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Remedial Investigation Report for the 200-ZP-1 Groundwater Operable Unit

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

United States Department of Energy
P.O. Box 550
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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EXECUTIVE SUMMARY

The 200-ZP-1 Groundwater Operable Unit (OU) is located under the northern part of the 200 West Area at the Hanford Site. The *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) requires that remedial investigation (RI) reports evaluate human and ecological risk and determine whether a feasibility study (FS) is needed to assess remedial alternatives for mitigating the risk. Multiple ecological and human health risk scenarios are discussed in Sections 5.0 and 6.0. Preliminary risk evaluation indicates that cancer risks exceed the thresholds for human health, thus triggering an FS. The ecological risk assessment concludes that using groundwater concentrations representative of the average, there is no evidence for potential ecological risk for 200-ZP-1 OU contaminants.

Based on the human health risk evaluation and ecological risk evaluation, an FS must be performed to evaluate the appropriate remedial alternatives. By agreement between the U.S. Department of Energy, Richland Operations Office (RL) and the U.S. Environmental Protection Agency (EPA), the detailed baseline risk assessment will be performed as part of the FS.

The 200 Areas of the Hanford Site contain four groundwater OUs: 200-ZP-1, 200-UP-1, 200-BP-5, and 200-PO-1. This RI report describes the aquifer characterization and groundwater remedial activities for the 200-ZP-1 OU in the 200 West Area. The plate map in Appendix A illustrates the groundwater monitoring well network, groundwater contaminant plumes, facilities, and other features of the 200-ZP-1 and 200-UP-1 OUs. The 200-ZP-1 OU includes Z Plant, T Plant, Low-Level Waste Management Areas 3 and 4 (LLWMA-3 and LLWMA-4), T Tank Farm, TX-TY Tank Farms, the State-Approved Land Disposal Site (SALDS), and various cribs and trenches that received liquid waste. The 200 West Area facilities and waste sites are shown on the plate map in Appendix B.

The primary objectives of this RI report for the 200-ZP-1 OU are listed below. After stating the objectives of this RI report, the regulatory basis and milestone information are discussed, followed by a more detailed discussion of each objective.

1. Estimate the nature and extent of groundwater contamination that currently exists within the 200-ZP-1 OU sufficiently to screen remediation alternatives in the subsequent FS and to support remediation activities.

2. Integrate and evaluate information from CERCLA and the *Resource Conservation and Recovery Act of 1976* (RCRA) efforts to identify potential saturated zone contaminants and characterize the subsurface hydrogeology and aquifer properties.
3. Determine if a FS and baseline risk assessment are required.
4. Determine if sufficient data have been collected to support the preparation of a baseline risk assessment and FS.
5. Present aquifer property and contaminant data to support fate and transport modeling.
6. Combine data from the 200-ZP-1 and 200-UP-1 OUs to develop a comprehensive distribution model of the carbon tetrachloride plume that underlies both areas.
7. Identify groundwater contaminants to be evaluated in human health and ecological risk assessments in the upcoming FS.

As agreed by EPA and RL in the October 2005 200 Area Unit Managers' meeting (FH 2005a), this RI report does not include a complete baseline risk assessment. The EPA subsequently agreed that the Pacific Northwest National Laboratory report, *Recent Site-Wide Transport Modeling Related to the Carbon Tetrachloride Plume at the Hanford Site* (Bergeron and Cole 2004), provides sufficient risk modeling and carbon tetrachloride groundwater plume analysis to support the preparation of this RI report. The forthcoming FS will include a baseline risk assessment. The contaminant of potential concern evaluation in this RI includes screening against preliminary remediation goals that are based on drinking water maximum contaminant levels or *Model Toxics Control Act* formula "B" numbers, which ever is lower. These goals are based on risk or best available technology when risk concentrations are not routinely measurable.

The RI activities for the 200-ZP-1 OU are described in this RI report according to the requirements of CERCLA and are consistent with the goals and objectives in the *Remedial Investigation/Feasibility Study Work Plan for the 200-ZP-1 Groundwater Operable Unit* (DOE-RL 2004c). This RI report conforms to the conditions set forth in the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) and amendments (Ecology et al. 2003) signed by the Washington State Department of Ecology (Ecology), EPA, and RL, including Tri-Party Agreement Milestone M-015-00C for completing all 200 Area non-tank farm OU pre-Record of Decision documents on or before December 31, 2008.

Contaminants from treatment, storage, and/or disposal (TSD) units in the 200-ZP-1 OU that impact groundwater are included in this RI report because the groundwater OU will be remediated under CERCLA. The TSD unit groundwater monitoring requirements are not considered in this RI report because either the conditions of *Washington Administrative Code* (WAC) 173-303-645(1)(e) have not been satisfied or a separate agreement exists on how requirements will be met. The Waste Site Remediation Project (WSRP) and the Tank Farms Project will predict impacts to the groundwater from the single-shell tank (SST) system RCRA TSD unit sites in the 200-ZP-1 OU when data are available. The WSRP is scheduled for completion in 2017. The anticipated groundwater data schedule for TSD units and certain non-TSD unit locations is outlined below:

- **SST system TSD unit Waste Management Area T (WMA-T):** 2028 closure date.
- **SST system TSD unit WMA-TX/TY:** 2028 closure date.
- **Low-Level Burial Grounds TSD unit LLWMA-3 and LLWMA-4:** No individual closure dates are established. However, all 200 Area non-tank farm OUs must be closed by 2024 in accordance with the Tri-Party Agreement Milestone M-016-00 (Ecology et al. 2003). Note also that a portion of LLWMA-4 is also part of the 200-UP-1 OU.
- **SALDS:** Although this disposal location is located outside of the 200 West Area boundary and it is not a TSD unit, a tritium plume from the discharge to SALDS is monitored but is not expected to impact other plumes in the 200-ZP-1 Groundwater OU. This disposal location is active, and no individual closure date is established other than Tri-Party Agreement Milestone M-016-00 (Ecology et al. 2003). The disposal location supports operation of the 200 Area Effluent Treatment Facility.

The WSRP is evaluating potential contaminant flux from CERCLA vadose zone waste sites to groundwater in the Z Plant vicinity. The ongoing vadose zone studies will continue to provide data for updating groundwater and risk assessment models. The WSRP is also evaluating the partitioning of dense nonaqueous phase liquids (DNAPLs), including the presence or absence of free-phase DNAPLs, within the 200-ZP-1 OU. The vadose zone and groundwater DNAPL investigations currently being performed in the vicinity of the 216-Z-9 Trench are addressed by the *Sampling and Analysis Plan for Investigation of Dense Nonaqueous Phase Liquid Carbon Tetrachloride at the 216-Z-9 Trench* (DOE-RL 2003d). The remaining DNAPL characterization

efforts are addressed by the sampling and analysis plan (SAP) in Appendix B of *Plutonium/ Organic-Rich Process Condensate/Process Waste Group Operable Unit RI/FS Work Plan: Includes the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units* (DOE-RL 2004b).

- **Objective #1:** The first RI objective is addressed in Sections 2.0, 3.0, and 4.0 for estimating the nature and extent of 200-ZP-1 groundwater contamination sufficiently to screen remediation alternatives in the subsequent FS and to support remediation activities. The approach for collecting and evaluating contaminant concentrations and modeling input parameters (e.g., geotechnical, hydrologic, and geochemical aquifer properties) is described in Section 2.0. Groundwater monitoring and characterization for the 200-ZP-1 RI were conducted in accordance with the SAP in Appendix A of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c).

  Section 3.0 describes several studies that were performed based on 200-ZP-1 OU groundwater data to develop a better understanding of the saturated zone contaminants and properties. The RCRA TSD unit groundwater monitoring results, SALDS groundwater monitoring results, interim pump-and-treat system performance, and pertinent vadose zone investigations are also summarized in Section 3.0

  Section 4.0 describes the contaminant of concern (COC) concentration and aquifer data, including depth-discrete sampling results that were obtained through the plans presented in Section 2.0.

  The current groundwater flow direction in the 200-ZP-1 OU is generally from west to east. The lateral extent of the plumes and their locations are shown in the plate map in Appendix A. The carbon tetrachloride groundwater plume emanates from the Z Plant area and underlies most of the 200 West Area, spanning across both the 200-ZP-1 and 200-UP-1 OUs. The nitrate plume underlies most of the operational area of 200 West Area in 200-ZP-1 OU. More localized plumes of chromium and technetium-99 underlie WMA-T. Technetium-99 is undergoing further evaluation with respect to its depth in the 200-ZP-1 OU east of the WMA-T area. The uranium plume underlies the T Plant area. Iodine-129 and tritium are spreading east, to an area northeast of the TX-TY Tank Farms. Two localized plumes of uranium and technetium-99 are located east of the TX-TY Tank Farms. A trichloroethylene (TCE) plume begins north of Z Plant and underlies the

TX-TY Tank Farms, extending north beyond WMA-T. Although a fluoride plume is noted in the annual Sitewide groundwater report (PNNL 2006), the risk evaluation did not note it as an identified risk driver.

A critical component of the 200-ZP-1 subsurface characterization effort is the collection of depth-discrete contaminant concentration and aquifer property data for evaluating the three-dimensional distribution and projected movement of contaminants in the saturated zone. Important depth-discrete data are described in Section 4.0 for monitoring wells that were drilled during fiscal year 2004 (FY04) and FY05. Additional depth-discrete data will be collected from wells that are planned to be drilled in the 200-ZP-1 OU. Four additional 200-ZP-1 RCRA wells (i.e., LLWMA-5, LLWMA-8, LLWMA-13, and LLWMA-17) are currently planned for the monitoring well network. The carbon tetrachloride and technetium-99 depth-discrete data are described in the discussion for the fourth RI objective in this executive summary.

- **Objective #2:** The second RI report objective is the integration of data from both CERCLA and RCRA programs, which are also described in Sections 2.0, 3.0, and 4.0. The following data were collected and evaluated from both RCRA and CERCLA wells:
  - COC concentrations
  - Aquifer properties
  - Depth-discrete groundwater results.

  For the carbon tetrachloride, data from both the 200-ZP-1 and the 200-UP-1 OUs were considered because this plume is in both OUs.

- **Objective #3:** Sections 2.0, 3.0, and 4.0 address the third RI objective of obtaining sufficient data to support fate and transport modeling. Section 2.0 identifies aquifer properties that are measured as inputs for fate and transport modeling. Saturated aquifer sediments were evaluated for particle-size distribution, calcium carbonate content, bulk density, lithology, hydraulic conductivity, cation exchange capacity, major cation content, total organic and inorganic carbon content, partition (or distribution) coefficient (K_d), and pH. In addition, groundwater properties included hydraulic gradient, well development parameters (i.e., flow rate, water-level drawdown, and pumping

performance), dispersivity, specific conductivity, alkalinity, dissolved oxygen, turbidity, pH, and temperature.

Section 3.0 describes the results of K_d and other aquifer studies. Aquifer slug tests and other studies provided data that will be used in the FS to predict the movement of COCs in the saturated zone and to evaluate their response to remedial alternatives. Several studies focused on the released amount, current disposition, and projected movement of carbon tetrachloride in the 200-ZP-1 OU. Depth-discrete groundwater monitoring data were collected to show the vertical distribution of COCs within the aquifer and to monitor the movement of COCs in groundwater over time. This information will be used to support the screening of alternatives and baseline risk assessment in the FS. Pilot tests may be required in the future to determine the viability of various remedial alternatives in an FS. Section 4.0 presents the results of the COC concentration and aquifer property data-gathering activities introduced in Section 2.0.

- **Objective #4:** The fourth RI objective is addressed in Sections 4.3 and 4.4. The fourth objective is to generate data to develop comprehensive model of the three-dimensional distribution of carbon tetrachloride in the 200-ZP-1 and 200-UP-1 OUs. In addition, depth-discrete data are presented to develop a localized three-dimensional model of technetium-99 in the WMA-T area.

  The lateral extent and varying concentrations of carbon tetrachloride in groundwater are described in Section 4.3. Depth-discrete groundwater concentration data for carbon tetrachloride and three of its potential degradation compounds (i.e., chloroform, methylene chloride, and chloromethane) from wells in both OUs are discussed in Section 4.4. Depth-discrete groundwater concentrations of the four compounds in 200-ZP-1 and 200-UP-1 OUs are combined on the three plate maps in Appendix C. These plate maps include cross-sections, vertical concentration plots, and isoconcentration contours of carbon tetrachloride (at three separate depth intervals) and its degradation products.

  The conceptual model of the carbon tetrachloride groundwater plume is that the plume extends vertically from the top of the unconfined aquifer near the disposal source areas by the Plutonium Finishing Plant, to the base of the unconfined aquifer at the top of the

Ringold Lower Mud Unit (Unit 8). The plume extends through the Ringold Formation to the top of basalt where the Unit 8 confining layer is absent, as at well 299-W13-1. The conceptual model also shows that as the distance from the source area increases in a downgradient direction, the highest carbon tetrachloride concentrations occur deeper in the unconfined aquifer. The model indicates that recharge from natural infiltration and less-contaminated former wastewater discharges contribute to reduced carbon tetrachloride concentrations in the upper portion of the unconfined aquifer in a downgradient direction from the source area.

Although not shown in the vertical plots on the plate maps in Appendix C, the approximate depth to groundwater in the wells ranges from about 67 to 76 m (220 to 250 ft) below ground surface (bgs) and the approximate depth to the Ringold Lower Mud Unit ranges from about 113 to 134 m (370 to 440 ft) bgs. In general, the elevation of the water table decreases from west to east, and the elevation of the Ringold Lower Mud Unit increases from southwest to northeast.

In general, the depth of the maximum concentration of chloroform is similar to the depth of the maximum concentration of carbon tetrachloride in each well. A few wells show low levels of methylene chloride present within the aquifer. Fewer wells have detectable concentrations of chloromethane. The chloroform, methylene chloride, and chloromethane contaminants may be the result of carbon tetrachloride degradation. In addition, if the degradation is from reductive dechlorination, the reduction occurs in the following order: carbon tetrachloride to chloroform, to methylene chloride, and then to chloromethane. This would account for the decreasing concentrations of the three degradation products.

In addition to carbon tetrachloride, depth-discrete data are collected for technetium-99. A technetium-99 plume has been identified northeast of WMA-T, where the T Tank Farm is located. The technetium-99 plume was previously thought to be located at the water table. A new well, 299-W11-25B, was located in the northeast corner of WMA-T to assess the vertical extent of the technetium-99. Recent data from well 299-W11-25B indicate technetium-99 concentrations at 180,000 pCi/L at a depth of 10 m (approximately 9.1 m [30 ft]) below the water table. It must be noted that the maximum

depth of the nitrate concentrations is the same as the maximum depth of the technetium-99 concentrations.

In order to assess the lateral extent of the technetium-99 plume in the deeper unconfined aquifer, well 299-W11-45 was drilled approximately 80 m (262.5 ft) downgradient (east) of well 299-W11-25B. Well 299-W11-45 was sampled every 1.5 m (4.9 ft) throughout the top 56 m (183.7 ft) of the aquifer. The nitrate and technetium-99 concentrations are shown in Figure 4-42. Again, the depth distributions of both contaminants are similar to that of well 299-W11-25B; however, the maximum concentrations are lower. Additional wells are planned in the area during FY06 to assess the lateral and vertical extent of the technetium-99 plume.

- **Objective #5:** The fifth RI objective is addressed in Sections 1.0, 2.0, 4.0, 5.0, and 6.0. The objective is to identify groundwater contaminants for detailed risk assessment in the upcoming FS; both human and ecological receptors are evaluated. Section 1.0 describes how groundwater contaminants are divided into two broad "Group A" and "Group B" categories. Group A is composed of eight contaminants with identified and mapped groundwater plumes: carbon tetrachloride, total chromium, iodine-129, nitrate, technetium-99, TCE, tritium, and total and radioactive uranium. Group B is composed of 47 other groundwater contaminants that are found in relatively lower concentrations and in fewer wells. Group A was evaluated using the logic in Figure 1-3, and Group B was evaluated using the logic in Figure 1-4. The result of the evaluation was a list of analytes that is shown in Table ES-1. The COCs for additional risk evaluation to human receptors include the Group A (i.e., eight major risk drivers) and six additional Group B analytes. Four analytes pose potential risk to the ecological receptors.

  Both groups of contaminants were subjected to a data quality assessment (DQA) process conducted according to the requirements of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) and *Data Quality Objectives Summary Report Supporting the 200-ZP-1 Operable Unit Remedial Investigation/Feasibility Study Process* (FH 2003c). The DQA presented in Appendix F demonstrates that the data meet the established data quality objectives.

  Section 6.0 presents the results of initial fate and transport and risk modeling for carbon tetrachloride, technetium-99, iodine-129, and total and radioactive uranium. It is

emphasized that this is not the baseline risk assessment that will be performed in the FS. Tables 6-6, 6-7, and 6-8 summarize the preliminary risks and doses. Depending on the risk scenario, the hazard quotient (HQ) for carbon tetrachloride ranged from 171 to 815. The HQs greater than one must be address in the FS. Total uranium HQs for both scenarios range from 8.57 to 49.5, which is well above one. The cancer risks range from 2.94E-04 to 1.93E-06, depending on the risk scenario and radionuclide.

Table ES-1. Contaminants of Concern for Risk Evaluation in the Feasibility Study.

Human Health COCs			Ecological COCs
Group A (Potential Major Risk Driver) Analytes	Group B Analytes With <10% of Results > PRG and 95% UCL of Results > PRG	Group B Analytes With >10% of Results > PRG and 95% UCL of Results > PRG	HQ >1, Average Concentration and 0.5 DF, as Discussed in Section 7.4
Carbon tetrachloride[a]	Antimony	Hexavalent chromium	Carbon tetrachloride
Chromium (total)	1,2-dichloroethane	Iron	Cyanide
I-129	Tetrachloroethylene (PCE)	Chloroform	Hexavalent chromium
Nitrate			Uranium (total)
Tc-99			
Trichloroethylene (TCE)			
Tritium			
Uranium (total and radioactive)			

[a] Retain methylene chloride for additional evaluation because it is a potential degradation product of carbon tetrachloride.

COC = contaminant of concern
DF = dilution factor
HQ = hazard quotient
PRG = preliminary remediation goal
UCL = upper confidence limit

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LIST OF TERMS

AAMSR	aggregate area management study report
ACTSTL	Alternatives for Carbon Tetrachloride Source Term Location
AEA	*Atomic Energy Act of 1954*
ALARA	as low as reasonably achievable
ARAR	applicable or relevant and appropriate requirement
ASTM	American Society for Testing and Materials
bgs	below ground surface
BCG	biota concentration guide
BDAC	Biota Dose Assessment Committee
CAS	Chemical Abstract Services
CEC	cation exchange capacity
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
COPEC	contaminant of potential environmental concern
CRDL	contract-required detection limit
DF	dilution factor
DNAPL	dense nonaqueous phase liquid
DO	dissolved oxygen
DOE	U.S. Department of Energy
DQA	data quality assessment
DQO	data quality objective
DWS	drinking water standard
EC	electrical conductivity
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERA	expedited response action
FH	Fluor Hanford, Inc.
FS	feasibility study
FY	fiscal year
GAC	granular activated carbon
gpm	gallons per minute
HEIS	Hanford Environmental Information System
HQ	hazard quotient
HSRAM	*Hanford Site Risk Assessment Methodology*
HUMAN	Human Health Risk Assessment Module
IRM	interim remedial measure
ITRD	Innovative Treatment and Remediation Demonstration
K_a	abiotic degradation
K_d	partition (or distribution) coefficient
K_h	hydraulic conductivity

LFI	limited field investigation
LLBG	Low-Level Burial Grounds
LLWMA	low-level waste management area
MCL	maximum contaminant limit
MDL	method detection limit
MTCA	*Model Toxics Control Act*
NAPL	nonaqueous phase liquid
ND	nondetect
NTU	nephelometric turbidity unit
ORP	U.S. Department of Energy, Office of River Protection
OU	operable unit
PCE	tetrachloroethylene
PFP	Plutonium Finishing Plant
PNNL	Pacific Northwest National Laboratory
ppm	parts per million
ppmv	parts per million by volume
PQL	practical quantitation limit
PRF	Plutonium Reclamation Facility
PRG	preliminary remediation goal
PUREX	Plutonium Uranium Extraction (Plant)
QC	quality control
RAIS	Risk Assessment Information System
RAO	remedial action objective
RBC	risk-based concentration
RCBRA	River Corridor Base Risk Assessment
RCRA	*Resource Conservation and Recovery Act of 1976*
RDR/RAWP	remedial design report/remedial action work plan
RECUPLEX	Recovery of Uranium and Plutonium by Extraction
REDOX	Reduction-Oxidation (Plant)
RESRAD	RESidual RADioactivity dose model
RfD	reference dose
RFI/CMS	*Resource Conservation and Recovery Act of 1976* field investigation/ corrective measures study
RI	remedial investigation
RL	U.S. Department of Energy, Richland Operations Office
ROD	Record of Decision
SALDS	State-Approved Land Disposal Site
SAP	sampling and analysis plan
SARA	*Superfund Amendments and Reauthorization Act of 1986*
SST	single-shell tank
STOMP	Subsurface Transport Over Multiple Phases
SVE	soil vapor extraction
TBD	to be determined
TCE	trichloroethylene
TIC	total inorganic carbon

TOC	total organic carbon
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
TSD	treatment, storage, and disposal
UCL	upper confidence limit
UPR	unplanned release
VET	Vista Engineering Technologies, LLC
VOC	volatile organic compound
WAC	*Washington Administrative Code*
WDOH	Washington State Department of Health
WMA	waste management area
WMU	waste management unit
WSRP	Waste Site Remediation Project
XRD	x-ray diffraction

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METRIC CONVERSION CHART

Into Metric Units			Out of Metric Units		
If You Know	*Multiply By*	*To Get*	*If You Know*	*Multiply By*	*To Get*
Length			**Length**		
inches	25.4	millimeters	millimeters	0.039	inches
inches	2.54	centimeters	centimeters	0.394	inches
feet	0.305	meters	meters	3.281	feet
yards	0.914	meters	meters	1.094	yards
miles	1.609	kilometers	kilometers	0.621	miles
Area			**Area**		
sq. inches	6.452	sq. centimeters	sq. centimeters	0.155	sq. inches
sq. feet	0.093	sq. meters	sq. meters	10.76	sq. feet
sq. yards	0.836	sq. meters	sq. meters	1.196	sq. yards
sq. miles	2.6	sq. kilometers	sq. kilometers	0.4	sq. miles
acres	0.405	hectares	hectares	2.47	acres
Mass (weight)			**Mass (weight)**		
ounces	28.35	grams	grams	0.035	ounces
pounds	0.454	kilograms	kilograms	2.205	pounds
ton	0.907	metric ton	metric ton	1.102	ton
Volume			**Volume**		
teaspoons	5	milliliters	milliliters	0.033	fluid ounces
tablespoons	15	milliliters	liters	2.1	pints
fluid ounces	30	milliliters	liters	1.057	quarts
cups	0.24	liters	liters	0.264	gallons
pints	0.47	liters	cubic meters	35.315	cubic feet
quarts	0.95	liters	cubic meters	1.308	cubic yards
gallons	3.8	liters			
cubic feet	0.028	cubic meters			
cubic yards	0.765	cubic meters			
Temperature			**Temperature**		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius	Celsius	multiply by 9/5, then add 32	Fahrenheit
Radioactivity			**Radioactivity**		
picocuries	37	millibecquerel	millibecquerels	0.027	picocuries

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1.0 INTRODUCTION

The remedial investigation (RI) activities for the 200-ZP-1 Groundwater Operable Unit (OU) are described in this report in accordance with the requirements of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA). This RI report conforms to the conditions set forth in the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) and amendments (Ecology et al. 2003) signed by the Washington State Department of Ecology (Ecology), U.S. Environmental Protection Agency (EPA), and U.S. Department of Energy (DOE), Richland Operations Office (RL), including Tri-Party Agreement Milestone M-015-00C for completing all 200 Area non-tank farm OU pre-Record of Decision (ROD) documents on or before December 31, 2008. The RI report supports the final remedy selection for the 200-ZP-1 OU in the *Remedial Investigation/Feasibility Study Work Plan for the 200-ZP-1 Groundwater Operable Unit* (DOE-RL 2004c), as agreed upon by RL and EPA.

