarized in Table 9-3. These estimates were prepared to meet the -30 to +50 percent range of accuracy recommended in EPA (EPA/540/G-89/004) CERCLA guidance.

Table 9-3. Comparison of Remedial Alternative Costs for the 200-UP-1 Groundwater OU

Site: 200-UP-1 GW OU **Base Year:** 2015
Location: Hanford, WA **Date:** 1/31/2012
Phase: FS

Item Description	No Action	Alternative 2	Alternative 3	Alternative 4
		45 Year Time frame	35 year Time frame	25 Year Time frame
Capital Cost	$0	$88,048,000	$131,346,000	$141,629,000
Total O&M/Periodic Cost (non-discounted)	$0	$340,790,000	$266,854,000	$282,253,000
Average Annual O&M Cost (overall duration)	$0	$6,8156,000	$6,671,000	$9,408,000
Total Non-Discounted	$0	$428,837,000	$398,200,000	$423,881,000
Total Present Value (Discounted)*	$0	$304,043,000	$319,083,000	$342,180,000
Total Present Value – 30%	$0	$212,831,000	$223,359,000	$239,526,000
Total Present Value +50%	$0	$456,065,000	$478,625,000	$513,270,000

Note 1: Present Value discount percent used is 2.7 percent.

Note 2: The initial capital costs for construction of the 200 West Pump-and-Treat Facility was accounted for in the 200-ZP-1 ROD in 2008.

Range of accuracy is expected to be +50-30 percent.

* The total net present value cost, capital cost, O&M cost, and periodic costs do not include design, construction and O&M allowances for the I-129 final remedy.

The cost estimates for each remedial alternative include allowances for; capital costs, O&M and periodic costs. These are defined below:

1. Capital costs consist primarily of expenditures incurred to construct the remedy (e.g., construction of a groundwater treatment system and related site work). It also include all labor, equipment, and material costs for mobilization/demobilization; site work; installation of extraction, containment, or treatment systems; and disposal of waste products.

2. O&M costs are those post-construction costs necessary to support the remedy until PRGs are achieved. These costs are estimated on an annual basis. Annual O&M costs include all labor,

equipment, and material costs for; monitoring; operating and maintaining of extraction, injection, and treatment systems; and waste disposal.

3. Periodic costs occur only once every few years (e.g., five-year reviews, non-annual equipment replacement, and well rehabilitation/replacement) or expenditures that occur only once during the entire remedial time frame (decommissioning costs of facilities).

9.3.2 Sustainable Evaluation Factors

With increased emphasis on development and implementation of remedial alternatives that include "green" or "sustainable elements" a sustainable evaluation factor was also included as part of the comparative evaluation of alternatives. Sustainable elements considers the complete life-cycle impacts of an alternative such as energy consumption, air quality emissions (green-house gas and hazardous substances), water use, material and waste generation, and land-ecosystem effects.

Alternatives 3 and 4 were judged to have less favorable sustainable elements than the No Action alternative and Alternative 2, and therefore, were ranked lower. The primary basis for the lower ranking for Alternatives 3 and 4 was the increased energy use associated with the higher groundwater pumping rates, increased energy use associated with construction and operation of the third treatment train needed to handle the higher flow rates, increased greenhouse gas emissions associated with the higher energy demands, and the greater solid waste volumes (spent treatment media) associated with operation and maintenance of the third treatment train.

9.4 NEPA Values

This section discusses the incorporation of NEPA values into CERCLA documents. This is consistent with DOE Order 451.1B, Chg. 1 that requires CERCLA actions to address and incorporate NEPA values such as socioeconomic, ecological, offsite, and cumulative impacts in CERCLA documents to the extent practicable.

Alternatives to address the release or threatened release of hazardous substances have been identified and analyzed in this RI/FS (Section 9). The No Action Alternative would not mitigate the environmental impacts from the hazardous substances. All other alternatives could mitigate the impacts associated with the release or threatened release, as well as provide for the remediation of the hazardous substances. Specifically, the application of the substantive environmental protection standards identified as ARARs would reduce impacts of the hazardous substances on air, surface waters, soil, groundwater, plants, and animals to levels that have been identified by regulation.

NEPA values associated with remediation are based on the detailed information presented in this RI/FS including the area and Site characteristics (Chapters 1, 2, and 3), COC identification (Chapters 6 and 7), and the development and analysis of RA alternatives (Chapters 8 and 9). Applying a "sliding scale" of NEPA analysis to the 200-UP-1 Groundwater OU using DOE's NEPA guidance (DOE, 2004, *Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements: Second Edition*), and considering the ARARs presented in Chapter 7, the principle resource areas of concern include: contaminated groundwater, liquid and solid radioactive and hazardous waste treatment residuals, air emissions, potential adverse effects to historic and cultural resources, ecological resources, socioeconomics (including environmental justice concerns), and transportation associated with implementation of the RA.