The location of the 200-ZP-1 OU within the 200 West Area of the Hanford Site is shown in Figure 1-1. The 200-ZP-1 Groundwater OU is one of two groundwater OUs located within the 200 West groundwater aggregate area of the Hanford Site. A plate map of the 200-ZP-1 and the 200-UP-1 OUs is presented in Appendix A. The 200-ZP-1 OU groundwater underlies Z Plant, T Plant, Low-Level Waste Management Areas 3 and 4 (LLWMA-3 and LLWMA-4), T Tank Farm, TX-TY Tank Farms, the State-Approved Land Disposal Site (SALDS), and various cribs and trenches receiving liquid waste. The 200-ZP-1 OU background, physical setting, contaminants of concern (COCs), and conceptual model information are discussed in various project documents and are summarized in Section 1.5.

As described in the 200-ZP-1 RI/FS work plan (DOE-RL 2004c), the primary goals of the RI report are to define the nature and extent of groundwater contamination as it is currently understood, and to present analytical and other data that will later be used to support the preparation of a baseline risk assessment and a feasibility study (FS). The FS will support the selection of a final remedy. Tri-Party Agreement Milestone M-015-00C requires the completion of all non-tank farm pre-ROD documents by December 31, 2008.

For the 200-ZP-1 CERCLA RI/FS process, the baseline risk assessment will be reported in the FS. As agreed upon by RL and EPA, and as documented in an attachment to the October 2005, 200 Area Unit Managers' Meeting minutes (FH 2005a), a baseline risk assessment is not included in the RI report because of pending efforts to acquire sufficient modeling data, including the following:

- Additional carbon tetrachloride analysis of groundwater samples from the base of the unconfined aquifer
- Installation and sampling of at least three new wells in the vicinity of the Old Laundry Facility and T Plant
- Completion of a technetium-99 study in the T Plant area
- Estimation of the carbon tetrachloride and technetium-99 mass in the unconfined aquifer
- Update of the vadose zone and groundwater models to facilitate parameter adjustments, addition of new data, and inclusion of a declining water table

- Projection of whether identified groundwater plumes could migrate outside the 200 West Area.

The above risk assessment data and modeling requirements were discussed and agreed upon by EPA, RL, Fluor Hanford, Inc. (FH), and Pacific Northwest National Laboratory (PNNL) representatives in Central Plateau Remediation Project meetings on August 3, 2005, and September 15, 2005. The EPA subsequently agreed that PNNL's report, *Recent Site-Wide Transport Modeling Related to the Carbon Tetrachloride Plume at the Hanford Site* (Bergeron and Cole 2004), provides sufficient risk modeling and carbon tetrachloride groundwater plume analysis to support the RI report preparation, and no additional modeling was required at this time. Future modeling plans are described in further detail in Section 7.3.

A number of treatment, storage, and/or disposal (TSD) units and a non-TSD unit disposal location are located within the 200-ZP-1 OU boundary. Possible COCs originating from these TSD units that are impacting groundwater have been included in this RI report because the groundwater OU will be remediated under CERCLA. The TSD compliance issues are not considered in this RI report because these facilities are regulated under the *Resource Conservation and Recovery Act of 1976* (RCRA). The Waste Site Remediation Project (WSRP) and the Tank Farms Project will predict impacts to groundwater from RCRA sites in the 200-ZP-1 OU when data are available. The WSRP is scheduled for completion in 2017. The anticipated groundwater data schedule is outlined below:

- **Single-Shell Tank (SST) system TSD unit Waste Management Area T (WMA-T):** 2028 closure date.
- **SST system TSD unit WMA-TX/TY:** 2028 closure date.
- **Low-Level Burial Grounds (LLBG) TSD unit LLWMA-3 and LLWMA-4:** No individual closure dates are established. However, all 200 Area non-tank farm OUs must be closed by 2024 in accordance with the Tri-Party Agreement Milestone M-016-00 (Ecology et al. 2003).
- **SALDS:** Although this disposal location is located outside of the 200 West Area boundary and it is not a TSD unit, a tritium plume from the discharge to this location is monitored because it could impact other plumes in the 200-ZP-1 Groundwater OU. This disposal location unit is active and no individual closure date is established other than Tri-Party Agreement Milestone M-016-00 (Ecology et al. 2003). The disposal location supports operations of the 200 Area Effluent Treatment Facility.

Additional waste sites that could impact groundwater are described in Sections 1.5 and 3.4. Major groundwater COCs (described later in this RI as "Group A" COCs) that were released at each waste site, or that were detected in associated groundwater samples, are discussed in Section 3.4. The waste sites include the T, TX, and TY Tank Farms. Additional discussion of the "Group A" COCs are presented in Section 4.3, including technetium-99 in Section 4.3.5. The groundwater distribution of carbon tetrachloride and technetium-99 are further discussed in Section 4.4.

Monitoring and characterization activities performed in support of this RI report were conducted in accordance with the sampling and analysis plan (SAP) in Appendix A of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c). In addition to data collected in support of the 200-ZP-1 RI/FS work plan, groundwater data from 1988 to the present are also included in this RI report.

Geotechnical, hydrologic, and geochemical data from sediments (which are needed for contaminant fate and transport modeling) are summarized in Sections 2.0 and 3.0. Depth-discrete groundwater data are presented in Section 4.0. Soil lithology is presented in Section 3.0. Additional descriptions of the parameters are available in the documents that are referenced in those sections.

The WSRP is continuing to evaluate potential contaminant flux from CERCLA vadose zone waste sites to groundwater in the vicinity of Z Plant. The ongoing vadose zone studies will continue to provide data for updating groundwater and risk assessment models. The WSRP is also evaluating the partitioning of dense nonaqueous phase liquids (DNAPLs), including the presence or absence of free-phase DNAPLs, within the 200-ZP-1 OU. The vadose zone and groundwater DNAPL investigations currently being performed in the vicinity of the 216-Z-9 Trench are addressed in the *Sampling and Analysis Plan for Investigation of Dense Nonaqueous Phase Liquid Carbon Tetrachloride at the 216-Z-9 Trench* (DOE-RL 2003d). The remaining DNAPL characterization efforts are addressed by the SAP in Appendix B of the *Plutonium/ Organic-Rich Process Condensate/Process Waste Group Operable Unit RI/FS Work Plan: Includes the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units* (DOE-RL 2004b).

1.1 PURPOSE

The primary purposes of the 200-ZP-1 RI report are (1) to define the nature and extent of groundwater contamination in the 200-ZP-1 OU; (2) to integrate and analyze information from various CERCLA and RCRA characterization studies, reports and meetings; (3) to provide a preliminary assessment of risks to the human and ecological population; (4) to identify the key COCs that pose the major risks to human health and the environment from the 55 COCs (Table 1-1) identified in the 200-ZP-1 RI/FS work plan (DOE-RL 2004c); and (5) to define vadose zone, groundwater, and risk evaluation parameters. As agreed upon by RL and EPA, and as documented in an attachment to the October 2005 200 Area Unit Managers' Meeting minutes (FH 2005a), a baseline risk assessment is not included in this RI report, but rather will rather be included in the FS.

Data analysis in this RI report is focused on the wells listed in Table 1-2, which includes the wells listed in Appendix A, Table A3-2, of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c), as well as a number of RCRA wells that are being used to supplement the database. Table 1-3 presents the original Table A3-2 from the 200-ZP-1 RI/FS work plan. Information about the TSD units and SALDS is presented for completeness. Wells and monitoring constituents related to TSD unit and SALDS compliance are determined from their respective groundwater monitoring plans, not from Tables 1-2 and 1-3.

The RI characterization efforts to date were based on EPA's *Guidance for the Data Quality Objectives Process* (EPA 2000), which was used to develop the SAP in Appendix A of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c). Both EPA and RL participated in the data quality objectives (DQO) process and generally concurred with the results. The results from this process are documented in the *Data Quality Objectives Report Supporting the 200-ZP-1 Operable Unit Remedial Investigation/Feasibility Study Process* (FH 2003c).

1.2 DOCUMENT ORGANIZATION

This RI contains eight major sections and eleven appendices as listed below:

- Section 1.0, Introduction
- Section 2.0, RI Approach
- Section 3.0, Other Supporting Studies Performed Outside of the 200-ZP-1 RI/FS Process
- Section 4.0, RI Results
- Section 5.0, Human and Ecological Risk Evaluation
- Section 6.0, Risk Evaluation
- Section 7.0, Summary
- Section 8.0, References
- Appendix A, Plate Map of 200-UP-1 and 200-ZP-1 Monitoring Network
- Appendix B, Plate Map of Hanford Site 200 Area Waste Sites
- Appendix C, Shallow, Middle, and Deep Plate Maps of Carbon Tetrachloride Depth-Discrete Groundwater Data for the 200 West Area
- Appendix D, 200 Area Maps of Liquid Release Inventory Data
- Appendix E, Complete COC Data Set
- Appendix F, Data Evaluation and Data Summary Tables
- Appendix G, COC Concentration Trend Graphs
- Appendix H, Data Quality Assessment
- Appendix I, Summary Data Results from Each COC Evaluation Logic
- Appendix J, Detailed Data Results from Each COC Evaluation Logic
- Appendix K, Minimum and Maximum Nondetected and Detected Analytes
- Appendix L, Vertical COC Concentration Plots for RI/FS Wells
- Appendix M, Vertical COC Concentration Plots for Other 200-ZP-1 Wells
- Appendix N, Vertical COC Concentration Plots for Sediments and Soil Gas from the RI/FS Wells
- Appendix O, Gamma Logs
- Appendix P, Soil Inventory.

1.3 SUPPORTING DOCUMENTS AND REMEDIAL INVESTIGATION BASIS

Supporting documents for this RI report are summarized in Table 1-4. Other references are listed in Section 8.0.

1.4 DATA EVALUATION METHODOLOGY

The data evaluation procedures described below are designed to differentiate between COCs that require more extensive human health risk assessment in the FS and other COCs that are not the major determinants of human health risk. The procedures are applied to all of the wells listed in Table 1-2. Alternative procedures could be followed during compliance monitoring after a ROD is approved.

1.4.1 Contaminants of Concern Identification

Groundwater plumes are identified for eight major COCs and are shown on the map in Figure 1-2 and the plate map in Appendix A. These are referred to throughout the remainder of this RI report as "Group A" COCs. None of the 47 other COCs are found in high enough concentrations and/or in enough wells to justify drawing plumes; these are referred to throughout the remainder of this RI report as "Group B" COCs. The monitoring and extraction wells within the mapped plume boundaries are included in Table 1-2. A separate set of evaluation procedures is presented for each of the COC groups. Flowcharts of the procedures are shown in Figure 1-3 for Group A COCs and in Figure 1-4 for Group B COCs. The logic for the COC evaluation was documented in an attachment to the October 2005 200 Area Unit Managers' Meeting minutes (FH 2005a). The outcome of these evaluations is presented in Section 4.2.

The "Group A" COC groundwater plumes on the plate map in Appendix A are primarily based on interpretations of 200-ZP-1 groundwater analytical data from fiscal year 2005 (FY05). Groundwater analytical data from FY03 through FY04 are included from 200-ZP-1 wells for which FY05 data are unavailable. The areal depiction of the eight plumes in Appendix A is intended to represent an estimated lateral extent of each "Group A" COC for the indicated concentration or activity level in the shallow portion of the unconfined aquifer. The depicted isopleths are derived from annual average concentrations and activity levels and are not based solely on depth-discrete analytical data.

1.4.1.1 Group A Contaminant of Concern Data Evaluation. Eight groundwater plumes are mapped in the 200-ZP-1 OU, as discussed in the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) and *Hanford Site Groundwater Monitoring for Fiscal Year 2005* (PNNL 2006). The eight Group A COCs include the following: total chromium, carbon tetrachloride, iodine-129, nitrate, technetium-99, trichloroethylene (TCE), tritium, and radioactive/total uranium. The Group A COCs were previously identified as potential human health risk drivers in the 200-ZP-1 RI/FS work plan. Each Group A COC is separately evaluated for monitoring and extraction wells within the mapped plume boundaries in Figure 1-2. For ease of evaluation, the question numbers identified in Figure 1-3 are also identified in brackets in each step below:

1. For each Group A COC, analytical data are grouped into one data set from wells within the applicable plume boundary. The wells that are grouped for data evaluation are associated with a mapped plume and are listed as "Group A" wells in Table 1-2. Other wells in Table 1-2 were not used if they were not associated with a mapped groundwater plume. The result is eight data sets that are evaluated in steps 2 through 4 below.
2. If the Group A COC concentration for any sample in a data set is greater than twice the preliminary remediation goals (PRGs) [A-1] (Figure 1-3) or if 10% or more of the concentrations in the data set exceed the PRGs, the COC is included in the baseline risk assessment and potential remedial actions are evaluated in the FS [A-2] (Figure 1-3).

No further statistical analysis is required at this time. Additional statistical analysis is not precluded for the FS or compliance monitoring.

3. If less than 10% of the Group A COC concentrations in the data set exceed the PRGs, then the concentration trend is evaluated in the RI according to the following decision rules and statistical analyses:
   - For concentrations below the method detection limit (MDL), 50% of the MDL is used in statistical calculations. If no MDL exists, the practical quantitation limit (PQL) is used.
   - If less than 15% of the data are between the MDL and the PQL, then assign a value equal to the PQL to each data point.
   - If 15% to 50% of the concentrations are below the PQL, and all PQLs are equal and the data are distributed normally or log normally, then use Cohen's method to calculate the mean, standard deviation, and upper confidence limit (UCL).
   - If 15% to 50% of the concentrations are below the PQL, and all PQLs are not equal, and/or the data are not distributed normally or log normally, then other applicable statistical analyses will be selected. The logic and statistical reference will be provided in the subsequent discussions when these alternate approaches are required.
   - If greater than 50% of the concentrations are below the PQL, then the largest value in the data set is substituted for the UCL.
4. If the concentration for the 95% UCL or the largest PQL from step 3 exceeds the PRG, then potential remedial actions are evaluated in the FS for the primary COC. Otherwise, no further action is required [A-3] (Figure 1-3).

1.4.1.2 Group B Secondary Contaminant of Concern Data Evaluation. The Group B COCs include contaminants that were detected in the wells listed in Table 1-2 (also see Section 4.2 and Table 1-5 of this RI report). The selected limit in Table 1-5 is the PRG or action limit. The source column in Table 1-5 provides the basis of the PRG, as previously detailed in the 200-ZP-1 RI/FS work plan (DOE-RL 2004c). The Group B COCs are also based on Table A1-7 in Appendix A of the 200-ZP-1 RI/FS work plan.

Table 1-5 specifies the PRG or selected limit for the antimony as the maximum contaminant level (MCL). The MCL is lower than the contract-required detection limit (CRDL). The goal is for the CRDL to be well below the PRG, which is the MCL in this case. Previously used analytical methods cannot routinely achieve CRDLs below the MCL. Efforts are being made to specify methods (e.g., graphite furnace atomic absorption) that will meet the MCL. In addition, antimony is not a primary "risk driver" in the 200-ZP-1 OU. The EPA's *Risk Assessment Guidance for Superfund (RAGS), Volume 1, Human Health Evaluation Manual (Part A), Interim Final* (EPA 1989) and *Washington Administrative Code* (WAC) 173-340-707 indicate that a CRDL may be used to assess the need for action if EPA methods are used and reasonable approaches are implemented to lower reporting limits. Because antimony is not a primary "risk driver" and reasonable CRDLs have been attempted, added efforts to obtain CRDLs below the 6 μg/L MCL are not planned at this time.

The following procedures for identifying "indicator substances" are obtained from WAC 173-340-703. The procedures are intended to determine whether any of the secondary COCs should be included in the baseline risk assessment.

For each Group B COC, analytical data from wells within the 200-ZP-1 OU (see Table 1-2) are grouped into a single data set. Each of Group B COCs is evaluated separately. For each step below, the question number from Figure 1-4 (e.g., B-1) is identified in brackets:

1. No further action is required for analytes that are not detected [B-0] (Figure 1-4).
2. If all of the results for the analyte are below the PRG, no further action is required [B-1] (Figure 1-4).
3. If any result for a detected analyte is above the PRG and the analyte is a common laboratory solvent (e.g., methylene chloride, acetone, toluene, etc.), the associated sample is evaluated for potential cross-contamination with the "5–10 rule." The 5-10 rule is based on the EPA's *Laboratory Data Validation Functional Guidelines for Evaluating Organic Analyses* (Bleyler 1988) and Chapter 1 of *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods* (EPA 1999). These rules indicate that the detection of the analyte may be due to contamination if the associated sample concentrations are less than 5 times the blank or (for common laboratory contaminants) are less than 10 times the blank. Note that the blank may be a laboratory preparation blank, a trip blank, or a field blank. Common laboratory contaminants, as defined by the EPA's functional guidelines, are methylene chloride, toluene, acetone, and the phthalate compounds [B-2, yes] (Figure-1-4).
   - No further action is required if the detected concentrations of the analyte are less than either 5 or 10 times the applicable field blank concentrations [B-4, no] (Figure 1-4).
   - For analytes with concentrations greater than 5 or 10 times the field blank concentrations, the analytical data and samples are further evaluated for persistence, frequency, trends, location, and presence of an identified plume [B-4, yes] (Figure 1-4).
4. An analyte that is not a common laboratory solvent or plasticizer is included in the baseline risk assessment if 10% or more of its detected concentrations exceed PRGs. No further statistical analysis is required. Potential remediation of the analyte would be considered in the pending baseline risk assessment of the FS based on persistence in the environment, location of wells containing the analyte, frequency of detection, etc. [B-3, yes] (Figure 1-4).
5. For analytes that are not common laboratory solvents and are detected above the PRGs at a frequency of less than 10%, the analytes are evaluated for persistence, frequency, trends, location, presence of an identified plume, and chemical and physical properties that affect fate and transport. The decision rules and statistical analyses applied to primary COCs may also be applied to the secondary COCs. The Group B COC evaluation of similar frequency of detection are listed below [B-3, no] (Figure 1-4):
   - For concentrations below the MDL, 50% of the MDL is used in statistical calculations. If no MDL exists, the PQL is used.

- If less than 15% of the data are between the MDL and PQL, then assign a value equal to the PQL to each data point.
- If 15% to 50% of the concentrations are below the PQL, all PQLs are equal, and the data are distributed normally or log normally, then use Cohen's method to calculate the mean, standard deviation, and UCL.
- If 15% to 50% of the concentrations are below the PQL, and all PQLs are not equal, and/or the data are not distributed normally or log normally, then other applicable statistical analyses will be selected. The logic and statistical reference will be provided in the subsequent discussions when these alternate approaches are required.
- If greater than 50% of the concentrations are below the PQL, then the largest value in the data set is substituted for the UCL.

1.4.2 Modeling Approach

As documented in an attachment to the October 2005 200 Area Unit Managers' Meeting minutes (FH 2005a), RL and EPA agreed to defer a baseline risk assessment to the FS to allow more time for completion of groundwater plume characterization efforts. The 200-ZP-1 drilling, sampling, analysis, and modeling efforts are currently focused on developing a detailed understanding of the distribution and movement of four major risk-driving COCs in the vadose and saturated zones: carbon tetrachloride, technetium-99, iodine-129, and uranium. If possible, the characterization results will be included in a baseline risk assessment that is planned as part of the FS. The objective of the baseline risk assessment will be to evaluate the risks associated with predicted COC concentrations at potential exposure locations. Known and potential future COC sources will be evaluated within a relevant timeframe.

The assumed scenario for the baseline risk assessment will be based on the long-term effect of discontinuing pump-and-treat operations on existing key COC plumes. The analysis will include the current interpretations of existing plumes as initial conditions and will extend from the present through a period of 1,000 years. Potential future sources of key COCs from waste sites and facilities within the 200-ZP-1 OU will be generated using inventory estimates and the release and vadose zone using Subsurface Transport Over Multiple Phases (STOMP) transport tools.

1.4.3 Human Health Risk Evaluation

As documented in an attachment to the October 2005 200 Area Unit Managers' Meeting minutes (FH 2005a), RL and EPA agreed to limit the risk discussion in this RI report to the following:

- Preliminary estimated risks associated with the carbon tetrachloride plume developed in a previous modeling study in *Recent Site-Wide Transport Modeling Related to the Carbon Tetrachloride Plume at the Hanford Site* (Bergeron and Cole 2005)
- Preliminary estimated risks based on current interpretations of carbon tetrachloride, iodine-129, technetium-99, and uranium groundwater plumes that originate within the 200-ZP-1 OU and exceed drinking water standards (DWSs), as presented in *Hanford Site Groundwater Monitoring for Fiscal Year 2005* (PNNL 2006).

The preliminary risk information in this RI report is developed from an October 2005 update to previously predicted carbon tetrachloride concentration levels (Bergeron and Cole 2004, 2005). The preliminary risks are also based on the scenarios described in a September 1999 letter report

(BHI 1999a), in *Hanford Site Risk Assessment Methodology* (HSRAM) (DOE-RL 1995b), and in *Screening Assessment and Requirements for a Comprehensive Assessment: Columbia River Comprehensive Impact Assessment* (DOE-RL 1998). The risk scenarios are based on potential exposure pathways (e.g., ingestion, inhalation, and dermal) for COCs in groundwater, surface water, and sediments and include ingestion through consumption of contaminated fish, meat, and produce.

The Human Health Risk/Impact Module uses estimates of media- and time-specific concentrations to estimate potential impacts on the ecology of the Columbia River corridor, the health of persons who might live in or use the corridor or the upland Hanford environment, the local economy, and cultural resources. The modules that provide ecological impacts or impacts on the local economy and cultural resources are not used as a part of this RI or the planned FS.

The Human Health Risk Assessment Module (HUMAN) framework can estimate cancer and non-cancer risks to humans from contaminants in the study region. The routes of exposure will vary based on the scenarios for the assessment. The scenarios are focused on the use of potentially contaminated water and exposure to potentially contaminated soil and sediment. Locations on the Hanford Site can be assessed for various scenarios within the framework. The groundwater pathway is the primary exposure route for the contaminants. The model includes irrigation in the residential farmer scenario, which adds contamination from groundwater to the irrigated soil. The residential farmer scenario is similar to that previously used on the Hanford Site (DOE-RL 1995b), except that exposure originates from the river pathway rather than the groundwater pathway.

Two categories of impacts, carcinogenic and systemic effects, will be estimated in the human health risk assessment to evaluate an adverse impact from a contaminant to humans. Impacts will be assessed with the HUMAN computer code that was used in the Columbia River comprehensive impact assessment (DOE-RL 1998). The metrics include the following:

- Carcinogenic effects will be evaluated for radionuclides and carcinogenic chemicals. The incremental lifetime cancer risk will be calculated using available slope factors, which assumes adding in the toxic effects from all carcinogenic contaminants. In addition, the results of the human health impact assessment will be presented as an annual dose for the radionuclides considered, which is specified under DOE Order 5400.5 and DOE O 435.1.
- Systemic effects will be evaluated for noncarcinogenic radionuclides (e.g., nephrotoxic effects of uranium) and chemicals. The hazard quotient (HQ) will be calculated using available reference doses (RfDs), which assumes adding in the toxic effects from all noncarcinogenic contaminants.

Contaminants in the environment may adversely affect human health and the environment when two conditions are met: (1) the key components of a system are exposed to the contaminant, and (2) the exposure exceeds a threshold above which effects are probable. Impact is defined as an adverse change in the system being examined. The transport modules provide estimates of time-dependent contaminant concentrations from Hanford Site sources in a time-dependent manner in the vadose zone, groundwater, and the Columbia River and its associated river sediments.

Preliminary risk information presented will be developed from a selected set of existing plume concentration levels that exceed DWSs and past-predicted concentration levels of carbon tetrachloride estimated by Bergeron and Cole (2005). Risk estimates will be based on standard

exposure scenarios similar to those defined in the HSRAM (DOE-RL 1995b). During the period of institutional control, land use in the Central Plateau is assumed to be exclusive industrial, which will preclude the use of groundwater; thus, there is no dose to the industrial worker from contaminated plumes. For purposes of the risk discussion in this RI, risks estimated consider drinking water only and residential farmer scenarios using groundwater. The baseline risk analysis that is deferred until the FS may consider a broader set of exposure scenarios.

1.4.4 Ecological Risk Evaluation

There are no direct exposure pathways from Central Plateau groundwater to ecological receptors. The main concern for ecological exposure occurs at the Columbia River. Ecological risks are evaluated in this RI by a simple bounding analysis that includes three exposure scenarios. The bounding analysis will not account for contributions from multiple groundwater OUs, but it is expected to demonstrate which contaminants and OU are more likely to present ecological risks to the Columbia River.

First, groundwater concentrations are compared to applicable ecological indicators that are protective of aquatic and riparian organisms. The indicator concentrations are protective of aquatic organisms and are compiled from the 100 Area and 300 Area River Corridor Baseline Risk Assessment (RCBRA), as documented in *Data Quality Objectives Summary Report for the 100 Area and 300 Area Component of the River Corridor Baseline Risk Assessment* (BHI 2005). The undiluted comparison is the worst-case condition and will indicate if there are potential ecological effects from the OU.

Two dilution scenarios are also evaluated to estimate the more likely impact of groundwater contaminants on the OU. The dilution scenarios address a mass-balance dilution of groundwater in the hyporheic zone and a mass-balance dilution in the Columbia River. Each of these two dilution scenarios is also compared to applicable ecological indicator concentrations for aquatic and riparian organisms.

1.4.5 Data Completeness

The groundwater monitoring data were examined for completeness. Table 1-6 presents the monitoring well category or type of data as discussed in the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) versus the information presented in this RI report. In addition, differences between the requirements of the 200-ZP-1 RI/FS work plan and the information presented are discussed.

For routine groundwater monitoring, specific wells were listed for analysis of specific COCs at various frequencies. The table presented in the 200-ZP-1 RI/FS work plan (Table A3-2) (DOE-RL 2004c) is presented in this RI report as Table 1-6, along with Table 1-2, which shows both the original requested wells and the additional wells that were used in the COC evaluation. The additional wells were included to ensure that the higher concentrations in the center of the plumes were considered for the COC risk evaluation. Data from 1988 indicate that the RI/FS wells were sampled numerous times for most COCs.

Section A.3.2.4 of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) requires additional monitoring for a selected list of COCs for selected list of wells. The original 200-ZP-1 RI/FS work plan presented details to explain that not all the COCs needed to be monitored in all wells every quarter or ever year. Thus, for the complete list of COCs, it was agreed that select wells

will be monitored for all the COCs twice and if no detects were found, then additional monitoring will not be required. Table A3-3 of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) identifies the seven wells where these additional COCs were required to be run. The results of the COC completeness evaluation are listed in Table 1-7 for the seven wells required to be tested in the 200-ZP-1 RI/FS work plan, as well as three supplemental wells. A majority of the wells have been analyzed for the majority of the COCs at least once.

The modeling input parameters were discussed in Section A3.2.4 and Table A2-2 of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c). Sections 2.0 and 4.0 of this RI report discuss the results of the geochemical, hydrogeological, and physical parameter sampling that will be used to support future contaminant fate and transport modeling.

Depth-discrete data for carbon tetrachloride were required for eight wells in the 200-ZP-1 RI/FS work plan (DOE-RL 2004c). Depth-discrete analytical data were also collected from a number of additional wells. Depth-discrete data are available for the following 19 wells, which are referred to as "RI/FS wells" in this RI report (Table 1-8): 299-W10-24, 299-W11-25B (well "T1"), 299-W11-43 (well "H"), 299-W11-45 (well "T2"), 299-W13-01 (well "G"), 299-W14-11, 299-W14-13, 299-W14-14, 299-W14-19, 299-W15-42 (well "A"), 299-W15-43, 299-W15-44, 299-W15-46, 299-W15-49 (well "C"), 299-W15-50 (well "E"), 299-W15-152 (well "F"), 299-W17-01 (well "I"), 299-W18-16 (well "D"), and 699-50-74 (well "T"). Depth-discrete data from the 19 RI/FS wells that were available in February 2006 were included in this RI report. Subsequent depth-discrete data, including partition (or distribution) coefficient (K_d) values, are expected from three new wells that are planned for drilling during FY06 and two new wells in FY07 in the vicinity of the Old Laundry Facility. The five planned wells are designated as "AA," "BB," "CC," "DD," and "EE." A sixth well is being held in reserve. Additional data from these new wells will be included as an appendix to the FS.

1.5 BACKGROUND FOR THE 200-ZP-1 OPERABLE UNIT

Numerous liquid waste discharges occurred in the 200 Areas since operations began on the Hanford Site in 1945. Low-level waste was disposed in open trenches and ponds and later flushed with fresh water. Potential sources of groundwater contamination at the 200-ZP-1 OU are listed in Table 1-9 for the Group A COCs. The T, TX, and TY Tank Farms are included in Table 1-9. Various waste sites overlying the 200-ZP-1 OU are further described in Section 3.4. As discussed in Section 3.4, vadose zone waste sites overlying the 200-ZP-1 OU are grouped into several OUs according to the operations associated with each site. A RI report for the 200-PW-1 OU is expected to address many of the Group A COC waste sources when it is completed. The waste sites listed in Table 1-9 and other potential sources of 200-ZP-1 groundwater contamination will be evaluated further in the 200-ZP-1 FS as needed to develop remedial options. While the information presented in Table 1-9 is from the Soil Inventory Model (Rev. 1), this does not preclude the use of additional source inventory information in later stages of the CERCLA process.

Liquid release inventory data are illustrated for selected years from 1944 through 1973 on the maps of the 200-ZP-1 and 200-UP-1 areas in Appendix D. Also, the plate maps presented in Appendices A and B show the contamination source areas that could potentially provide the largest impact to groundwater in the future.

Summaries of historical operations and disposal practices for the T and Z Plants are presented in the following subsections. Detailed information on discharges to these units can be found in a previous DQO summary report (FH 2003c), the Z Plant source aggregate area management study report (AAMSR) (DOE-RL 1992c), and the T Plant source AAMSR (DOE-RL 1992b).

1.5.1 T Plant

The T Plant was built in 1944 and operated as one of the first separation facilities at the Hanford Site. The 221-T Building (also known as T Plant, or T Canyon Building) housed the first operational, full-scale, bismuth-phosphate separation facility in the world. The dilute plutonium-nitrate solution generated through this process was transferred to the 224-T Bulk Reduction Building where it was purified to reduce volume using the lanthanum-fluoride process. Operations in the 221-T and 224-T Buildings ceased in 1956. Primary waste streams from the 221-T and 224-T Buildings included process waste and aqueous process waste that were discharged to tanks, cribs, and trenches. Decontamination wastewater was discharged to a crib. The associated analytical laboratory operated from 1944 to 1956 and produced aqueous process waste that was discharged to a crib.

The 221-T Building was used for a series of testing programs from 1964 to 1990. The beginning portion of the process facility of 221-T housed the Containment Systems Testing Facility from 1964 to 1969. These programs were managed by Pacific Northwest Laboratory from 1964 to 1969 and by Westinghouse Hanford Company from 1976 to 1990. Current operations in the 221-T Building include services in radioactive decontamination and reclamation, as well as decommissioning of process equipment. T Plant will receive sludge from the cleanout of the K Basins.

Plutonium scrap in liquid and solid forms was stored in the 224-T Building beginning in the early 1970s. The scrap was removed from the 224-T Building in 1985 (although the building was not decontaminated) when it was converted to a TSD unit identified as the 224-T Transuranic Waste Storage and Assay Facility. The storage area, an old processing hood, and all of the piping associated with plutonium-separation processing remain entombed in the building. The 224-T Transuranic Waste Storage and Assay Facility conducted nondestructive assays and examinations of newly generated, contact-handled, transuranic solid waste packages to meet the Waste Isolation Pilot Plant waste acceptance criteria requirements.

1.5.2 Z Plant Aggregate Area

The Z Plant began operation in 1945 as the Plutonium Isolation Facility, which concentrated plutonium-nitrate solution produced by either of the separation facilities (T Plant or B Plant) and converted the concentrate to a plutonium-nitrate paste for shipment to Los Alamos, New Mexico, for further refinement. This operation took place from 1945 to 1949. Primary waste streams from the Plutonium Isolation Facility included process waste and wastewaters that were discharged to a ditch, several cribs, and a reverse well.

In 1949, the 234-5 (or Z Plant) was constructed to produce plutonium metal. The 234-5, or Z Plant Complex (also referred to as the Plutonium Finishing Plant [PFP]), operated continuously from 1949 to 1973 and then intermittently from 1985 to 1988. The Z Plant processed plutonium from the 200 East and 200 West Area separation facilities to a plutonium metal and/or plutonium oxide. Primary waste streams from the PFP included process waste and wastewaters that were discharged to cribs, tanks, ponds, ditches, and seepage basins.

Plutonium recovery facilities also operated in the Z Plant process area. These included the Recovery of Uranium and Plutonium by Extraction (RECUPLEX) Facility (234-5Z Building) that operated from 1955 to 1962 and the Plutonium Reclamation Facility (PRF) (236-Z) that operated from 1964 to 1979 and again from 1984 to 1987. These facilities recovered plutonium from the PFP liquid waste stream. The primary waste streams from the RECUPLEX Facility included aqueous process waste, organic solvent waste, and spent silica gel that were discharged to a ditch, pond, trench, and french drain. The primary waste streams from the PRF included aqueous process waste and organic process waste that were discharged to trenches, cribs, and tile fields. The RECUPLEX Facility was shut down after a criticality event in 1962.

A process line also operated in the 242-Z Building from 1949 to 1959, and again from 1964 to 1976, to recover americium from the PFP waste stream. The primary waste stream from the americium recovery was spent ion-exchange resin that was discharged to ditches and a pond. The americium recovery process also generated an organic waste stream (carbon tetrachloride and dibutyl butyl phosphonate). This facility shut down after an explosion in 1976 in one of the recovery units.

An analytical laboratory has operated at Z Plant from 1955 to the present. The primary waste stream from the laboratory includes process wastes, used or discarded reagents, and wastewater discharged to cribs.

The *200-ZP-1 IRM Phase II and III Remedial Design Report* (DOE-RL 2006a) states that between 1955 and 1973, an estimated 600,000 to 900,000 kg of carbon tetrachloride were discharged to the soil column within the 200-ZP-1 OU. The total estimated mass of dissolved carbon tetrachloride, TCE, and chloroform in groundwater was estimated at 4,400 kg, 0.14 kg, and 30.6 kg, respectively.

The pump-and-treat system for the 200-ZP-1 OU, located near the PFP, was implemented in accordance with the *Declaration of the Interim Record of Decision for the 200-ZP-1 Operable Unit* (EPA et al. 1995). The interim remedial action objectives (RAOs) are as follows:

- Prevent further movement of contaminants from the highest concentration area of the carbon tetrachloride plume (i.e., greater than 2,000 μg/L contour).
- Reduce contamination in the area of highest carbon tetrachloride concentrations.
- Provide information that will lead to the development of a final remedy that will be protective of human health and the environment.

The 200-ZP-1 OU pump-and-treat system was implemented in a three-phase approach. Phase I operations consisted of the pilot-scale treatability test between August 29, 1994, and July 19, 1996, around the 216-Z-12 Crib. During this phase, contaminated groundwater was removed through a single extraction well (299-W18-1) at a rate of approximately 151 L/min [40 gallons per minute (gpm)], treated using granular activated carbon (GAC), and then returned to the aquifer through an injection well (299-W18-4). For more detailed information about operations during the treatability test, refer to *200-ZP-1 Operable Unit Treatability Test Report* (DOE-RL 1995a).

Concurrent with Phase I operations, the interim ROD for the 200-ZP-1 OU (EPA et al. 1995) was issued in June 1995. The selected remedy was to use groundwater pump-and-treat technology to minimize further migration of carbon tetrachloride, chloroform, and TCE in the groundwater and to remove mass.

Phase II operations commenced August 5, 1996, in accordance with the interim ROD (EPA et al. 1995) and Tri-Party Agreement Milestone M-16-04A. The 1996 groundwater plume was the basis for the interim action ROD. The well field configuration during Phase II operations consisted of three extraction wells (299-W15-33, 299-W15-34, and 299-W15-35) pumping at a combined rate of approximately 567.8 L/min (150 gpm) and a single injection well (299-W15-29). Groundwater was treated using an air stripper to release carbon tetrachloride into a vapor phase, and GAC was used to collect the vapor. For a detailed description of the treatment system setup and operation, refer to *200-ZP-1 Phase Interim Remedial Measure Quarterly Report, October – December 1996* (BHI 1997a). Phase II operations were terminated on August 8, 1997, to transition to Phase III operations.

Phase III operations began on August 29, 1997, satisfying Tri-Party Agreement Milestone M-16-04B. The well field for Phase III operations was expanded to include six extraction wells (existing three wells, plus wells 299-W15-32, 299-W15-36, and 299-W15-37) and five injection wells (single existing, plus wells 299-W18-36, 299-W18-37, 299-W18-38, and 299-W18-39). The total pumping rate was increased to more than 800 L/min (200 gpm) versus a total treatment system capacity of 1,893 L/min (500 gpm). The treatment process for the Phase III system used the same air-stripping and GAC systems used in Phase II. Extraction wells were installed to contain the high-concentration portion of the carbon tetrachloride plume located near PFP, as required by the interim ROD (EPA et al. 1995). The southernmost extraction well (299-W15-37) was converted to a monitoring well in January 2001 because of its limited impact on hydraulic capture of the high-concentration portion of the plume (DOE-RL 2003a). In 2004, extraction wells 299-W15-45 and 299-W15-47 were brought on-line to replace extraction wells 299-W15-32 and 299-W15-33, which were no longer producing adequate flow. The reduction in flow from these two wells was predominately a result of dropping water levels. Because the screen in well 299-W15-33 is only 6.1 m (20 ft) in length, dropping water levels had a significant impact on production rates. Although well 299-W15-32 has a 12.2–m (40-ft)-long screen in it, the upper portion of the saturated zone showed higher production rates. As water levels dropped, the formation produced less water. Wells 299-W15-45 and 299-W15-47 have 15.2-m (50-ft) and 18.3–m (60-ft) screens in them, respectively.

Elevated carbon tetrachloride concentrations detected in well 299-W15-40 in the late 1990s were originally thought to be an isolated hot spot. However, the most recent installation of monitoring wells 200-W15-41, 299-W15-44, and 299-W15-765 indicated that the 2,000 µg/L carbon tetrachloride plume known to be present in the vicinity of PFP also extends well to the north, just beyond the northern end of the TX-TY Tank Farms. In July 2005, four additional extraction wells (299-W15-40, 299-W15-43, 299-W15-44, and 299-W15-765) were brought on-line to capture this northern lobe of the 2,000 µg/L carbon tetrachloride plume. The results from the modeling of groundwater flow from these four additional extraction wells shows the northern lobe of the carbon tetrachloride plume will be fully captured. The combined total pumping rate from all nine extractions of the wells is greater than 1,135.6 L/min (300 gpm).

Figure 1-1. Location of 200 West Area and 200-ZP-1 Groundwater Operable Unit.