For purposes of implementing the RA alternatives described in Chapters 8 and 9 of this document, when groundwater in the 200-UP-1 Groundwater OU is found to be contaminated with hazardous substances in concentrations presenting unacceptable risk to human health and the environment, that threat will be

mitigated by meeting the applicable ARAR standards as well as following current DOE policy and guidance. The net anticipated effect could be an overall positive contribution to cumulative environmental effects at the Site through TMV reductions of COC concentrations and transfer of all above ground treatment residuals into a facility that has been designed and legally authorized to safely contain such contaminants. DOE expects that ERDF will be the primary facility to receive treatment residuals. NEPA values specifically associated with ERDF were addressed in DOE/RL-94-41, *NEPA Roadmap for the Environmental Restoration Disposal Facility Regulatory Package*.

Table 9-4 describes the NEPA values (resource area and relevant NEPA considerations) most relevant to and potentially affected by the actions occurring under this RA.

The alternatives presented in this FS are within the scope of DOE/EIS-0391, *Draft Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*. DOE expects that the final action for the 200-UP-1 Groundwater OU will support the eventual final Tank Farm and Waste Management Environmental Impact Statement preferred alternative.

Table 9-4. NEPA Values Evaluation

NEPA Values	Description	Evaluation (Includes the Evaluation for Each Alternative)
Transportation	Considers impacts of the proposed action on local traffic (traffic at the Site) and traffic in the surrounding region.	Implementation of Alternatives 2 to 4 would be expected to produce short-term impacts on local traffic. A majority of the impact is associated with increased vehicle traffic associated with transport of construction materials, in addition to conveyance of extracted groundwater to the 200 West Groundwater Treatment Facility and treatment residuals to ERDF. Transportation impacts were considered in the ERDF RI/FS, DOE/RL-93-99, as part of the evaluation of short-term effectiveness and implementability. NEPA values specifically associated with ERDF were addressed in DOE/RL-94-41. Transportation impacts associated with the No Action Alternative are negligible and considerably less than for the other alternatives.
Air Quality	Considers potential air quality concerns associated with emissions generated during the proposed action.	Airborne releases associated with Alternatives 2 to 4 would be expected to be minor with the use of appropriate work and treatment controls (dust suppressants during construction and air treatment provisions where required). Any potential of airborne release of contaminants during the RAs would be controlled in accordance with DOE radiation control and air pollution control standards, to minimize emissions of air pollutants at the Site, and protect all communities outside the Site boundaries. Operation of trucks and other diesel-powered equipment for these alternatives would be expected, in the short term, to introduce quantities of sulfur dioxide, nitrogen dioxide, particulates, and other pollutants to the atmosphere, typical of similar-sized construction projects. These releases would not be expected to cause any air quality standards to be exceeded and (as needed) dust generated during remedial activities would be minimized by watering or other dust-control measures. Vehicular and equipment emissions would be controlled and mitigated in compliance with the substantive standards for air quality protection that apply to the Site.

Table 9-4. NEPA Values Evaluation

NEPA Values	Description	Evaluation (Includes the Evaluation for Each Alternative)
Natural, Cultural, and Historical Resources	Considers impacts of the proposed action on wildlife, wildlife habitat, archeological sites and artifacts, and historically significant properties.	Impacts on ecological resources in the vicinity of the RAs would be mitigated in accordance with DOE/RL-96-32 and DOE/RL-96-88, and with the applicable standards of all relevant biological species protection regulations. Because a majority of the 200-UP-1 Groundwater OU has already been evaluated or disturbed, implementation of DOE/RL-98-10 and consultation with area Tribes would help ensure appropriate mitigation to avoid or minimize any adverse cultural or historical resource effects and address any relevant concerns. Impacts to other cultural values will be minimized through implementation of DOE/RL-98-10, DOE/RL-2005-27, and consultation with area Tribes as needed. This will help ensure appropriate mitigation to avoid or minimize any adverse effects to natural and cultural resources and address any other relevant concerns. Potential impacts to cultural and historical resources that may be encountered during the short-term construction activities associated with implementing the action would be mitigated through compliance with the appropriate substantive requirements of the *National Historic Preservation Act of 1966* and other ARARs related to cultural preservation.
Socioeconomic Impacts	Considers impacts pertaining to employment, income, other services (water and power utilities), and the effect of implementation of the proposed action on the availability of services and materials.	The proposed alternatives are within the scope of current RL environmental restoration activities and would have minimal impact on the current availability of services and materials. This work would be expected to be accomplished largely using employees from the existing contractor workforce. Even if remedial activities create additional service sector jobs, the total expected increase in employment would be expected to be less than 1 percent of the current employment levels. The socioeconomic impact of the project would contribute to the continuing overall positive employment and economic impacts on eastern Washington communities from Site cleanup operations.
Environmental Justice	Considers whether the proposed response actions would have inappropriately or disproportionately high and adverse human health and the environment effects on minority or low-income populations.	Per Executive Order 12898, DOE seeks to ensure that no group of people bears a disproportionate share of negative environmental consequences resulting from proposed federal actions. No impacts are associated with proposed activities associated with the 200-UP-1 Groundwater OU that could reasonably be determined to affect any member of the public; therefore, they would not have the potential for high and disproportional adverse impacts on minority or low-income groups.