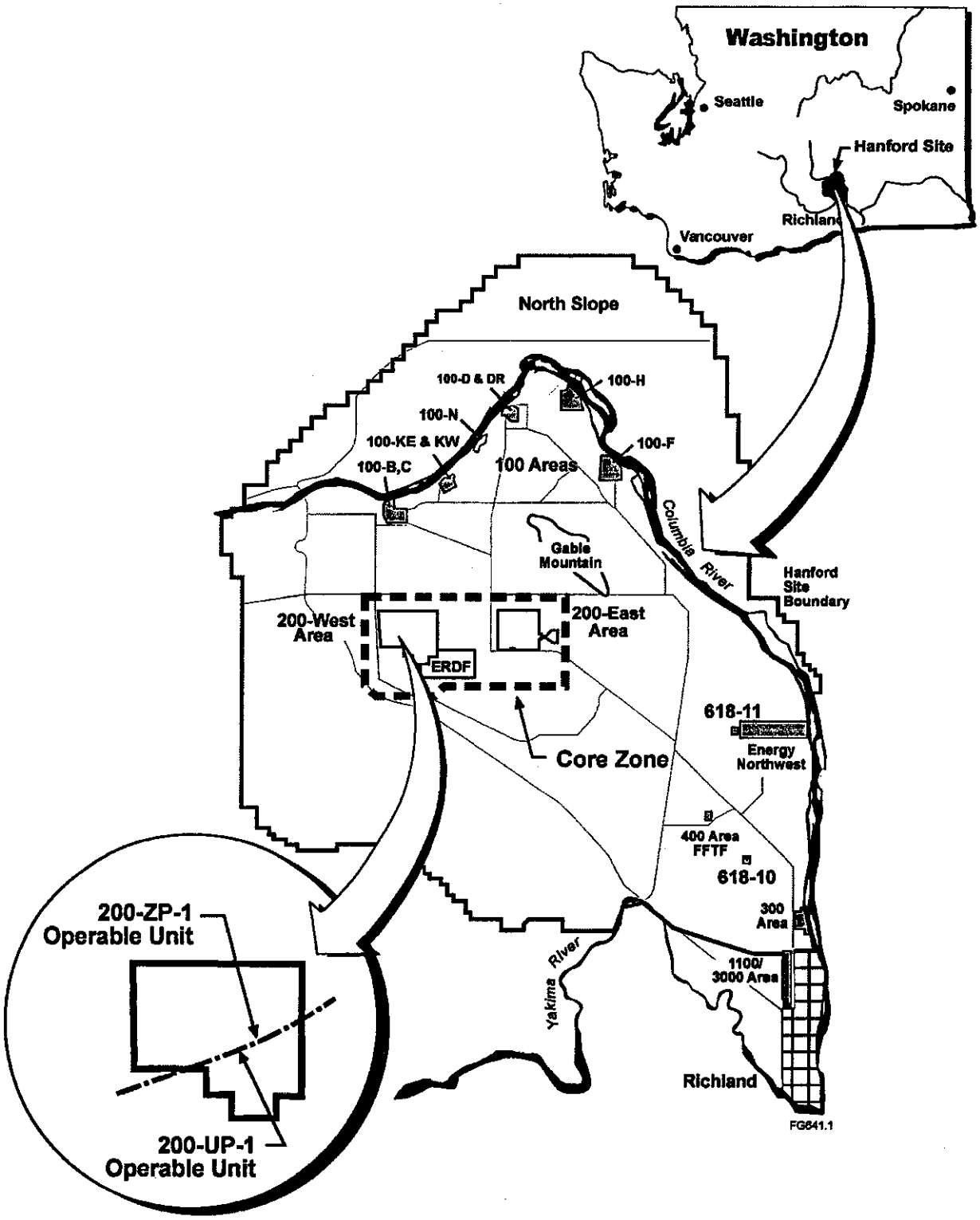
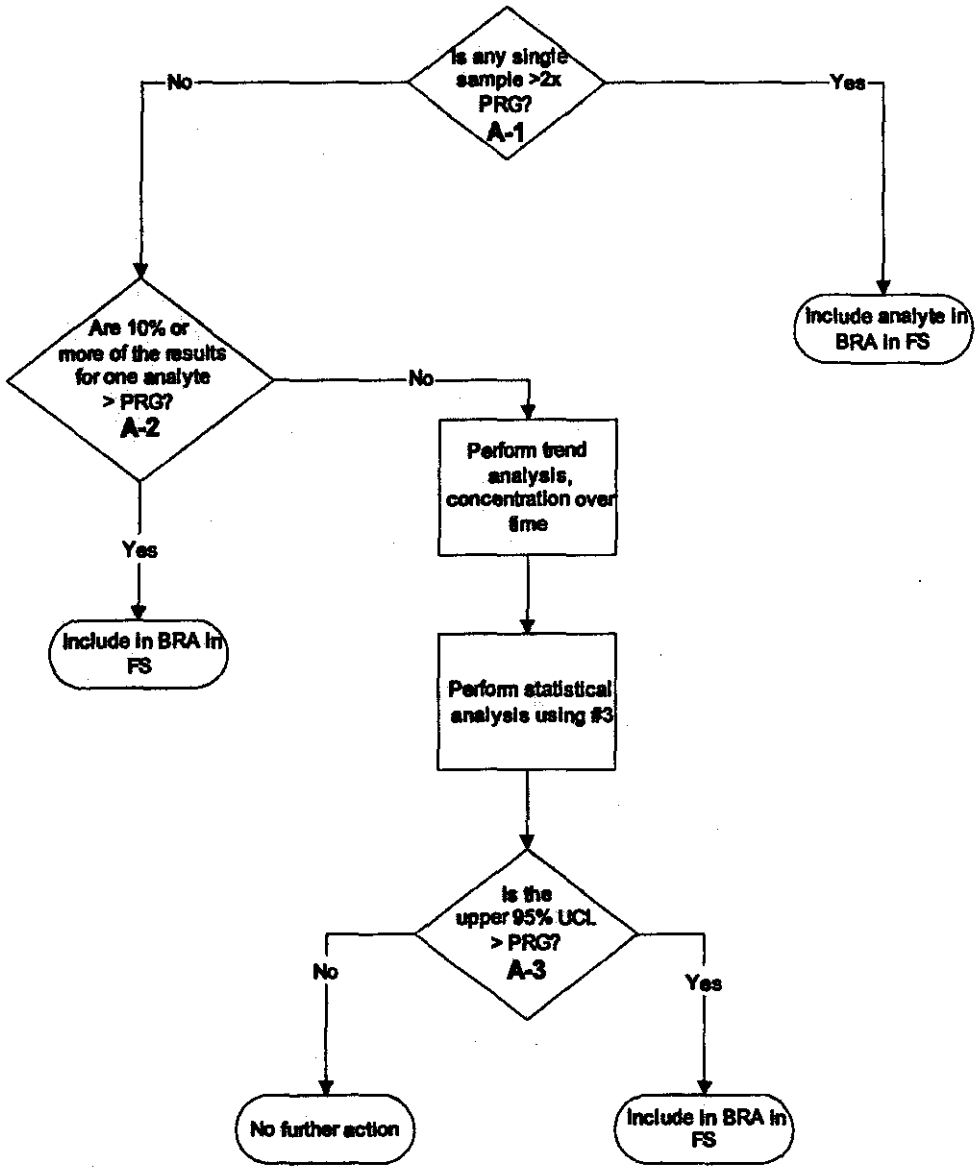


Figure 1-2. Plate Map of 200 West Area.

Figure 1-3. Logic Chart for Group A Contaminants – Approach for Known Plumes.[a]

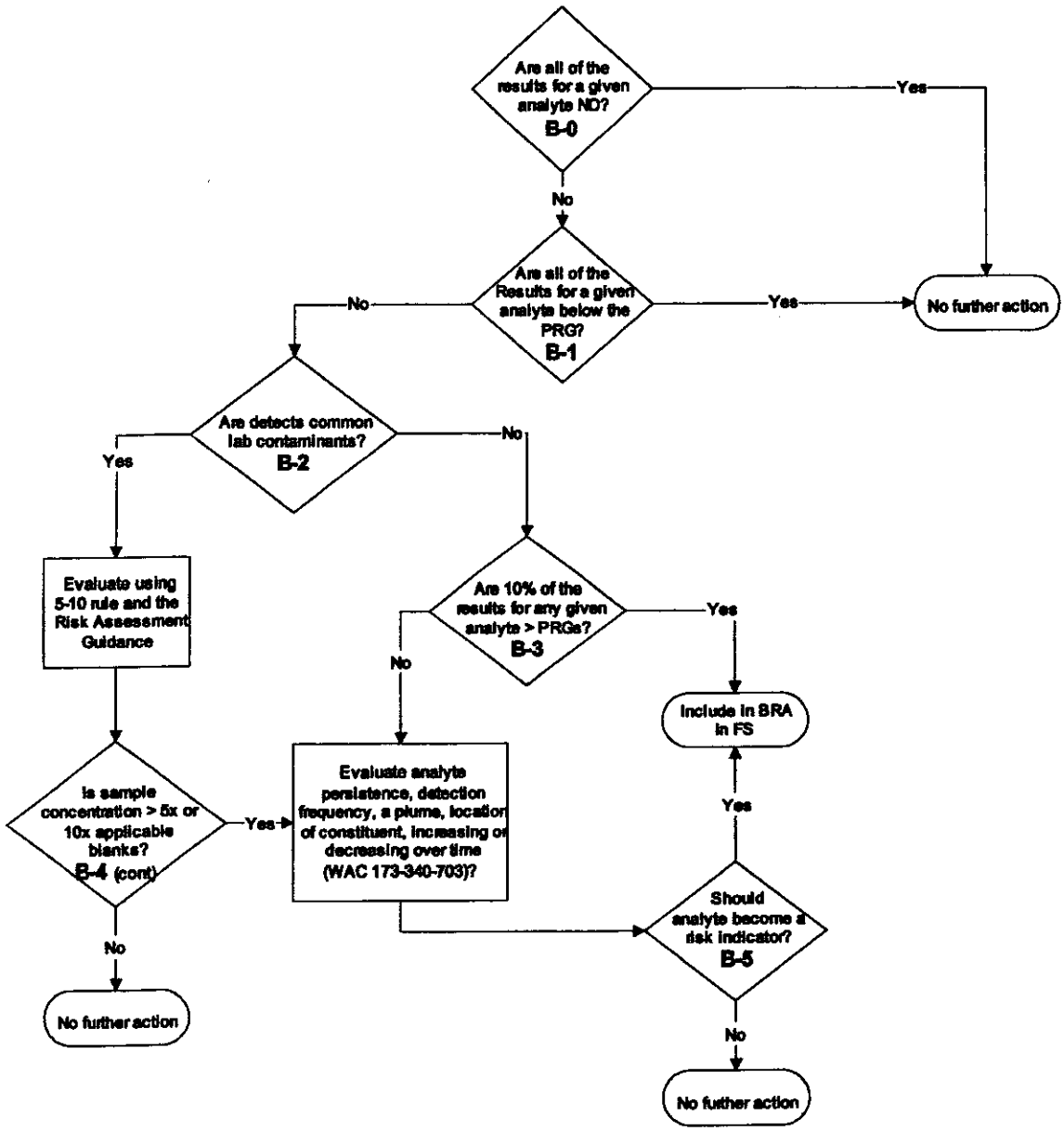


ACRONYMS

BRA	-	Baseline Risk Assessment
FS	-	Feasibility Study
PRG	-	Preliminary Remediation Goal
UCL	-	Upper Confidence Limit

[a] The A-# in the figure corresponds to question numbers in the decision diamonds.

Figure 1-4. Logic Chart for Group B Contaminants – Approach for Analytes Not Part of Known Plume.[a]



ACRONYMS

BRA	-	Baseline Risk Assessment
FS	-	Feasibility Study
PRG	-	Preliminary Remediation Goal

[a] The "B-#" in the figure corresponds to question numbers in the decision diamond.

Table 1-1. Final List of Contaminants of Concern in the 200-ZP-1 Groundwater Operable Unit. (2 sheets)

Radiological COCs		Nonradiological COCs
COC Element	COC Isotope	Metals
Beta Emitters		Antimony
Carbon	C-14	Arsenic
Iodine	I-129	Cadmium
Selenium	Se-79	Chromium
Strontium	Sr-90	Chromium (hexavalent)
Technetium	Tc-99	Iron
Tritium	H-3	Lead
Alpha Emitters		Lithium
Neptunium	Np-237	Magnesium
Protactinium	Pa-231	Manganese
Uranium	U-234	Mercury
Uranium	U-235	Nickel
Uranium	U-238	Selenium
Gamma Emitters		Silver
Cesium	Cs-137	Uranium
		Volatile Organics
		Acetone
		Benzene
		Carbon disulfide
		Carbon tetrachloride[a]
		Chloroform
		Chlorobenzene
		Ethyl benzene
		Methylene chloride
		Methyl ethyl ketone
		4-methyl-2-pentanone (hexone, MIBK)
		n-butylbenzene

Table 1-1. Final List of Contaminants of Concern in the 200-ZP-1 Groundwater Operable Unit. (2 sheets)

Radiological COCs	Nonradiological COCs
	1,2-dichloroethylene (cis and trans)
	1,2-dichloroethane (DCA)
	Toluene
	1,1,1-trichloroethane (TCA)
	Trichloroethylene (TCE)
	Tetrachloroethylene (PCE)
	Xylene (total)
	Non-Metals
	Ammonium
	Cyanide
	Fluoride
	Nitrite
	Nitrate
	Phosphate[b]
	Semi-Volatile Organics
	Cresols
	Kerosene
	Phenols (total)

[a] Carbon tetrachloride is being remediated in accordance with the 200-ZP-1 Record of Decision (EPA et al. 1995).
[b] Includes orthophosphate plus organo-phosphates.
COC = contaminant of concern

Table 1-2. Contaminants of Concern and Wells Evaluated for Risk in 200-ZP-1 Operable Unit. (8 sheets)

Well	RCRA and/or CERCLA Sampling Program	Identified in 200-ZP-1 RI/FS Work Plan	Location[a]	Group A COCs[b]								Group B COCs[c]
				Carbon Tetrachloride	Trichloroethylene (TCE)	Chromium (Total)	Nitrate	Technetium-99	Uranium	Iodine-129	Tritium	Other Detected Analytes in Table 1-5 That Are Not Group A COCs
299-W6-02	C			X								X
299-W6-07	R			X	X		X	X		X	X	X
299-W6-10	R and C	W		X	X	X	X		X	X	X	X
299-W6-11	R		SALDS								X	X
299-W6-12	R		SALDS								X	X
299-W7-01	R		LLWMA-3	X	X	X	X	X	X	X	X	X
299-W7-04	R and C	W	LLWMA-3	X	X	X	X	X	X	X	X	X
299-W7-05	R		LLWMA-3 and SALDS	X	X	X	X	X	X	X	X	X
299-W7-06	R										X	X
299-W7-07	R		LLWMA-3	X	X	X	X	X	X	X	X	X
299-W7-08	R			X	X	X	X	X	X	X	X	X
299-W7-09	R										X	X
299-W7-11	R										X	X
299-W7-12	R and C	W	LLWMA-3 and SALDS	X	X	X	X	X	X	X	X	X
299-W8-01	R and C	W	LLWMA-3 and SALDS	X	X	X	X	X	X	X	X	X
299-W10-01	R and C	W	WMA-T	X	X	X	X	X		X	X	X
299-W10-04	R and C	W	WMA-T	X	X	X	X	X		X	X	X
299-W10-05	R and C	W		X	X	X	X	X		X	X	X

Table 1-2. Contaminants of Concern and Wells Evaluated for Risk in 200-ZP-1 Operable Unit. (8 sheets)

Well	RCRA and/or CERCLA Sampling Program	Identified in 200-ZP-1 RI/FS Work Plan	Location[a]	Group A COCs[b]								Group B COCs[c]
				Carbon Tetrachloride	Trichloroethylene (TCE)	Chromium (Total)	Nitrate	Technetium-99	Uranium	Iodine-129	Tritium	Other Detected Analytes in Table 1-5 That Are Not Group A COCs
299-W10-08	R		WMA-T			X	X	X			X	X
299-W10-13	R and C	W		X	X	X	X	X	X	X	X	X
299-W10-17	R			X		X	X	X			X	X
299-W10-19	R		LLWMA-3	X	X	X	X	X	X	X	X	X
299-W10-20	R and C	W	LLWMA-3	X	X	X	X	X	X	X	X	X
299-W10-21	R and C	W	LLWMA-3	X	X	X	X	X	X	X	X	X
299-W10-22	R and C	W	WMA-T	X	X	X	X	X	X	X	X	X
299-W10-23	R and C	W	WMA-T	X	X	X	X	X	X	X	X	X
299-W10-24	R		WMA-T			X	X	X			X	X
299-W10-26	R		WMA-TX/TY			X	X	X		X	X	X
299-W10-27	R		WMA-TX/TY			X	X	X			X	X
299-W10-28	R		WMA-T			X		X			X	X
299-W11-03	R and C	W		X	X		X	X	X	X	X	X
299-W11-06	R and C	W		X	X		X	X	X	X	X	X
299-W11-07	R and C	W	WMA-T	X	X	X	X	X	X	X	X	X
299-W11-10	R and C	W		X	X		X	X		X	X	X

Table 1-2. Contaminants of Concern and Wells Evaluated for Risk in 200-ZP-1 Operable Unit. (8 sheets)

Well	RCRA and/or CERCLA Sampling Program	Identified in 200-ZP-1 RI/FS Work Plan	Location[a]	Group A COCs[b]								Group B COCs[c]
				Carbon Tetrachloride	Trichloroethylene (TCE)	Chromium (Total)	Nitrate	Technetium-99	Uranium	Iodine-129	Tritium	Other Detected Analytes in Table 1-5 That Are Not Group A COCs
299-W11-12	R		WMA-T			X	X	X			X	X
299-W11-13	R and C	W		X	X	X	X	X		X	X	X
299-W11-14	R and C	W		X	X	X	X	X	X	X	X	X
299-W11-18	R and C	W		X	X	X	X	X	X	X	X	X
299-W11-24	R					X	X	X			X	X
299-W11-37	R and C	W		X	X	X	X	X	X	X	X	X
299-W11-39	R		WMA-T			X	X	X			X	X
299-W11-40	R		WMA-T			X	X	X			X	X
299-W11-41	R		WMA-T			X	X	X		X	X	X
299-W11-42	R		WMA-T	X	X	X	X	X		X	X	X
299-W11-43 (H)[d]	C	W		X					X			X
299-W12-01	R and C	W		X	X	X	X	X	X	X	X	X
299-W13-01 (G)[e]	C	W		X	X		X				X	X
299-W14-05	R			X		X	X	X			X	X
299-W14-06	R		WMA-TX/TY	X	X	X	X	X		X	X	X
299-W14-13	R		WMA-TX/TY			X	X	X		X	X	X

Table 1-2. Contaminants of Concern and Wells Evaluated for Risk in 200-ZP-1 Operable Unit. (8 sheets)

Well	RCRA and/or CERCLA Sampling Program	Identified in 200-ZP-1 RI/FS Work Plan	Location[a]	Group A COCs[b]								Group B COCs[c]
				Carbon Tetrachloride	Trichloroethylene (TCE)	Chromium (Total)	Nitrate	Technetium-99	Uranium	Iodine-129	Tritium	Other Detected Analytes in Table 1-5 That Are Not Group A COCs
299-W14-14	R and C	W	WMA-TX/TY	X	X	X	X	X	X	X	X	X
299-W14-15	R		WMA-TX/TY			X	X	X		X	X	X
299-W14-16	R and C	W	WMA-TX/TY	X	X	X	X	X		X	X	X
299-W14-17	R		WMA-TX/TY			X	X	X		X	X	X
299-W14-18	R		WMA-TX/TY			X	X	X		X	X	X
299-W14-19	R		WMA-TX/TY			X	X	X		X	X	X
299-W15-01	R and C	W		X	X		X					X
299-W15-02	R and C	W		X	X	X	X	X		X	X	X
299-W15-07	R and C	W		X	X		X	X				X
299-W15-11	R and C	W		X	X		X	X			X	X
299-W15-15	R and C	W	LLWMA-4	X	X	X	X	X	X	X	X	X
299-W15-16	R		LLWMA-4	X	X	X	X	X	X	X	X	X
299-W15-17	R and C	W	LLWMA-4	X	X	X	X	X				X
299-W15-30	R and C	W		X	X	X	X	X				X
299-W15-31A	R and C	W		X	X		X	X				X
299-W15-32	R			X	X	X	X	X		X	X	X

Table 1-2. Contaminants of Concern and Wells Evaluated for Risk in 200-ZP-1 Operable Unit. (8 sheets)

Well	RCRA and/or CERCLA Sampling Program	Identified in 200-ZP-1 RI/FS Work Plan	Location[a]	Group A COCs[b]								Group B COCs[c]
				Carbon Tetrachloride	Trichloroethylene (TCE)	Chromium (Total)	Nitrate	Technetium-99	Uranium	Iodine-129	Tritium	Other Detected Analytes in Table 1-5 That Are Not Group A COCs
299-W15-33	R		g	X	X		X	X		X	X	X
299-W15-34	R and C	W	g	X	X		X	X		X	X	X
299-W15-35	R and C	W	g	X	X	X	X	X	X	X	X	X
299-W15-36	R and C	W	g	X	X		X	X		X	X	X
299-W15-38	R and C	W	g	X	X	X	X					X
299-W15-39	R and C	W	g	X	X	X	X				X	X
299-W15-40	R and C	W	WMA-TX/TY	X	X	X	X	X		X	X	X
299-W15-41	R and C	W	WMA-TX/TY	X	X	X	X	X		X	X	X
299-W15-42[e]	R and C	W	g	X	X	X	X	X			X	X
299-W15-43	R and C	W	g	X	X	X	X	X			X	X
299-W15-44	R and C	W	WMA-TX/TY	X	X	X	X	X		X	X	X
299-W15-45	R and C	W	g	X	X		X	X				X
299-W15-46[d]	R		g	X	X	X	X	X	X	X	X	X
299-W15-47	R and C	W	g	X	X		X	X				X
299-W15-49 (C)[d]	C	W	g	X			X					X
299-W15-50 (E)[e]	C	W	g	X	X	X	X					X

Table 1-2. Contaminants of Concern and Wells Evaluated for Risk in 200-ZP-1 Operable Unit. (8 sheets)

Well	RCRA and/or CERCLA Sampling Program	Identified in 200-ZP-1 RI/FS Work Plan	Location[a]	Group A COCs[b]								Group B COCs[c]
				Carbon Tetrachloride	Trichloroethylene (TCE)	Chromium (Total)	Nitrate	Technetium-99	Uranium	Iodine-129	Tritium	Other Detected Analytes in Table 1-5 That Are Not Group A COCs
299-W15-152 (F)	C	W	g	X	X		X					X
299-W15-763	R		WMA-TX/TY			X	X	X			X	X
299-W15-765	R		WMA-TX/TY	X	X	X	X	X		X	X	X
299-W17-01 (I)[e]	R and C	W	g	X	X	X	X	X		X	X	X
299-W18-01	R and C	W	g	X	X	X	X					X
299-W18-04	R		g	X	X							X
299-W18-16 (D)[e]	C	W	g	X	X		X					X
299-W18-23	R and C	W	LLWMA-4	X	X	X	X	X	X	X	X	X
299-W18-24	R		g	X	X	X	X	X	X	X	X	X
299-W18-27	R and C	W	g	X	X	X	X		X			X
699-19-88	R		g	X	X	X	X		X		X	X
699-26-89	R		g				X				X	X
699-34-88	R		g	X	X		X				X	X
699-36-93	R		g				X				X	X
699-39-79	R		g	X	X	X	X	X		X	X	X
699-43-89	R and C	W	g	X	X	X	X	X	X	X	X	X

Table 1-2. Contaminants of Concern and Wells Evaluated for Risk in 200-ZP-1 Operable Unit. (8 sheets)

Well	RCRA and/or CERCLA Sampling Program	Identified in 200-ZP-1 RI/FS Work Plan	Location[a]	Group A COCs[b]								Group B COCs[c]
				Carbon Tetrachloride	Trichloroethylene (TCE)	Chromium (Total)	Nitrate	Technetium-99	Uranium	Iodine-129	Tritium	Other Detected Analytes in Table 1-5 That Are Not Group A COCs
699-44-64	R and C	W	g				X	X	X	X	X	X
699-45-69A	R and C	W	g	X			X			X		X
699-47-60	R and C	W	g	X	X	X	X	X	X	X	X	X
699-48-71	R and C	W	SALDS	X	X	X	X		X	X	X	X
699-48-77A	R and C	W	SALDS	X	X	X	X	X	X	X	X	X
699-48-77D	R		SALDS	X	X	X	X		X		X	X
699-49-79	R		SALDS	X	X		X				X	X
699-49-100C	R		g	X	X	X	X	X	X	X	X	X
699-50-74 (T)[e]	C	W	g	X			X				X	X
699-50-85	R		g	X	X		X				X	X
699-51-75	R		SALDS	X	X		X				X	X
699-55-60A	C	W	g	X	X	X	X	X	X	X	X	X
699-55-76	R		g				X				X	X
699-55-89	R		g	X	X		X				X	X
LLWMA-5[f]	R and C	W	g	X	X		X				X	X
LLWMA-8[f]	R and C	W	g	X	X		X					X

Table 1-2. Contaminants of Concern and Wells Evaluated for Risk in 200-ZP-1 Operable Unit. (8 sheets)

Well	RCRA and/or CERCLA Sampling Program	Identified in 200-ZP-1 RI/FS Work Plan	Location[a]	Group A COCs[b]								Group B COCs[c]
				Carbon Tetrachloride	Trichloroethylene (TCE)	Chromium (Total)	Nitrate	Technetium-99	Uranium	Iodine-129	Tritium	Other Detected Analytes in Table 1-5 That Are Not Group A COCs
LLWMA-13[f]	R and C	W	g	X	X		X			X	X	X
LLWMA-17[f]	R and C	W	g	X	X	X	X				X	X

NOTE: Reference in this table to the 200-ZP-1 RI/FS work plan refers to the *Remedial Investigation/Feasibility Study Work Plan for the 200-ZP-1 Groundwater Operable Unit* (DOE-RL 2004c).

[a] LLWMA-3 = Low-Level Waste Management Area 3, LLWMA-4 = Low-Level Waste Management Area 4, LLWMA-5 = Low-Level Waste Management Area 5, SALDS = State-Approved Land Disposal Site, WMA-T = Waste Management Area T, WMA-TX/TY = Waste Management Area TX/TY.

[b] Primary human health and ecological risk drivers.

[c] Secondary human health and ecological risk drivers.

[d] Wells 299-W11-43, 299-W15-46, and 299-W15-49 are key wells with depth-discrete groundwater and soil samples.

[e] Other wells with depth-discrete samples.

[f] Wells not yet drilled at the end of calendar year 2005.

[g] Outside the perimeter of a WMA or SALDS.

C = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA)
COC = contaminant of concern
R = *Resource Conservation and Recovery Act of 1976* (RCRA)
RI/FS = remedial investigation/feasibility study
SALDS = State-Approved Land Disposal Site

Table 1-3. Routine Sampling and Analysis Requirements for the 200-ZP-1 Operable Unit Groundwater Monitoring Well Network. (4 sheets)

Well Number	Sampling Frequency	Onsite			Offsite								
		Carbon Tetrachloride	Chloroform	Trichloroethylene (TCE)	Technetium-99	Uranium	Iodine-129	Tritium	Chromium (Total)	Arsenic	Cadmium	Nitrate	Other
Group A or B		A	B	A	A	A	A	A	A	B	B	A	B
LLWMA-13[i] (new well)	Quarterly	X		X			X	X			X	X	
299-W6-10	Annual	X		X		X	X	X			X	X	
299-W7-4[g]	Annual	X		X								X	
LLWMA-17[i] (new well)	Quarterly	X		X				X	X			X	Antimony, iron
LLWMA-5[i] (new well)	Quarterly	X		X				X				X	
299-W7-12[e]	Biennial	X						X				X	
299-W8-1[d]	Biennial	X						X				X	
299-W10-1	Annual	X	X	X				X	X	X		X	
299-W10-4[g]	Semi-annual	X	X	X	X		X	X	X	X		X	Fluoride
299-W10-5	Annual	X	X	X	X			X	X		X	X	VOC[e]
299-W10-13[e]	Biennial	X		X								X	
LLWMA-8[i] (new well)	Quarterly	X		X							X	X	
299-W10-20[e]	Biennial	X	X	X								X	
299-W10-21	Annual	X	X	X				X			X	X	
299-W10-22	Semi-annual	X		X	X	X	X	X	X			X	
299-W10-23[g]	Annual	X	X	X	X	X	X	X	X	X	X	X	Fluoride
299-W11-3	Semi-annual	X		X		X	X	X				X	
299-W11-6	Semi-annual	X		X		X	X					X	
299-W11-7	Annual	X	X	X	X	X	X		X	X	X	X	Fluoride

Table 1-3. Routine Sampling and Analysis Requirements for the 200-ZP-1 Operable Unit Groundwater Monitoring Well Network. (4 sheets)

Well Number	Sampling Frequency	Onsite			Offsite								
		Carbon Tetrachloride	Chloroform	Trichloroethylene (TCE)	Technetium-99	Uranium	Iodine-129	Tritium	Chromium (Total)	Arsenic	Cadmium	Nitrate	Other
299-W11-10	Semi-annual	X	X									X	
299-W11-13	Semi-annual	X	X	X	X		X	X	X	X	X	X	
299-W11-14[g]	Semi-annual	X	X	X		X	X	X				X	Fluoride
299-W11-18	Annual	X	X	X	X	X	X	X	X		X	X	VOC[c], fluoride
299-W11-37	Semi-annual	X		X		X	X	X				X	
299-W12-1	Annual	X					X	X				X	
299-W14-14	Annual	X	X	X	X		X	X	X		X	X	Fluoride
299-W14-16	Annual	X		X	X		X	X	X			X	
299-W15-1	Semi-annual	X	X	X								X	
299-W15-2	Annual	X	X	X	X							X	
299-W15-7	Semi-annual	X	X	X	X							X	
299-W15-11	Semi-annual	X	X	X	X			X				X	
299-W15-15	Annual	X	X								X	X	
299-W15-17	Semi-annual	X	X	X	X				X		X	X	
299-W15-30	Semi-annual	X	X	X	X				X		X	X	
299-W15-31A	Semi-annual	X	X	X	X							X	
299-W15-34	Annual	X	X	X	X							X	Methylene chloride
299-W15-35[g]	Annual	X	X	X	X				X			X	Methylene chloride
299-W15-36	Annual	X	X	X								X	Methylene chloride
299-W15-38	Annual	X	X	X					X			X	
299-W15-39	Semi-annual	X	X	X								X	
299-W15-40	Semi-annual	X	X	X	X			X	X		X	X	
299-W15-41	Semi-annual	X	X	X	X			X			X	X	
299-W15-42	Semi-annual	X	X	X	X				X		X	X	Iron, methylene chloride

Table 1-3. Routine Sampling and Analysis Requirements for the 200-ZP-1 Operable Unit Groundwater Monitoring Well Network. (4 sheets)

Well Number	Sampling Frequency	Onsite			Offsite								
		Carbon Tetrachloride	Chloroform	Trichloroethylene (TCE)	Technetium-99	Uranium	Iodine-129	Tritium	Chromium (Total)	Arsenic	Cadmium	Nitrate	Other
299-W15-43	Semi-annual	X	X	X	X			X				X	Manganese
299-W15-44	Semi-annual	X	X	X	X		X	X				X	Manganese
299-W15-45	Quarterly	X	X	X	X							X	
299-W15-47	Quarterly	X	X	X	X							X	
299-W18-1	Semi-annual	X	X	X							X	X	
299-W18-23	Annual	X	X		X	X						X	
299-W18-27	Annual	X	X	X		X						X	
699-43-89[e]	Biennial	X	X	X	X	X	X	X	X	X	X	X	Strontium-90
699-44-64[e]	Biennial				X	X	X	X				X	
699-45-69A[e]	Biennial	X					X					X	
699-47-60[e]	Biennial	X	X	X	X	X	X	X	X			X	
699-48-71[e]	Biennial	X		X		X	X	X				X	
699-48-77A[e,g]	Biennial	X						X	X			X	Iron
699-55-60A[e]	Biennial	X	X	X	X	X	X	X	X			X	
New well "C"[d] (299-W15-49)	Quarterly	X	X									X	
New well "D"[d] (299-W18-16)	Quarterly	X	X	X								X	
New well "E"[d] (299-W15-50)	Quarterly	X	X	X					X			X	
New well "F"[d,i]	Quarterly	X	X	X								X	
New well "G" (299-W13)[h]	Quarterly	X	X	X				X				X	
New well "H"[d]	Quarterly	X				X							

Table 1-3. Routine Sampling and Analysis Requirements for the 200-ZP-1 Operable Unit Groundwater Monitoring Well Network. (4 sheets)

Well Number	Sampling Frequency	Onsite			Offsite								
		Carbon Tetrachloride	Chloroform	Trichloroethylene (TCE)	Technetium-99	Uranium	Iodine-129	Tritium	Chromium (Total)	Arsenic	Cadmium	Nitrate	Other
New well "I" (299-W17)[a]	Quarterly	X	X	X	X		X	X	X			X	
New well "T"[h]	Quarterly	X						X				X	

Quality control requirements: duplicates = 5%; equipment rinsate blanks = one per 10 well trips; and field transfer blanks = one per day when volatile organic analytes are sampled.

[a] Semi-annual sampling will be conducted every other quarter (i.e., first and third or second and fourth quarters of FY05).
[b] Annual samples will be taken in either the third or fourth quarter of FY05.
[c] The VOCs are 1,2-dichloroethane, benzene, tetrachloroethene, and methylene chloride.
[d] Biennial samples that are not scheduled for FY05.
[e] Biennial samples that are scheduled for FY05.
[f] Sampling frequency is consistent with that required by the *Remedial Investigation/Feasibility Study Work Plan for the 200-ZP-1 Groundwater Operable Unit* (DOE-RL 2004c).
[g] Does not include supplemental analyses to support the remedial investigation/feasibility study process.
[h] To be installed in FY06 or out-years.
[i] To be installed in FY05.
[j] To be installed in early FY05.

FY = fiscal year
LLWMA = low-level waste management area
VOC = volatile organic compound

Table 1-4. 200-ZP-1 Operable Unit Existing References. (13 sheets)

Reference	Summary
Remedial Investigation/ Feasibility Study Work Plan for the 200-ZP-1 Groundwater Operable Unit, DOE/RL-2003-55, Rev. 0 (DOE-RL 2005e)	The work plan directs the data collection that allows completion of the RI/FS. The work plan was generated according to CERCLA requirements. The work plan evaluated historical COC data, generated target action levels, or preliminary remediation goals, and provides the location and types of samples for groundwater and sediments. The work plan also discussed all the tasks related to characterization. The work plan appendix includes the sampling and analysis plan that details the wells to sample and the cocks requiring analysis. The work plan serves as the basis for the RI and FS reports.
200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program, DOE/RL-98-28, Rev. 0 (DOE-RL 1999)	The Implementation Plan outlines the framework for implementing assessment activities in the 200 Areas to ensure consistency in documentation, level of characterization, and decision making. The Implementation Plan also consolidates background information and other typical work plan materials to serve as a single reference source for this type of information. This Implementation Plan does not provide detailed information about the assessment of individual waste sites or groups. Site-specific data needs, DQOs, data collection programs, and associated assessment tasks and schedules will be defined in subsequent group-specific (i.e., OU-specific) work plans. A common regulatory framework is established that integrates the RCRA, CERCLA, *Federal Facility Regulations*, and Tri-Party Agreement requirements into one standard approach for 200 Area cleanup activities. The Implementation Plan also streamlines work plans that are required for each waste site group by consolidating background information to provide a single referenceable source for this information. This allows the information in the group-specific work plans to focus on waste group or waste site-specific information. The background information includes an overview of the 200 Area facilities and processes, their operational history, contaminant migration concepts, and a list of COCs. It also documents and evaluates existing information to develop a site description and conceptual model of expected site condition and potential exposure pathways. With this conceptual understanding, preliminary potential ARARs, preliminary RAOs, and remedial action alternatives are identified. The alternatives are broadly defined but represent potential alternatives that may be implemented on at the site. The identification of potential alternatives helps to ensure the data needed to fully evaluate the alternatives are collected during the RI. The specific type and quality of data are to be defined through the site-specific DQOs and form the basis for the data collection programs. The 200 Areas strategy recognized the inter-relationships between the various activities in the area and the need to integrate with other Environmental Restoration and Hanford Site projects/programs. The Implementation Plan describes the approach for interfacing with other programs and agencies, the integrated schedule of activities that addressed both RCRA and CERCLA program requirements, and the public participation process.
200 West Groundwater Aggregate Area Management Study Report, DOE/RL-92-16, Rev. 0 (DOE-RL 1993)	Evaluates various sources and COPCs applicable to the OU.

Table 1-4. 200-ZP-1 Operable Unit Existing References. (13 sheets)

Reference	Summary
200-ZP-1 Groundwater Sampling and Analysis Plan/Quality Assurance Plan, BHI-00038, Rev. 1 (BHI 1995)	This SAP provides the rationale for development of three monitoring network designs (i.e., remedial action, plume periphery, and detection-level assessment networks), the DQOs associated with each design, the specifics for each network (i.e., wells, sampling schedules, and parameters), and supporting work that influences future network modifications. Requirements that address the treatability test groundwater monitoring phase of this investigation are detailed in Rev. 0 of this SAP. Treatability testing was completed on March 31, 1995. Each of these three monitoring networks is designed to address general and specific DQOs. The well networks are nested in areas of high contamination (remedial action assessment wells), low contamination (plumes periphery assessment wells), and where no contamination has been detected (detection-level assessment wells). Monitoring wells selected for each category may change over the course of the IRM to reflect remedial action activities. The network closest to the area of highest contamination will likely change the most as the IRM develops. The SAP also presents the 1995 perimeter of the carbon tetrachloride plume within the 200-ZP-1 OU and identifies the wells to be sampled for remedial action assessment and to track the plume periphery. It identifies the sampling frequency, the analyses to be performed, and a list of wells from which groundwater-level measurements will be collected.
200-ZP-1 IRM Phase II and III Remedial Design Report, DOE/RL-96-07, Rev. 1 (DOE-RL 2006a)	The 200-ZP-1 remedial design report presents the objectives and rationale developed for the design and implementation of the selected IRM for the 200-ZP-1 OU. The IRM was chosen in accordance with CERCLA. This remedial design report addresses the design for "Alternative 2, Groundwater Pump-and-Treat System." The goal is to reduce further migration of carbon tetrachloride, chloroform, and TCE in the groundwater of the 200 West Area. The Phases II and III IRM treatment system will be designed to hydraulically contain and reduce the contaminant mass in the high-concentration portion (i.e., the 2,000 to 3,000 ppm contour) of the carbon tetrachloride plume. The 200-ZP-1 IRM consisted of three phases. The Phase I treatment system, which originated as a treatability test, began operations in August 1994 south of the 234-5Z Plant. The Phase I treatment system provided a 227-L/min (60-gpm) treatment capacity using liquid-phase GAC to remove organic contamination from the extracted groundwater. One extract well and one injection well provided the groundwater inlet stream and treated effluent disposal functions for the system. Successful results from the Phase I treatment system treatability test resulted in continued operation until startup of the Phase II treatment system. The objective of the Phase II treatment system was to initiate hydraulic containment of the 2,000 to 3,000 ppb contour of the carbon tetrachloride plume. The Phase II treatment was located north of the 234-5Z Plant and will use air stripping and vapor-phase GAC adsorption. The objective of the Phase II treatment system is to further contain the high-concentration portion of the contaminant plume. The Phase III treatment system will upgrade the Phase II treatment system to a process flow rate of up to 1,893 L/min (500 gpm) by adding required extraction and injection wells and associated piping runs.
Assessment of Carbon Tetrachloride Groundwater Transport in Support of the Hanford Carbon Tetrachloride Innovative Technology Demonstration Program, PNNL-13560 (Truex et al. 2001)	Includes a literature review of distribution coefficients and abiotic hydrolysis degradation rates for carbon tetrachloride.

Table 1-4. 200-ZP-1 Operable Unit Existing References. (13 sheets)

Reference	Summary
Carbon Tetrachloride Field Investigation Report for Drilling in the Vicinity of PFP and the 216-Z-9 Trench, BHI-01631, Rev. 0 (BHI 2002a)	In 2001, two existing wells near the 216-Z Trench were deepened to characterize the distribution of carbon tetrachloride at the waste site. The deepened wells were completed as soil vapor extraction wells to enhance vadose zone remediation activities. In February 2002, a groundwater extraction/monitoring well was installed in the vicinity of PFP to evaluate the distribution of carbon tetrachloride at the site and to potentially enhance groundwater remediation activities. This report provides soil, soil vapor, and groundwater sampling results from deepening of wells 299-W15-84 and 299-W15-95 at the 216-Z-9 Trench, and information related to the drilling of wells 299-W15-42 and 299-W15-764 inside the PFP protected area. It also provides an evaluation of the then current conceptual models of the 216-Z-9 Trench and surrounding area using hydrological and chemical/geochemical data from the deepened wells in addition to data from nearby wells to assess subsurface contaminant distribution and refine the site conceptual model.
Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site, PNNL-11800 (Kincaid et al. 1998)	A composite analysis was prepared for the Hanford Site considering only sources in the 200 Area Plateau. Estimating doses to hypothetical members of the public for the composite analysis was a multi-step process involving the estimation or simulation of inventories; waste release to the environment; migration through the vadose zone, groundwater, and atmospheric pathways; and exposure and dose. Doses were estimated for based on the agriculture, residential, industrial, and recreational land-use scenarios. The radionuclides included in the vadose zone and groundwater pathway analyses of future releases were carbon-14, chlorine-36, selenium-79, technetium-99, iodine-129, and uranium isotopes. In addition, tritium and strontium-90 were included because they exist in groundwater plumes. Radionuclides considered in the atmospheric pathway included tritium and carbon-14. The analysis indicated that most of the radionuclide inventory in past-practice liquid discharge and solid waste burial sites on the 200 Area Plateau was projected to be released in the first several hundred years following Hanford Site closure. The radionuclide doses for all of the exposure scenarios outside of a defined buffer zone were all less than 3 mrem/yr, which is well below the performance objectives of 100 mrem/yr or the ALARA objective of 30 mrem/yr. Several sources of uncertainty were noted in the first iteration of the composite analysis, with the largest uncertainty associated with the inventories of key mobile radionuclides. Other sources of uncertainty in the analysis arose from the conceptual and numerical models of contaminant migration and fate in the vadose zone and assumption regarding source-term release models and end states. The composite analysis demonstrated a significant separation in time between past-practice discharges and disposals, and active and planned disposal of solid waste, environment restoration waste, and immobilized low-activity waste. The higher integrity disposal facilities and surface covers of these active and planned disposal delay releases, and the releases do not superimpose on the plumes from the near-term past-practice disposals.

Table 1-4. 200-ZP-1 Operable Unit Existing References. (13 sheets)

Reference	Summary
Data Quality Objective Summary Report for Establishing a RCRA/CERCLA/AEA Integrated 200 West and 200 East Area Groundwater Monitoring Network, CP-15329, Rev. 0 (FH 2003b)	The purpose of this DQO process was to assess the current groundwater monitoring well networks for the 200 West and 200 East Areas. This assessment was needed to address changing contaminant plume conditions (e.g., plume migration) and to ensure that monitoring activities meet the requirements for remediation performance monitoring (i.e., CERCLA monitoring), sitewide surveillance monitoring to meet the requirements of DOE orders, and detection/assessment monitoring to meet the requirements of RCRA. This DQO summary report was prepared in support of DOE's Cleanup, Constraints, Challenges Team (C3T) process. Because of the changing shape of the groundwater contaminant plume contours over time and changing programmatic needs, the 200 West and 200 East groundwater monitoring network is required to be periodically re-evaluated. The objective of the groundwater CERCLA remediation performance monitoring program is to provide a routine assessment of the effectiveness of groundwater remediation activities within the 200-ZP-1 and 200-UP-1 OUs. The objectives of the sitewide surveillance monitoring program are as follows: • Determine baseline conditions of groundwater quality and quantity. • Characterize and define hydrogeologic, physical, and chemical trends in the groundwater system. • Identify existing and potential groundwater contamination sources. • Assess existing and emerging groundwater quality problems. • Evaluate existing and potential offsite impacts of groundwater contamination. • Provide data on which decisions can be made concerning land disposal practices and the management and protection of groundwater resources. Finally, the objective of the RCRA detection program is to identify if TSD units are impacting groundwater quality. If impacts to groundwater are detected, the objective of the RCRA assessment program is to define the rate and extent of contaminant migration. This DQO process identified the optimum number of groundwater wells to be monitored to meet these objectives and determined that a number of new groundwater wells needed to be installed. The identity of wells in the monitoring network, sampling frequency, the analyses to be performed, the detection limit requirements, and other analytical performance requirements (e.g., precision and accuracy) were defined in this document. The resulting groundwater monitoring network fulfilled the needs of the three major Hanford Site regulatory monitoring activities (i.e., CERCLA, RCRA, and AEA).