Table 9-4. NEPA Values Evaluation

NEPA Values	Description	Evaluation (Includes the Evaluation for Each Alternative)
Cumulative Impacts (Direct and Indirect)	Considers whether the proposed action could have cumulative impacts on HHE when considered together with other activities locally, at the Site, or in the region.	The environmental concern for the 200-UP-1 Groundwater OU is COC concentrations exceeding PRGs within the targeted attainment areas. Because of the temporary nature of the activities and their remote location, cumulative impacts on air quality or noise with other Site or regional construction and cleanup projects would be minimal. When groundwater in this OU is found to be contaminated with hazardous substances in concentrations presenting a material threat to HHE, that threat would be mitigated. The net anticipated effect could be a positive contribution to cumulative environmental effects at the Site through TMV reduction and transfer of all treatment residuals into a facility that has been designed and legally authorized to safely contain such contaminants (i.e., the ERDF). Treatment residuals generated under any alternative would meet the ERDF waste acceptable criteria as described in WCH-191. Wastes generated during implementation of the proposed alternatives would be manageable within the capacities of existing facilities. For perspective, ERDF received more than 700,000 tons of waste in CY 2008 and more than 430,000 tons in CY 2007.
Mitigation	Considers whether or not if adverse impacts cannot be avoided, response action planning should minimize them to the extent practicable. This value identifies required mitigation activities.	Compliance with the substantive requirements of the ARARs would mitigate potential environmental impacts on the natural environment, including migratory birds and endangered species. DOE has also established policies and procedures for the management of ecological and cultural resources when actions might affect such resources (DOE/RL-96-32, DOE/RL-96-88, and DOE/RL-98-10). Cultural resource and biological species reviews/surveys are undertaken that also provide suggested mitigation activities to ensure that adverse effects associated with implementing the actions are minimized or avoided. Health and safety procedures, documented in the HSP, established by Site contractors, would mitigate risks to workers from the remedial activities.
Irreversible and Irretrievable Commitment of Resources	Considers the use of nonrenewable resources for the proposed response actions and the effects that resource consumption would have on future generations. (When a resource [energy minerals, water, wetland] is used or destroyed and cannot be replaced within a reasonable amount of time, its use is considered irreversible.)	Alternatives 2 to 4 would require long-term use of hydroelectric power to operate P&T equipment. Non-renewable fossil fuels will also be irreversibly used by O&M personnel. Restoration of formerly disturbed areas at the completion of the RA would be expected to result in a net benefit to the groundwater and environmental resources within the 200-UP-1 Groundwater OU.

Table 9-4. NEPA Values Evaluation

NEPA Values	Description	Evaluation (Includes the Evaluation for Each Alternative)

Sources: DOE/RL-93-99, *Remedial Investigation and Feasibility Study Report for the Environmental Restoration Disposal Facility*.

DOE/RL-94-41, *NEPA Roadmap for the Environmental Restoration Disposal Facility Regulatory Package*.

DOE/RL-96-32, *Hanford Site Biological Resources Management Plan*.

DOE/RL-96-88, *Hanford Site Biological Resources Mitigation Strategy*.

DOE/RL-98-10, *Hanford Cultural Resources Management Plan*.

DOE/RL-2005-27, *Revised Mitigation Action Plan for the Environmental Restoration Disposal Facility*.

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations.*

WCH-191, *Environmental Restoration Disposal Facility Waste Acceptance Criteria.*

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