Table 1-4. 200-ZP-1 Operable Unit Existing References. (13 sheets)

Reference	Summary
Declaration of the Interim Record of Decision for the 200-ZP-1 Operable Unit (EPA et al. 1995)	The interim ROD for the 200-ZP-1 OU presents a description of the selected interim remedy for carbon tetrachloride, chloroform, and TCE groundwater contamination in the vicinity of the PFP. The interim remedial action was chosen in accordance with CERCLA, SARA, the Tri-Party agreement and, to the extent practicable, the "National Oil and Hazardous Substances Pollution Contingency Plan" (40 CFR 300). The State of Washington concurred with the selected remedy. The selected remedy consists of pumping the highest concentration zone of the contaminated plume at 200-ZP-1 and treatment using air stripping. The selected remedy is intended to reduce contaminant mass within the plume and minimize migration of carbon tetrachloride, chloroform, and TCE from the 200 West Area. The high-concentration portion of the plume corresponds to that area having contaminant greater than or equal to 2,000 ppm carbon tetrachloride. The interim action is protective of human health and the environment in the short term and is intended to provide adequate protection until a final ROD is signed. The groundwater removed will be treated to meet requirements before discharge. This interim action is only part of the total remedial action for the 200-ZP-1 OU and is considered cost effective. The interim RAOs are as follows: • Prevent further movement of contaminants from the highest concentration area of the carbon tetrachloride plume (i.e., >2,000 µg/L contour). • Reduce contamination in the area of highest carbon tetrachloride concentrations. • Provide information that will lead to the development of a final remedy that will be protective of human health and the environment.
Findings from Groundwater Compliance Monitoring Evaluation Inspection at the T and TX/TY Waste Management Areas, letter from B. Wilson (Ecology) to K. Klein (RL) and H. Boston (ORP), dated November 20, 2001 (Wilson 2001)	This letter reported that neither the vertical nor horizontal extent of contamination to groundwater in the T or TX/TY TSD units have been delineated in accordance with 40 CFR 265.93(d)(4)(i), Subpart F. The letter notes that unfiltered groundwater samples should be collected when in situ turbidity measurement goals have been reached.
Fiscal Year 2004 Annual Summary Report for the 200-UP-1 and 200-ZP-1 Pump-and-Treat Operations, DOE/RL-2004-72, Rev. 0 (DOE-RL 2005c)	The document summarizes performance of the groundwater pump-and-treat systems in FY04 and discusses the changes that have been observed in the plume shape and concentration during the reporting period.

Table 1-4. 200-ZP-1 Operable Unit Existing References. (13 sheets)

Reference	Summary
Hanford Site Groundwater Management Plan: Accelerated Cleanup and Protection, DOE/RL-2002-68, Rev. 0 (DOE-RL 2003b)	This document lays out a plan developed by DOE, in conjunction with EPA and Ecology, to accelerate cleanup. The goal is to return groundwater to its highest beneficial use, where practicable, or which will at least prevent further degradation. The previous baseline shows remediation beginning in 2008 and extending to 2024. The new accelerated schedules illustrated in this document show that the baseline will begin in 2004 and will be completed by 2012. The document contains discussion of specific results that can be expected using the accelerated plan for cleanup. These results and expected dates of completion include the following: • Remediate high-risk wastes: 2011. • Shrink the contaminated areas: 2112. • Reduce recharge: 2012. • Remediate groundwater: 2012. • Evaluate groundwater monitoring needs: ongoing. Plans to deal with waste sites in close proximity to the tank farms require further work and will depend greatly on the strategy employed to close the tanks. The regions selected for completion by 2012 avoid those areas immediately adjacent to tank farms until and integrated approach to waste site remediation and tank closure can be developed. In addition to accelerated schedules for cleanup and groundwater protection, the document contains definition and discussion of various proposed groundwater protection boundaries (e.g., core zone and outside the core zone). As part of the integrated accelerated plan, an area closure strategy for the Central Plateau is discussed. Three major areas in the 200-ZP-1 Groundwater OU are identified: • T Plant area closure • T Tank Farm area closure • PFP area closure. When cleanup is implemented on an area-by-area basis, these coordinated efforts to control sources, implement remedial action, and assess and monitor impact are expected to place major portions of the Central Plateau into a condition of long-term stewardship monitoring starting in 2006.

Table 1-4. 200-ZP-1 Operable Unit Existing References. (13 sheets)

Reference	Summary
Hanford Site Groundwater Monitoring for Fiscal Year 2002, PNNL-14187 (PNNL 2003)	This report presents the results of groundwater and vadose zone monitoring and remediation for FY02 on the Hanford Site. Water-level monitoring was performed to evaluate groundwater flow directions, to track changes in water levels, and to relate such changes to evolving disposal practices. Water levels over most of the Hanford Site continued to decline between March 2001 and March 2002. The most extensive plumes are tritium, iodine-129, and nitrate, which all had multiple sources and are mobile in groundwater. The largest portions of these plumes are migrating from the central Hanford Site (Central Plateau) to the southeast, toward the Columbia River. Concentrations of tritium, nitrate, and some other contaminants continued to exceed drinking water standards in groundwater discharging to the river in FY02. However, contaminant concentrations in river water remained low and were far below standards. Carbon tetrachloride and associated organic constituents form a relatively large plume beneath the central portion of the Hanford Site. Hexavalent chromium is present in smaller plumes beneath the reactor areas along the river and beneath the central portion of the Site. Strontium-90 exceeds standards beneath each of the reactor areas, and technetium-99 and uranium are present in the 200 Areas. Other minor contaminant plumes are also noted. Interim groundwater remediation in the 100 and 200 Areas continued in 2002. The objective of the two interim remediation (pump-and-treat) systems in the 200-ZP-1 and 200-UP-1 Groundwater OUs in the 200 West Area is to prevent the spread of carbon tetrachloride and technetium-99/uranium plumes. This annual report presents groundwater contours and the perimeter of the carbon tetrachloride, chloroform, and TCE plumes within the 200-ZP-1 OU, as well as groundwater contours and the perimeter of the technetium-99 and uranium plumes within the 200-UP-1 OU. Also provided are maps showing the location of sampled groundwater wells and the frequency at which wells are sampled, the depth of well screens, etc. In FY02, modelers completed an initial assessment of 10 contaminants, simulating their movement over the years 1944 through 3050. Specific modeling of plume movements in the 200 Areas and local-scale modeling of the 200 Area pump-and-treat IRMs were reported.
Hydrogeologic Conceptual Model for the Carbon Tetrachloride and Uranium/ Technetium Plumes in the 200 West Area: 1994 Through 1999 Update, BHI-01311, Rev. 0 (BHI 1999b)	Summarizes the geological and hydrogeological conceptual model for the carbon tetrachloride plume in the 200 West Area. Includes a summary of analytical results for carbon tetrachloride sampling (through 1999) at depths greater than 10 m (32.8 ft) below the water table.

Table 1-4. 200-ZP-1 Operable Unit Existing References. (13 sheets)

Reference	Summary
Remedial Investigation Data Quality Objectives Summary Report for the 200-PW-1 Operable Unit Phase I Representative Waste Sites, BHI-01477, Rev. 0 (BHI 2001b)	This Phase I DQO summary report supported the remedial action decision-making processes for the 200-PW-1 organic-rich/plutonium-rich waste group OU. The RI was to be conducted under CERCLA. The waste sites in the 200-PW-1 OU received effluents from the Z Plant complex, including PFP processes, which contained significant concentrations of chemicals and radionuclides. Data collected during the RI was to be used to determine if the waste sites were contaminated above levels that will require remedial action, to support evaluation of remedial alternatives and/or closure strategies, and to verify or refine the preliminary conceptual contaminant distribution models. The data were generated mainly through soil sampling and analysis. The DQO process used the concept of analogous site contaminant data to reduce the amount of characterization required to support RI/FS decisions. This approach involves the grouping of sites with similar process histories, structures, and contaminants and then choosing one or more representative sites for comprehensive field investigation, including sampling during the RI activities. Findings from the RI at representative sites are then used to make remedial action decisions for all of the waste sites in the OU. Nonrepresentative sites for which field data have not been collected are assumed to have contaminant characteristics similar to the representative sites that are characterized. A ROD will be issued through the RI/FS process using the data collected during the RI. The analogous sites (i.e., those not sampled during the RI) will be addressed during the confirmatory sampling phase to ensure that the remedial action specified in the ROD is appropriate and to provide design data as needed. Following remedial actions, verification samples will be collected to support site closeout.

Table 1-4. 200-ZP-1 Operable Unit Existing References. (13 sheets)

Reference	Summary
"Summary of Comprehensive Groundwater Monitoring Evaluation Report, T and TX-TY Tank Farms," March 1, 2001 (contained in the *Data Quality Objectives Summary Report for Establishing a RCRA/CERCLA/ AEA Integrated 200 West and 200 East Groundwater Monitoring Network* [FH 2003b])	This document notes that in 1996, there were statistically significant increases in chromium, technetium-99, and cobalt-60 in well 299-W11-27, which is located on the north side of TSD unit T. The plume that affected well 299-W11-27 is now being detected in well 299-W11-23, located to the east of well 299-W11-27. The TX-TY TSD unit was placed in assessment groundwater monitoring (40 CFR 265.93[d][4]) after elevated waste constituent and indicator parameter measurements/observations (specific conductivity) occurred in downgradient monitoring wells. Elevated levels of chromium, tritium, technetium-99, and cobalt-60 were observed in samples from well 299-W14-12, which is located on the east side of TSD unit TX-TY. In 1998, a tritium and iodine-129 plume was detected in well 299-W14-2, located on the east side of TSD unit TX-TY. **TX TANK FARM** Eight TX Tank Farm tanks (TX-105, TX-107, TX-110, TX-113, TX-114, TX-115, TX-116, and TX-117) are "suspected/confirmed leaking single-shell tanks." At least 10 UPRs have been documented within the vicinity of the TSD unit TX: • UPR-200-W-5 occurred in 1950 and resulted from leaky jumpers/overflow around the 251-TX-155 diversion box. • UPR-200-W-126 occurred in 1975 during repair of 241-TX-153. The UPR was a liquid spill on the east side of the TX Tank Farm. • UPR-200-W-129 occurred in 1971 during testing of jumpers at the 241-TX-113 tank. This UPR occurred while a new jumper assembly was being leak tested. Apparently a valve was inadvertently closed, which caused contaminated liquid to spray through the pit cover blocks. The extent of the contamination was not documented. • UPR-200-W-149 occurred in 1977 and consisted of a suspected leak from 241-TX-107 tank after high monitoring counts in gross-gamma log of dry well were detected. A reported 2,500 gal of waste leaked from this tank. • UPR-200-W-17 occurred in 1952 and consisted of a spill during transfer/pumping from the 241-TX-106 to 241-TX-114 tank. The contaminated material covered an area 9.5 m by 182.9 m (300 ft by 600 ft). The contaminated liquid contained concentrations of cesium-137, nobelium, ruthenium, strontium-90, and zirconium. • UPR-200-W-29 occurred in 1954 and consisted of the failure of an unencased line connecting 241-T-152 and 241-TX-153 diversion boxes, during which first-cycle supernatant from 241-T-105 tank was released. • UPR-200-W-100 occurred in 1954 when waste spilled from the line connecting the 241-TX-105 and 241-TX-118 tanks. Contaminated liquid from the leak covered an area approximately 30.3 m by 38.13 m (100 ft by 125 ft). The contaminated liquid contained approximately 10 Ci of fission products. • UPR-200-W-135 occurred in 1954 and consisted of a leak (approximately 1,000 gal of supernatant) north of the 241-TX-155 diversion box. • UPR-200-W-99 occurred in 1968 as a result of airborne contamination that emanated from the 241-TY-153 diversion box. Two plumes containing strontium-90 were identified northeast and southeast of the diversion box. This UPR lies just outside the east TX Tank Farm fence. • UPR-200-W-76 occurred in 1997 and consisted of contaminated rabbit fecal pellets that covered an area 45.75 m by 91.5 m (150 ft by 300 ft) in the northwest corner of the tank farm. The fecal mater contained cesium-137, cesium-134, europium-152, europium-154, and strontium-90.

Table 1-4. 200-ZP-1 Operable Unit Existing References. (13 sheets)

Reference	Summary
[continued] "Summary of Comprehensive Groundwater Monitoring Evaluation Report, T and TX-TY Tank Farms," March 1, 2001 (contained in the *Data Quality Objectives Summary Report for Establishing a RCRA/CERCLA/ AEA Integrated 200 West and 200 East Groundwater Monitoring Network* [FH 2003b])	**TY TANK FARM** Five TY Tank Farm tanks (TY-101, TY-103, TY-104, TY-105, and TY-106) are "suspected/confirmed leaking single-shell tanks." At least four documented UPRs have occurred within the perimeter fence of the TY Tank Farm: • UPR-200-W-150 occurred in 1973 and was associated with tank TY-103. Overflow of the 241-TX diversion box flowed back into tank TY-103, depositing 3.3 cm (1.3 in.) of sludge waste. No significant activity increases were observed in the tank TY-103 monitoring boreholes. This release has been referred to as a "flooding event"; however, there are no details documented that describe the extent of the release. • UPR-200-W-151 occurred in 1974 and was associated with tank TY-104. Leakage of approximately 1,400 gal of supernatant from this tank was identified by a liquid-level decrease of 0.76 cm (0.3 in.). Remaining liquids in the tank were removed using salt well pumping. • UPR-200-W-152 occurred in 1960 and was associated with tank TY-105. Tank TY-105 was designated a confirmed leaker as a result of this release. A salt well was installed to remove liquids from the tank via salt well pumping. • UPR-200-W-153 occurred in 1959 and was associated with tank TY-106. Tank TY-106 was designated a confirmed leaker of unknown quantity of tributyl phosphate waste as a result of this release. The intensity of radiation in monitoring borehole 52-06-05 increased and then stabilized. Diatomaceous earth was added to the tank to stabilize the liquid waste.
T and TX/TY Waste Management Areas Regulatory Deficiencies, letter from B. Wilson (Ecology) to K. Klein (RL) and H. Boston (ORP), dated April 18, 2002 (Wilson 2002)	This letter reported that aquifer properties (i.e., flow direction, flow rates, etc.) are fundamental requirements for RCRA groundwater monitoring systems. Furthermore, the nature and extent of contamination at these TSD units have neither been empirically defined nor confirmed by adequate groundwater monitoring data. Also, site-specific dispersivity has not been adequately factored into groundwater modeling to provide a sound basis for point-of-compliance well locations and spacing.
T Plant Source Aggregate Area Management Study Report, DOE/RL-91-61, Rev. 0 (DOE-RL 1992b)	This report presents the results of an aggregate area management study for the T Plant aggregate area in the 200 Areas of the Hanford Site. This scoping-level study provides the basis for initiating RI/FS activities under CERCLA or RFI/CMS activities under RCRA. The report also integrates select RCRA TSD closure activities with CERCLA and RCRA past-practice investigations. The Hanford Site past-practice strategy focuses on reaching early decisions to initiate and complete cleanup projects, maximizing the use of existing data, coupled with focused short-timeframe investigations where necessary. The strategy includes three paths for interim decision making and a final remedy selection process for the OU that incorporates the three paths and integrates sites not addressed in those paths. The three paths for interim decisions making include the ERA, IRM, and LFI paths. The strategy requires that AAMSRs be prepared to provide an evaluation of existing site data to support initial path decisions. This AAMSR is one of 10 reports that will be prepared for each of the 10 aggregate areas defined in the 200 Areas. The T Plant aggregate area contains a variety of waste disposal and storage units in addition to its plutonium finishing and recovery facilities and support facilities. Historically, high-level wastes were discharged to the soil column through cribs, trenches, and other facilities. Low-level wastes (e.g., cooling and condensate water) were allowed to percolate into the ground through drains and open ditches. Based on construction, purpose, or origin, the T Plant aggregate area WMUs fall into one of the 10 aggregate area subgroups. As a result of the data evaluation process, no WMUs were recommended for ERAs, 33 WMUs were recommended for LFIs (which could lead to IRMs), and 36 WMUs were recommended for final remedy selection. The document also provided insight into the various sources and COPCs applicable to the OU.

Table 1-4. 200-ZP-1 Operable Unit Existing References. (13 sheets)

Reference	Summary
TX Tank Farm Vadose Characterization Boring Request, letter from J. Hedges (Ecology) to R. Yasek (ORP), dated March 4, 2002 (Hedges 2002)	In this letter, Ecology requested that ORP consider extending the vadose zone borehole of the eastern side of TX Tank Farm to the groundwater. The basis for this request included the results from the vadose boring at S-SX Tank Farms that was completed as groundwater monitoring well 299-W23-19 and currently represents the point of the highest technetium-99 groundwater concentration measured at the Hanford Site.
Waste Site Groupings for 200 Areas Soil Investigations, DOE/RL-96-81, Rev. 0 (DOE-RL 1997)	The analogous site approach concept was a key element in the development of the *200 Areas Soil Remediation Strategy – Environmental Restoration Program* (DOE-RL 1996) because many of the 200 Area waste sites share similarities in geological conditions, functions, and types of waste received. As a result, the need to establish waste site groups for 200 Area waste sites was identified as an initial step in the implementation of the 200 Areas soil remediation strategy (DOE-RL 1996). The purpose of this document was to identify logical waste site groups for characterization based on criteria established in 200 Areas soil remediation strategy. Specific objectives of the document included the following; • Finalize waste site groups based on the approach and preliminary groupings identified in the 200 Areas soil remediation strategy. • Prioritize the waste site groups based on criteria developed in the 200 Areas soil remediation strategy. • Select representative sites that best represent typical and worst-case condition for each waste group. • Develop conceptual models for each waste group. Waste site group prioritization and representative site selection will support a more efficient and cost-effective approach to characterizing the 200 Area waste sites. Characterization efforts will be limited to representative sites, the data from which will be used to remedial action decisions for all waste sites within a group (consistent with the analogous site approach). Waste site group properties will be used to establish a sequence in which the representative sites are expected to be addressed. The conceptual models developed in this document provide an initial prediction of the nature and extent of primary COC and support the selection of representative sites and prioritization of groups.

Table 1-4. 200-ZP-1 Operable Unit Existing References. (13 sheets)

Reference	Summary
Z Plant Source Aggregate Area Management Study Report, DOE/RL-91-58, Rev. 0 (DOE-RL 1992c)	This report presents the results of an aggregate area management study for the Z Plant aggregate area in the 200 Areas of the Hanford Site. This scoping-level study provides the basis for initiating RI/FS activities under CERCLA or RFI/CMS activities under RCRA. The report also integrates select RCRA TSD closure activities with CERCLA and RCRA past-practice investigations. The Hanford Site past-practice strategy focuses on reaching early decisions to initiate and complete cleanup projects, maximizing the use of existing data, coupled with focused short-timeframe investigations where necessary. The strategy includes three paths for interim decision making and a final remedy selection process for the OU that incorporates the three paths and integrates sites not addressed in those paths. The three paths for interim decisions making include the ERA, IRM, and LFI paths. The strategy requires that AAMSRs be prepared to provide an evaluation of existing site data to support initial path decisions. This AAMSR is one of 10 reports that will be prepared for each of the 10 aggregate areas defined in the 200 Areas The Z Plant aggregate area contains a variety of waste disposal and storage units in addition to its plutonium finishing and recovery facilities and support facilities. Historically, high-level wastes were discharged to the soil column through cribs, trenches, and other facilities. Low-level wastes (e.g., cooling and condensate water) were allowed to percolate into the ground through drains and open ditches. Based on construction, purpose, or origin, the Z Plant aggregate area WMUs fall into one of the 10 aggregate area subgroups. As a result of the data evaluation process, 5 WMUs were recommended for ERAs, no WMUs were recommended for IRMs, 32 WMUs were recommended for LFIs (which could lead to IRMs), and 18 WMUs were recommended for final remedy selection. The document also provided insight into the various sources and COPCs applicable to the OU.
Hanford Virtual Library	This database was used to identify historical data and levels of COPCs measured in groundwater from particular wells.

Table 1-4. 200-ZP-1 Operable Unit Existing References. (13 sheets)

Reference	Summary
AAMSR	= aggregate area management study report
AEA	= *Atomic Energy Act of 1954*
ALARA	= as low as reasonably achievable
ARAR	= applicable or relevant and appropriate requirement
CERCLA	= *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	= *Code of Federal Regulations*
COC	= contaminant of concern
COPC	= contaminant of potential concern
DOE	= U.S. Department of Energy
DQO	= data quality objective
Ecology	= Washington State Department of Ecology
EPA	= U.S. Environmental Protection Agency
ERA	= expedited response action
FY	= fiscal year
GAC	= granular activated carbon
gpm	= gallons per minute
IRM	= interim remedial measure
LFI	= limited field investigation
ORP	= U.S. Department of Energy, Office of River Protection
OU	= operable unit
PFP	= Plutonium Finishing Plan
ppm	= parts per million
RAO	= remedial action objective
RCRA	= *Resource Conservation and Recovery Act of 1976*
RFI/CMS	= RCRA field investigation/corrective measures study
RI/FS	= remedial investigation/feasibility study
RL	= U.S. Department of Energy, Richland Operations Office
ROD	= Record of Decision
SAP	= sampling and analysis plan
SARA	= *Superfund Amendments and Reauthorization Act of 1986*
TCE	= trichloroethylene
Tri-Party Agreement	= *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 2003)
TSD	= treatment, storage, and disposal
UPR	= unplanned release
WMU	= waste management unit

Table 1-5. Preliminary Target Action Levels and Basis[a] for Groundwater Contaminants of Concern. (5 sheets)

COC	Primary MCL	Secondary MCL[a]	CLARC Groundwater Method B[c]	Background[b]	CRDL	Selected Limit[d]	Source[d]	Comments
Volatile Organics – Units for Nonradiological COCs (µg/L)								
Acetone	—	—	7200	—	20	7200	CLARC	CLARC > CRDL. CERCLA COC in current groundwater well monitoring network.[f]
Benzene	5	—	0.795	—	5	5	CRDL	CLARC < MCL and CRDL > CLARC.
Carbon disulfide	—	—	800	—	5	800	CLARC	CLARC > CRDL. CERCLA COC in current groundwater well monitoring network.[f]
Carbon tetrachloride	5	—	0.337	—	3	3	CRDL	CRDL > CLARC. CERCLA COC in current groundwater well monitoring network.[f]
Chloroform	80	—	7.17	—	5	7.17	CLARC	CLARC < MCL and CLARC > CRDL. CERCLA COC in current groundwater well monitoring network.[f]
Chlorobenzene	100	—	160	—	5	100	Primary MCL[e]	MCL < CLARC, and MCL > CRDL
Ethyl benzene	700	—	800	—	5	700	Primary MCL[e]	MCL < CLARC, and MCL > CRDL
Methylene chloride	5	—	5.83	—	1	5	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
Methyl ethyl ketone	—	—	4,800	—	10	4,800	CLARC	CLARC > CRDL.
4-methyl-2-pentanone (hexone, MIBK)	—	—	640	—	10	640	CLARC	CLARC > CRDL.
N-butyl benzene	—	—	320	—	5	320	CLARC	CLARC > CRDL.
Cis 1,2-dichloroethylene	70	—	80	—	10	70	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
Trans 1,2-dichloroethylene	100	—	160	—	10	100	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
1,2-dichloroethane (DCA)	5	—	0.481	—	5	5	CRDL	CLARC < MCL and CRDL > CLARC.
Toluene	1,000	—	1,600	—	5	1,000	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
1,1,1-trichloroethane (TCA)	200	—	7,200	—	5	200	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
Trichloroethylene (TCE)	5	—	3.98	—	5	5	CRDL	CLARC < MCL and CLARC < CRDL. CERCLA COC in current groundwater well monitoring network.[f]

Table 1-5. Preliminary Target Action Levels and Basis[a] for Groundwater Contaminants of Concern. (5 sheets)

COC	Primary MCL	Secondary MCL[a]	CLARC Groundwater Method B[a]	Background[b]	CRDL	Selected Limit[a]	Source[d]	Comments
Tetrachloroethylene (PCE)	5	—	0.081	—	5	5	CRDL	CLARC < MCL and CLARC > CRDL.
Xylene (total)	10,000	—	1,600	—	10	1600	CLARC	MCL > CLARC, and CLARC > CRDL.
Semi-Volatile Organics – Units for Nonradiological COCs (µg/L)								
Cresols	—	—	80[g]	—	10	80	CLARC	CLARC > CRDL. CLARC based on p-cresol.
Kerosene	—	—	—	—	500	TBD[h]		No regulatory limits available.
Phenols (total)	—	—	4800	—	10	4800	CLARC	CLARC
Metals – Units for Nonradiological COCs (µg/L)								
Antimony	6	—	6.4	—	10	10	CRDL	MCL < CLARC, but CRDL > MCL.
Arsenic	10[e]	—	0.0583	10	10	10	CRDL	CLARC < MCL, CRDL= Hanford background > CLARC. CERCLA COC in current groundwater well monitoring network.[f]
Cadmium	5	—	8	<10	5	5	Primary MCL[e]	MCL < CLARC, and MCL = CRDL. CERCLA COC in current groundwater well monitoring network.[f]
Chromium (total)	100[a]	—	24,000	<30	10	100	Primary MCL[e]	MCL < CLARC, and MCL > CRDL. CERCLA COC in current groundwater well monitoring network.[f]
Chromium (hexavalent)	—	—	48[c]	—	10	48	CLARC	CLARC > CRDL. There is no drinking water MCL for hexavalent chromium.
Iron	—	300	—	86	50	300	Secondary MCL	MCL > CRDL. Secondary DWS = 300 µg/L (www.epa.gov/safewater/mcl.html). See footnote m.
Lead	15	—	—	<5	10	15	Primary MCL[e]	MCL > CRDL. Drinking water treatment levels = 15 µg/L (www.epa.gov/safewater/mcl.html).
Lithium	—	—	320	—	25	320	CLARC	CLARC
Magnesium	—	—	—	16,480	750	TBD[h]		No regulatory limits available.
Manganese	—	50	2,240	24.5	5	50	Secondary MCL	CLARC > CRDL. Secondary DWS = 50 µg/L (www.epa.gov/safewater/mcl.html). See footnote m.
Mercury	2	—	4.8	<0.1	0.5	2	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
Nickel	—	—	320	—	40	320	CLARC	CLARC > CRDL.

Table 1-5. Preliminary Target Action Levels and Basis[a] for Groundwater Contaminants of Concern. (5 sheets)

COC	Primary MCL	Secondary MCL[a]	CLARC Groundwater Method B[c]	Background[b]	CRDL	Selected Limit[d]	Source[d]	Comments
Selenium	50	—	80	—	10	50	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
Silver	—	100	80	—	10	80	CLARC	CLARC > CRDL.
Uranium (total)	30	—	48	3.43	0.1	30	Primary MCL[e]	MCL < CLARC, and MCL > CRDL. CERCLA COC in current groundwater well monitoring network.[f]
Vanadium	—	—	112	15	50	112	CLARC	Noncarcinogen CLARC > CRDL.
Non-Metals – Units for Nonradiological COCs (µg/L)								
Ammonium	—	—	—	120	50	TBD[h]		No regulatory limits available.
Cyanide	200	—	320	—	5	200	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
Fluoride	4,000	2,000	960	775	500	960	CLARC	Primary MCL > background and CRDL. Secondary DWS is unenforceable and other standards are available.
Nitrate	44,285	—	7,086	12,400	75	12,400	Background	Background > CLARC and CRDL.
Nitrate as nitrogen	10,000	—	25,600	2,800	17	10,000	CLARC	MCL<CLARC, background < CLARC.
Nitrite	3,286	—	5,257	—	75	3,268	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
Nitrite as nitrogen	1,000	—	1,600	—	17	1,000	Primary MCL[e]	MCL < CLARC, and MCL > CRDL.
Phosphate	—	—	—	<1,000	500	TBD[h]		No regulatory limits available.
Radiological COCs – Beta Emitters – Units for Radiological COCs (pCi/L, unless otherwise noted)								
C-14	2,000[j]	—	—	—	200	2,000[j]	Primary MCL[j]	MCL > CRDL. MCL based on 4 mrem/yr. From /www.epa.gov/safewater/mcl.html (EPA et al. 1997).
I-129	1[j]	—	—	—	0.5	1[j, o]	Primary MCL[j]	MCL > CRDL. MCL based on 4 mrem/yr. CERCLA COC in current groundwater well monitoring network.[f] From www.epa.gov/safewater/mcl.html (EPA et al. 1997).
Se-79	4 mrem/yr[j]	—	—	—	30	4 mrem/yr[j]	Primary MCL[j]	MCL > CRDL. MCL based on 4 mrem/yr. From www.epa.gov/safewater/mcl.html (EPA et al. 1997).
Sr-90	8[j]	—	—	—	2	8[j]	Primary MCL[j]	MCL > CRDL. MCL based on 4 mrem/yr. CERCLA COC in current groundwater well monitoring network.[f] From www.epa.gov/safewater/mcl.html (EPA et al. 1997).

Table 1-5. Preliminary Target Action Levels and Basis[a] for Groundwater Contaminants of Concern. (5 sheets)

COC	Primary MCL	Secondary MCL[a]	CLARC Groundwater Method B[c]	Background[b]	CRDL	Selected Limit[d]	Source[e]	Comments
Tc-99	900[j,k]	—	—	—	20	900[j]	Primary MCL[j]	MCL > CRDL. MCL based on 4 mrem/yr. CERCLA COC in current groundwater well monitoring network.[f] From www.epa.gov/safewater/mcl.html (EPA et al. 1997).
H-3	20,000[j]	—	—	—	400	20,000[j]	Primary MCL[j]	MCL > CRDL. MCL based on 4 mrem/yr. From www.epa.gov/safewater/mcl.html (EPA et al. 1997).
Radiological COCs – Alpha Emitters – Units for Radiological COCs (pCi/L)								
Np-237	15	—	—	—	1	15	Primary MCL	MCL > CRDL.
Pa-231	15	—	—	—	1	15	Primary MCL	MCL > CRDL.
Radiological COCs – Gamma Emitters – Units for Radiological COCs (pCi/L)								
Cs-137	60[j]	—	—	—	15	60[j]	MCL[j]	CERCLA COC in current groundwater well monitoring network.[f]

[a] Primary MCLs were used where available and are assumed unless noted; secondary MCLs are noted in the comments column.
[b] From *Hanford Site Groundwater Background* (DOE-RL 1992a).
[c] WAC 173-340-740(4) groundwater Method B values from Ecology's *Cleanup Levels and Risk Calculations Under the Model Toxics Control Act Cleanup Regulation*, CLARC database tables (Ecology 2005) with additional IRIS risk information, August 2005.
[d] The selected limit is the lower of the MCL or CLARC values with the following exception: if the background or CRDL is higher, the higher of these is selected. If the CLARC tables allowed a choice between carcinogenic and noncarcinogenic values for groundwater, the lower was chosen. In some cases, no regulatory limit is available. In cases where the MCL is lower than the CRDL, efforts will be made to lower the CRDL. If this cannot be achieved, risk assessment guidance (EPA 1989) allows the use of the CRDL as the selected limit.
[e] Target action level represents primary MCL (on the Internet at www.epa.gov/safewater/mcl.html).
[f] From *Data Quality Objectives Summary Report for Establishing a RCRA/CERCLA/AEA Integrated 200 West and 200 East Groundwater Monitoring Network* (FH 2003b).
[g] It is not known which of the cresols might be found; therefore, target action levels were based on p-cresol and are a factor of 10 lower than the other cresols.
[h] These nonradiological COCs will be sampled and analyzed in FY04 and FY06 for wells identified in Section A3.2.1 of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c). If these COCs are not found during these sampling events, they will not be considered again in this CERCLA process. If these COCs are detected at levels deemed significant (greater than the CRDLs in Table A2-1 of the 200-ZP-1 RI/FS work plan), then a target action level may be established with RL and EPA concurrence.
[i] This radiological COC will be sampled and analyzed in FY04 and FY06 for wells identified in Section A3.2.1 of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c). If these COCs are not found during these sampling events, they will not be considered again in this CERCLA process. A calculation has not been performed to establish a target action level (pCi/L) from the drinking water regulatory requirement of 4 mrem/yr for these COCs. If these COCs are detected at levels deemed significant (greater than the CRDLs in Table A2-1 of the 200-ZP-1 RI/FS work plan), then a target action level may be established with RL and EPA concurrence to ensure that the hypothetical dose from these radionuclides is less than 4 mrem/yr outside the core zone.
[j] Target action level based on the estimated groundwater concentration that would result 4 mrem/yr (MCL) to the whole body or an organ if the groundwater water were used as drinking water (DOE-RL 2002b, Table 2-3).
[k] Technetium-99 remedial target action levels defined in *Record of Decision for the 200-UP-1 Interim Remedial Measure* (EPA et al. 1997).
[m] In some instances, drilling through basalt for the well may contribute to contamination of the well water with iron and manganese.
[n] Total chromium based on chromium III and VI values.
[o] Laboratory cannot routinely achieve 0.5 pCi/L, thus using 1.0 pCi/L, which is both CRDL and selected limit.

Table 1-5. Preliminary Target Action Levels and Basis[a] for Groundwater Contaminants of Concern. (5 sheets)

COC	Primary MCL	Secondary MCL[a]	CLARC Groundwater Method B[a]	Background[b]	CRDL	Selected Limit[d]	Source[d]	Comments

AEA = *Atomic Energy Act of 1954*
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CLARC = *Cleanup Levels and Risk Calculations Under the Model Toxics Control Act Cleanup Regulation*
COC = contaminant of concern
CRDL = contract-required detection limit
DWS = drinking water standard
Ecology = Washington State Department of Ecology
EPA = U.S. Environmental Protection Agency
FY = fiscal year
MCL = maximum contaminant level
RCRA = *Resource Conservation and Recovery Act of 1976*
RI/FS = remedial investigation/feasibility study
RL = U.S. Department of Energy, Richland Operations Office
TBD = to be determined
WAC = *Washington Administrative Code*

Table 1-6. Data Completeness. (2 sheets)

Monitoring Well Category	Data Required Based on 200-ZP-1 RI/FS Work Plan	Data Included in RI Report	Discussion
Routine groundwater monitoring	Table A3-2 wells and COCs[a]	Table 1-2 of this RI report includes all of the wells listed in Table A3-2 of the 200-ZP-1 RI/FS work plan, as well as additional wells.	Exceeds requirements of the 200-ZP-1 RI/FS work plan. Many wells are analyzed for COCs not required by the 200-ZP-1 RI/FS work plan. All data from 1988 through October 2005 are included. Additional wells were added that were not in the 200-ZP-1 RI/FS work plan.
Monitoring for additional COCs	Sample the following wells for all COCS in Table 1-5 of this RI report[b]. Wells will be sampled once in 2004 and once in 2006 for full COC list (Group A and Group B analytes). Wells listed in Table A3-3 of the 200-ZP-1 RI/FS work plan are as follows: 299-W7-4, 299-W10-4, 299-W11-14, 299-W14-13, 299-W15-152, 299-W15-47, and 699-48-77A.	Table 1-7 of this RI report lists the analytes (by well) that have been analyzed in either FY04 or FY05.	Most analytes were measured in the wells.
Modeling input parameters	The 200-ZP-1 RI/FS work plan requires that the following wells be analyzed for all COCs (Group A and Group B) and for applicable geochemical, hydrogeological, and physical parameters: 299-W11-43, 299-W15-46, and 299-W15-49.	Table 1-7 of this RI report lists the COCs analyzed. Sections 2.0 and 4.0 of this RI report discuss the results of the geochemical, hydrogeological, and physical parameters analysis. All data are complete for these three wells.	Select COCs were analyzed; additional analysis is forthcoming. Additional data were collected during the drilling of wells not listed in the 200-ZP-1 RI/FS work plan. Additional gamma logs are presented for 13 wells that were not discussed in the 200-ZP-1 RI/FS work plan.

Table 1-6. Data Completeness. (2 sheets)

Monitoring Well Category	Data Required Based on 200-ZP-1 RI/FS Work Plan	Data Included in RI Report	Discussion
Depth-discrete data for carbon tetrachloride and technetium-99 in groundwater.	Section A3.2.4 of the 200-ZP-1 RI/FS work plan indicates that depth-discrete groundwater sampling is required for all of the new wells proposed to be installed.	Depth-discrete data are presented in Section 4.4 and the plate maps in Appendix C.	Exceeds requirements. The 37 wells are presented with depth-discrete data for carbon tetrachloride on the plate maps found in Appendix C. This is significantly more than that required by the 200-ZP-1 RI/FS work plan. Two wells have depth-discrete technetium-99 data. In addition, select COCs other than carbon tetrachloride were analyzed at multiple depths from the 19 RI/FS wells.

NOTE: Reference to the 200-ZP-1 RI/FS work plan in this table is the Remedial Investigation/Feasibility Study Work Plan for 200-ZP-1 Groundwater Operable Unit (DOE-RL 2004c).

[a] All Group A analytes and select Group B (chloroform, arsenic, cadmium, antimony, iron, fluoride, manganese, strontium-90, methylene chloride, benzene, 1,2-dichloroethane, and tetrachloroethene for select wells).

[b] Table 2-1 of the 200-ZP-1 RI/FS work plan contains the same COC list as Table A1-7 of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c).

COC = contaminant of concern
FS = feasibility study
FY = fiscal year
RI = remedial investigation

Table 1-7. Completeness Analysis for Wells Requiring Full Contaminant of Concern List Analysis. (2 sheets)

COCs	299-W10-4[a]	299-W11-14[a]	299-W11-43[a]	299-W15-152[b]	299-W15-46[a]	299-W15-49[a]	299-W7-4[a]	699-48-77A[b]	299-W14-13[a]	299-W15-47[a]
1,1,1-trichloroethane (TCA)	X	X	X	X	X	X	X	X	X	X
1,2-dichloroethane (DCA)	X	X	X	X	X	X	X	X	X	X
4-methyl-2-pentanone (hexone, MIBK)	X	X	X	X	X	X	X	X	X	X
Acetone	X	X	X	X	X	X	X	X	X	X
Ammonium	X	X	X		X	X	X	X		
Antimony	X	X	X	X	X	X	X	X	X	
Arsenic	X	X	X		X	X	X	X		
Benzene	X	X	X	X	X	X	X	X	X	X
C-14		X	X		X	X	X	X		
Cadmium	X	X	X	X	X	X	X	X	X	
Carbon disulfide	X	X	X	X	X	X	X	X	X	X
Carbon tetrachloride	X	X	X	X	X	X	X	X	X	X
Chlorobenzene	X	X	X	X	X	X	X	X		X
Chloroform	X	X	X	X	X	X	X	X	X	X
Chromium (hexavalent)		X	X		X	X	X	X	X	
Chromium (total)	X	X	X	X	X	X	X	X	X	
Cis 1,2-dichloroethylene	X	X	X	X	X	X	X	X	X	X
Cresols	X	X	X	X	X	X	X	X		
Cs-137	X	X	X		X	X	X	X	X	
Cyanide	X	X	X		X	X	X	X	X	
Ethyl benzene	X	X	X	X	X	X	X	X		X
Fluoride	X	X	X	X	X	X	X	X	X	X
H-3	X	X	X		X	X	X	X	X	
I-129	X	X	X		X	X	X	X	X	X
Iron	X	X	X	X	X	X	X	X	X	
Kerosene	X	X	X			X	X			
Lead	X	X	X	X	X	X	X	X		
Lithium		X	X		X	X	X	X		
Magnesium	X	X	X	X	X	X	X	X	X	
Manganese	X	X	X	X	X	X	X	X	X	
Mercury	X	X	X	X	X	X	X	X		
Methyl ethyl ketone (syn: 2-butanone)	X	X	X	X	X	X	X	X	X	X

Table 1-7. Completeness Analysis for Wells Requiring Full Contaminant of Concern List Analysis. (2 sheets)

COCs	299-W10-4[a]	299-W11-14[b]	299-W11-43[a]	299-W15-152[b]	299-W15-46[a]	299-W15-49[a]	299-W7-4[b]	699-48-77A[b]	299-W14-13[b]	299-W15-47[b]
Methylene chloride	X	X	X	X	X	X	X	X	X	X
N-butyl benzene	X	X	X		X	X	X	X		
Nickel	X	X	X	X	X	X	X	X	X	
Nitrate	X	X	X	X	X	X	X	X	X	X
Nitrate as nitrogen	X	X	X		X	X	X	X	X	X
Nitrite	X	X	X	X	X	X	X	X	X	X
Nitrite as nitrogen	X	X	X		X	X	X	X	X	X
Np-237		X	X		X	X	X	X		
Pa-231		X	X		X	X	X	X		
Phenols (total)	c	c	c	c	X	c	c	c	c	c
Phosphate	X	X	X		X	X	X	X		
Se-79		X	X		X	X	X	X		
Selenium	X	X	X		X	X	X	X		
Silver	X	X	X	X	X	X	X	X	X	
Sr-90		X			X	X	X	X	X	X
Tc-99	X	X	X		X	X	X	X	X	X
Tetrachloroethylene (PCE) (syn: tetrachloroethene)	X	X	X	X	X	X	X	X	X	X
Toluene	X	X	X	X	X	X	X	X	X	X
Trans 1,2-dichloroethylene	X	X	X	X	X	X	X	X	X	X
Trichloroethylene (TCE) (syn: trichloroethene)	X	X	X	X	X	X	X	X	X	X
Uranium (total)	X	X	X		X	X	X	X		
Vanadium	X	X	X	X	X	X	X	X	X	
Xylene (total)	X	X	X	X	X	X	X	X	X	X

NOTE: Blank cells indicate currently missing data that will be collected in subsequent sampling events.

[a] Analyses run on samples from this well are beyond the requirements specified in the 200-ZP-1 RI/FS work plan (DOE-RL 2004c).

[b] Samples from this well were required to be run for the full list of COCs identified in the far-left column.

[c] Semi-volatile compounds, including selected phenols, may be sampled in subsequent sampling events.

COC = contaminant of concern
RI/FS = remedial investigation/feasibility study
X = data are present

Table 1-8. Remedial Investigation/Feasibility Study Wells from Which Depth-Discrete Groundwater Sampling Was Performed.

299-W10-24	299-W15-43
299-W11-25B (well "T1")	299-W15-44
299-W11-43 (well "H")	299-W15-46
299-W11-45 (well "T2")	299-W15-49 (well "C")
299-W13-01 (well "G")	299-W15-50 (well "E")
299-W14-11	299-W15-152 (well "F")
299-W14-13	299-W17-01 (well "I")
299-W14-14	299-W18-16 (well "D")
299-W14-19	699-50-74 (well "T")
299-W15-42 (well "A")	

Table 1-9. Potential Sources of Groundwater Contamination from Group A Contaminants of Concern at the 200-ZP-1 Operable Unit. (7 sheets)

Waste Site	Group A COCs	Units	Mean Quantity[a]
216-T-2	Chromium (total)	kg	2.504E+03
	Nitrate	kg	5.849E+04
	Iodine-129	Ci	2.935E-06
	Technetium-99	Ci	2.943E-03
	Tritium	Ci	7.138E-03
	Uranium (total)	kg	2.990E-01
216-T-3	Chromium (total)	kg	2.646E+03
	Nitrate	kg	6.468E+05
	Iodine-129	Ci	4.236E-07
	Technetium-99	Ci	9.571E-04
	Tritium	Ci	2.023E-05
	Uranium (total)	kg	2.005E+00
216-T-4A	Carbon tetrachloride	kg	3.618E+02
	Chromium (total)	kg	1.141E+04
	Nitrate	kg	3.701E+05
	Iodine-129	Ci	4.365E-04
	Technetium-99	Ci	6.681E-02
	Tritium	Ci	1.252E+03
	Uranium (total)	kg	6.071E+02
216-T-5	Chromium (total)	kg	1.208E+03
	Nitrate	kg	2.416E+05
	Technetium-99	Ci	1.498E-02
	Tritium	Ci	8.768E-03
	Uranium (total)	kg	2.422E+01
216-T-6	Chromium (total)	kg	6.830E+02
	Nitrate	kg	2.303E+05
	Iodine-129	Ci	3.485E-06
	Technetium-99	Ci	7.872E-03
	Tritium	Ci	2.127E-04
	Uranium (total)	kg	2.082E+01
216-T-7	Chromium (total)	kg	2.805E+04
	Nitrate	kg	6.550E+06
	Iodine-129	Ci	1.494E-05
	Technetium-99	Ci	1.898E-01
	Tritium	Ci	9.156E-02
	Uranium (total)	kg	3.392E+02
216-T-8	Chromium (total)	kg	2.101E+01
	Nitrate	kg	4.906E+02
	Iodine-129	Ci	2.171E-07
	Technetium-99	Ci	1.937E-04
	Tritium	Ci	4.383E-04
	Uranium (total)	kg	4.754E+01

Table 1-9. Potential Sources of Groundwater Contamination from Group A Contaminants of Concern at the 200-ZP-1 Operable Unit. (7 sheets)

Waste Site	Group A COCs	Units	Mean Quantity [a]
216-T-12	Chromium (total)	kg	2.335E+00
	Nitrate	kg	7.706E+04
	Iodine-129	Ci	8.823E-06
	Technetium-99	Ci	8.433E-03
	Tritium	Ci	7.922E+01
	Uranium (total)	kg	2.169E+02
216-T-14	Chromium (total)	kg	3.604E+02
	Nitrate	kg	1.078E+05
	Iodine-129	Ci	1.775E-03
	Technetium-99	Ci	2.034E-01
	Tritium	Ci	6.134E+00
	Uranium (total)	kg	3.443E+01
216-T-15	Chromium (total)	kg	3.732E+02
	Nitrate	kg	1.116E+05
	Iodine-129	Ci	1.839E-03
	Technetium-99	Ci	2.107E-01
	Tritium	Ci	6.354E+00
	Uranium (total)	kg	3.567E+01
216-T-16	Chromium (total)	kg	3.653E+02
	Nitrate	kg	1.093E+05
	Iodine-129	Ci	1.800E-03
	Technetium-99	Ci	2.062E-01
	Tritium	Ci	6.220E+00
	Uranium (total)	kg	3.495E+01
216-T-17	Chromium (total)	kg	2.811E+02
	Nitrate	kg	8.409E+04
	Iodine-129	Ci	1.385E-03
	Technetium-99	Ci	1.587E-01
	Tritium	Ci	4.785E+00
	Uranium (total)	kg	2.687E+01
216-T-18	Chromium (total)	kg	1.012E+02
	Nitrate	kg	3.282E+04
	Iodine-129	Ci	1.484E-03
	Technetium-99	Ci	1.539E-01
	Tritium	Ci	2.362E-01
	Uranium (total)	kg	5.523E+01
216-T-19	Carbon tetrachloride	kg	1.663E+03
	Chromium (total)	kg	1.131E+03
	Nitrate	kg	2.412E+05
	Technetium-99	Ci	7.906E-03
	Tritium	Ci	5.122E+03
	Uranium (total)	kg	1.284E+01

Table 1-9. Potential Sources of Groundwater Contamination from Group A Contaminants of Concern at the 200-ZP-1 Operable Unit. (7 sheets)

Waste Site	Group A COCs	Units	Mean Quantity [a]
216-T-20	Chromium (total)	kg	1.572E-02
	Nitrate	kg	1.965E+01
	Iodine-129	Ci	1.518E-07
	Technetium-99	Ci	1.084E-04
	Tritium	Ci	3.025E-01
	Uranium (total)	kg	1.067E-03
216-T-21	Chromium (total)	kg	1.659E+02
	Nitrate	kg	4.960E+04
	Iodine-129	Ci	8.168E-04
	Technetium-99	Ci	9.363E-02
	Tritium	Ci	2.823E+00
	Uranium (total)	kg	1.584E+01
216-T-22	Chromium (total)	kg	5.515E+02
	Nitrate	kg	1.650E+05
	Iodine-129	Ci	2.717E-03
	Technetium-99	Ci	3.114E-01
	Tritium	Ci	9.387E+00
	Uranium (total)	kg	5.270E+01
216-T-23	Chromium (total)	kg	5.321E+02
	Nitrate	kg	1.592E+05
	Iodine-129	Ci	2.622E-03
	Technetium-99	Ci	3.005E-01
	Tritium	Ci	9.059E+00
	Uranium (total)	kg	5.087E+01
216-T-24	Chromium (total)	kg	5.516E+02
	Nitrate	kg	1.650E+05
	Iodine-129	Ci	2.717E-03
	Technetium-99	Ci	3.114E-01
	Tritium	Ci	9.390E+00
	Uranium (total)	kg	5.270E+01
216-T-25	Chromium (total)	kg	1.070E+03
	Nitrate	kg	3.200E+05
	Iodine-129	Ci	5.270E-03
	Technetium-99	Ci	6.040E-01
	Tritium	Ci	1.821E+01
	Uranium (total)	kg	1.023E+02
216-T-26	Chromium (total)	kg	1.157E+03
	Nitrate	kg	3.753E+05
	Iodine-129	Ci	1.697E-02
	Technetium-99	Ci	1.760E+00
	Tritium	Ci	2.700E+00
	Uranium (total)	kg	6.330E+02

Table 1-9. Potential Sources of Groundwater Contamination from Group A Contaminants of Concern at the 200-ZP-1 Operable Unit. (7 sheets)

Waste Site	Group A COCs	Units	Mean Quantity [a]
216-T-27	Chromium (total)	kg	1.245E+03
	Nitrate	kg	2.971E+04
	Technetium-99	Ci	1.430E-03
	Tritium	Ci	8.347E-03
	Uranium (total)	kg	3.071E+01
216-T-28	Chromium (total)	kg	6.012E+03
	Nitrate	kg	1.603E+05
	Technetium-99	Ci	4.282E-02
	Tritium	Ci	2.502E-01
	Uranium (total)	kg	4.726E+02
216-T-32	Chromium (total)	kg	1.030E+04
	Nitrate	kg	2.497E+06
	Iodine-129	Ci	2.279E-07
	Technetium-99	Ci	1.334E-03
	Tritium	Ci	2.183E-04
	Uranium (total)	kg	5.903E-01
216-T-33	Chromium (total)	kg	2.157E+01
	Nitrate	kg	1.267E+03
	Iodine-129	Ci	2.926E-05
	Technetium-99	Ci	4.135E-03
	Tritium	Ci	7.664E-01
	Uranium (total)	kg	6.019E+01
216-T-34	Chromium (total)	kg	5.833E+03
	Nitrate	kg	1.362E+05
	Iodine-129	Ci	8.208E-03
	Technetium-99	Ci	7.371E-05
	Tritium	Ci	3.676E-04
	Uranium (total)	kg	6.366E+01
216-T-35	Chromium (total)	kg	3.000E+00
	Nitrate	kg	3.000E+00
	Uranium (total)	kg	3.012E+01
216-Z-1A	Carbon tetrachloride [f]	kg	2.68E+05
	Chromium (total)	kg	9.321E+01
	Nitrate	kg	1.320E+06
	Technetium-99	Ci	7.096E-05
	TCE [b]	kg	[b]
	Uranium (total)	kg	9.340E-02
216-Z-1&2	Carbon tetrachloride	kg	3.804E+04
	Chromium (total)	kg	1.611E+01
	Nitrate	kg	5.501E+04
	Technetium-99	Ci	4.771E-06
	Uranium (total)	kg	1.040E-02

Table 1-9. Potential Sources of Groundwater Contamination from Group A Contaminants of Concern at the 200-ZP-1 Operable Unit. (7 sheets)

Waste Site	Group A COCs	Units	Mean Quantity [a]
216-Z-3	Carbon tetrachloride	kg	2.248E+04
	Chromium (total)	kg	1.563E+01
	Nitrate	kg	1.880E+05
	Technetium-99	Ci	8.386E-06
	Uranium (total)	kg	1.639E-02
216-Z-8	Carbon tetrachloride	kg	3.617E+02
	Chromium	kg	2.422E-03
	Uranium (total)	kg	4.755E-06
216-Z-9	Carbon tetrachloride [g]	kg	3.05E+05
	Nitrate	kg	8.858E+05
	Technetium-99	Ci	3.498E-05
	TCE [b]	kg	[b]
	Uranium (total)	kg	2.519E-02
216-Z-12	Carbon tetrachloride	kg	1.350E+05
	Chromium (total)	kg	5.183E+01
	Nitrate	kg	4.368E+06
	Iodine-129	Ci	8.823E-06
	Technetium-99	Ci	2.109E-04
	Uranium (total)	kg	1.942E-01
216-Z-18	Carbon tetrachloride [e]	kg	2.20E+05
	Chromium (total)	kg	7.112E+00
	Nitrate	kg	8.412E+05
	Technetium-99	Ci	3.333E-05
	TCE [b]	kg	[b]
	Uranium (total)	kg	2.395E-02
241-Z-361 settling tank [d]	Nitrate	kg	[d]
	Technetium-99	Ci	[d]
	Uranium (total)	kg	[d]
241-T-101	Chromium (total)	kg	1.259E+01
	Nitrate	kg	2.152E+03
	Iodine-129	Ci	4.677E-04
	Technetium-99	Ci	3.038E-01
	Tritium	Ci	6.118E+00
	Uranium (total)	kg	9.518E-01
241-T-103	Chromium (total)	kg	1.237E+01
	Nitrate	kg	7.256E+02
	Iodine-129	Ci	7.086E-04
	Technetium-99	Ci	9.379E-01
	Tritium	Ci	3.923E-01
	Uranium (total)	kg	2.973E-01

Table 1-9. Potential Sources of Groundwater Contamination from Group A Contaminants of Concern at the 200-ZP-1 Operable Unit. (7 sheets)

Waste Site	Group A COCs	Units	Mean Quantity[a]
241-T-106	Chromium (total)	kg	5.041E+02
	Nitrate	kg	2.951E+04
	Iodine-129	Ci	2.461E-02
	Technetium-99	Ci	3.741E+01
	Tritium	Ci	1.538E+01
	Uranium (total)	kg	1.188E+01
241-T-108	Chromium (total)	kg	1.656E+00
	Nitrate	kg	8.047E+02
	Iodine-129	Ci	1.708E-05
	Technetium-99	Ci	1.234E-02
	Tritium	Ci	1.835E-02
	Uranium (total)	kg	1.176E-01
241-T-109	Chromium (total)	kg	4.237E+00
	Nitrate	kg	3.669E+02
	Iodine-129	Ci	2.372E-04
	Technetium-99	Ci	3.062E-01
	Tritium	Ci	7.856E-02
	Uranium (total)	kg	9.769E-02
241-T-111	Chromium (total)	kg	5.964E-01
	Nitrate	kg	1.192E+02
	Iodine-129	Ci	1.232E-10
	Technetium-99	Ci	7.396E-06
	Tritium	Ci	4.329E-06
	Uranium (total)	kg	1.207E-02
241-TX-107	Chromium (total)	kg	8.646E+01
	Iodine-129	Ci	4.809E-03
	Technetium-99	Ci	4.377E+00
	Tritium	Ci	1.121E+00
	Uranium (total)	kg	9.314E-01
241-TY-101	Chromium (total)	kg	9.490E+00
	Nitrate	kg	7.278E+02
	Iodine-129	Ci	5.005E-04
	Technetium-99	Ci	4.453E-01
	Tritium	Ci	1.506E-01
	Uranium (total)	kg	1.128E-01
241-TY-103	Chromium (total)	kg	3.245E+01
	Nitrate	kg	2.444E+03
	Iodine-129	Ci	1.808E-03
	Technetium-99	Ci	1.647E+00
	Tritium	Ci	4.211E-01
	Uranium (total)	kg	3.516E-01

Table 1-9. Potential Sources of Groundwater Contamination from Group A Contaminants of Concern at the 200-ZP-1 Operable Unit. (7 sheets)

Waste Site	Group A COCs	Units	Mean Quantity [a]
241-TY-104	Chromium (total)	kg	8.794E-01
	Nitrate	kg	9.640E+02
	Iodine-129	Ci	2.538E-05
	Technetium-99	Ci	1.979E-02
	Tritium	Ci	3.246E-02
	Uranium (total)	kg	1.644E-01
241-TY-105	Chromium (total)	kg	2.199E+01
	Nitrate	kg	2.410E+04
	Iodine-129	Ci	6.343E-04
	Technetium-99	Ci	4.946E-01
	Tritium	Ci	8.118E-01
	Uranium (total)	kg	4.106E+00
241-TY-106	Chromium (total)	kg	1.256E+01
	Nitrate	kg	1.377E+04
	Iodine-129	Ci	3.625E-04
	Technetium-99	Ci	2.826E-01
	Tritium	Ci	4.639E-01
	Uranium (total)	kg	2.348E+00
200-W-52 [c]	Technetium-99	Ci	[e]
	Uranium 234/238	kg	[e]

[a] *Hanford Soil Inventory Model, Rev. 1* (DOE-ORO-26744 [RPP-26744]) (CHG 2005). The quantity presented in this table is the mean reported in this reference. Appendix P presents a full print out of the pertinent analytes from SIMS database which includes mean, minimum, maximum, and standard deviation.

[b] TCE was identified as a COC for 216-Z-1A, 216-Z-9, 216-Z-18, and the T, TX, and TY Tank Farms in *Sampling and Analysis Plan for the 200-ZP-1 Groundwater Monitoring Well Network* (DOE-RL 2002b), but TCE was not separately reported in SIM. TCE is a potential degradation product of PCE.

[c] Technetium-99 and uranium-234/238 were identified as COCs at 200-W-52 in *T Area Technetium-99 Data Quality Objectives Summary Report* (WMP-28389, Draft A) (FH 2006c), but 200-W-52 was not separately identified in SIM. It is assumed that 200-W-52 is included with 200-T-7 in SIM.

[d] Nitrate, technetium-99, and total uranium identified as "Group A" COCs at 241-Z-361 settling tank in Table 3-3 of this RI report, but no quantities are listed in SIM.

[e] Carbon tetrachloride quantity for 216-Z-18 obtained from *1994 Conceptual Model of the Carbon Tetrachloride Contamination in the 200 West Area at the Hanford Site* (WHC-SD-EN-TI-248, Rev. 0) (WHC 1994). The SIM quantity for 216-Z-18 is 191,900 kg.

[f] Carbon tetrachloride quantity for 216-Z-1A obtained from *Plutonium and Organic-Rich Process Condensate and Process Waste Group Operational Unit RI/FS Work Plan: Includes the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units* (DOE-RL-2001-01, Rev. 0) (DOE-RL 2004b). The SIM quantity for 216-Z-1A is 306,500 kg.

[g] Carbon tetrachloride quantity for 216-Z-9 ranged from 130,000 kg to 480,000 kg in *Plutonium and Organic-Rich Process Condensate and Process Waste Group Operational Unit RI/FS Work Plan: Includes the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units* (DOE-RL-2001-01, Rev. 0) (DOE-RL 2004b). The SIM quantity for 216-Z-9 is 208,300 kg.

COC = contaminant of concern
RI = remedial investigation
SIM = Hanford Soil Inventory Model
TCE = trichloroethylene or trichloroethene
PCE = perchloroethylene, perchloroethene, or tetrachloroethene

2.0 REMEDIAL INVESTIGATION APPROACH

Section 2.0 provides an overview of the approach applied to the 200-ZP-1 RI report. Section 2.1 provides details on the groundwater monitoring that was performed within the 200-ZP-1 OU to support the CERCLA RI/FS process. Section 2.2 describes the approach used to define the three-dimensional distribution of COCs. Sections 2.3 and 2.4 review the geotechnical, hydraulic, and geochemical parameters that were tested for in order to support modeling activities.

2.1 GROUNDWATER MONITORING

The contaminant plumes in the 200-ZP-1 Groundwater OU are changing shape over time in response to multiple influences, which include (1) general groundwater flow, which is carrying contaminants downgradient; (2) pump-and-treat operations, which are containing the high-concentration portion of the carbon tetrachloride plume; (3) dropping groundwater elevations resulting from the termination of effluent releases to surrounding cribs, ponds, and trenches; and (4) elimination of groundwater mounds associated with the discharges to the T and U Ponds. Table A3-2 of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) identifies a total of 66 groundwater monitoring and extraction wells for routine sampling to ensure that movement of the contaminant plumes is carefully tracked. The annual Sitewide groundwater monitoring report and the annual summary report for 200-ZP-1 pump-and-treat operations provide the sampling results for the FY.

2.1.1 Enhanced Groundwater Monitoring Well Network

The 200-ZP-1 groundwater monitoring network was recently expanded by drilling eight new monitoring wells, as described in the 200-ZP-1 RI/FS work plan (DOE-RL 2004c). The eight new wells are included in the 66 wells mentioned in Section 2.1 (Tables 1-1 and 1-2) and are shown on the plate map in Appendix A. The new 200-ZP-1 wells were initially designated by letter codes "C" through "I" and "T"; a complete well identification number was then assigned to each well after it was drilled. Contaminant concentration data from the new wells are intended to further define COC groundwater plume boundaries and track contaminant movement (FH 2003c, 2003d). Wells 299-W15-42 (well "A") and 299-W15-45 (well "B") were installed prior to issuance of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) and are included in the 66 wells that are routinely sampled.

Wells 299-W15-49 (well "C"), 299-W18-16 (well "D"), 299-W15-50 (well "E"), and 299-W15-152 (well "F") were positioned to further define the carbon tetrachloride 2,000 µg/L isopleth. Well 299-W13-1 (well "G") was installed with the intent of identifying the eastern boundary of the 5 µg/L carbon tetrachloride isopleth. However, the detection of carbon tetrachloride during the drilling of well 299-W13-1 (well "G") in concentrations above 1,200 µg/L (just above the Ringold Lower Mud Unit) suggests that the eastern boundary of the 5 µg/L carbon tetrachloride contour is significantly farther to the east.

Well 299-W11-43 (well "H") was installed west of T Plant to identify the vertical distribution of COCs in this area and to provide data that can help evaluate the variability of geotechnical and geochemical properties within the unconfined aquifer. Well 299-W17-1 (well "I") was installed as an upgradient monitoring well. Well 699-50-74 (well "T") was installed north of T Plant to define the northern edge of the nitrate, carbon tetrachloride, and tritium plumes.

Table A3-2 of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) includes eight of the nine extraction wells that are connected to the 200-ZP-1 pump-and-treat system. A ninth extraction well, 299-W15-765, was not listed in Table A3-2 of the 200-ZP-1 RI/FS work plan because it was formerly designated as a RCRA monitoring well.

Four additional monitoring wells are planned (i.e., LLWMA-5, LLWMA-8, LLWMA-13, and LLWMA-17) for the 200-ZP-1 monitoring well network in calendar year 2006. The four planned wells are included in Table A3-2 of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c).

Depth-discrete groundwater samples were collected while drilling selected wells in the 200-ZP-1 OU to evaluate the vertical distribution of COCs, as well as hydraulic and geochemical properties within the unconfined aquifer. The COC concentrations, geotechnical, hydraulic, and geochemical analyses were also performed on sediment samples from boreholes for the same wells. Section 2.2 describes the 200-ZP-1 monitoring wells where depth-discrete sampling was performed.

2.1.2 Routine Monitoring Strategy

As described in the 200-ZP-1 RI/FS work plan (DOE-RL 2004c), the groundwater sampling frequency for the 200-ZP-1 monitoring well network depends primarily on how recently the well was installed and the results of past sampling events. New wells drilled during FY03 and later years are sampled quarterly during the year following installation, semi-annually during the second year after installation, and annually thereafter. Wells located near a contaminant plume perimeter are sampled biennially (i.e., every 2 years), if the contaminant concentrations are stable for several years. The sampling frequency may increase in wells where contaminant concentrations are irregular or increase. Table A3-2 in the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) and Table 1-4 of this RI report identify the COCs that are monitored in each well and the sampling frequency.

2.1.3 Monitoring for Additional Contaminants of Concern

During preparation of the 200-ZP-1 DQO summary report (FH 2003c), FH staff reviewed a number of historical documents for the purpose of identifying a comprehensive list of contaminants of potential concern (COPCs) for consideration during the CERCLA RI/FS process. A number of the COPCs were eliminated after reviewing historical analytical data, radioactive half-life, soil adsorption, and toxicity. The elimination of the COPCs was documented in the 200-ZP-1 DQO summary report (FH 2003c). The list of COCs provided in the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) were those used and evaluated in this RI report. The remaining COPCs became the COCs that are evaluated in Section 4.2 of this RI report.

In FY04, a strategy was implemented for identifying whether or not additional COCs are present in the aquifer by sampling specific wells (299-W7-4, 299-W10-4, 299-W11-14, 299-W14-13, 299-W15-47 [extraction well #4], 299-W15-152 (well "F"), and 699-48-77A) in the 200-ZP-1 groundwater monitoring well network. The selected wells are located either in highly contaminated areas of known plumes or immediately downgradient of selected waste sites. Table A3-3 of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) lists the selected wells, COCs, and rationale. Two sampling events were planned for FY04 and FY06. Table 1-5 specifies target action levels. Potential COCs that are detected above these limits are added to the routine sampling program discussed in Section 2.1.2. Potential COCs that are not detected above the

action levels during the first two sampling events will not be considered further in the RI/FS process.

2.2 THREE-DIMENSIONAL DISTRIBUTION OF CONTAMINANTS OF CONCERN

The three-dimensional distribution of COCs within the unconfined aquifer was estimated by collecting depth-discrete groundwater samples from selected wells drilled in the 200-ZP-1 OU and adjacent areas (DOE-RL 2004c). Depth-discrete groundwater samples were collected at approximately 9.1-m (30-ft) intervals as the wells were drilled and analyzed for volatile organic compounds (VOCs) with an onsite gas chromatograph. The VOC data were used to set the depth of the well screen and to define the distribution of contaminants within the aquifer. Section 4.4 and Appendices L and M present vertical plots of the depth-discrete analytical data. Plots of the depth-discrete data for carbon tetrachloride and its potential degradation compounds (i.e., chloroform, methylene chloride, and chloromethane) are also shown on the plate maps in Appendix C for the shallow (water table to 18 m [60 ft] below water table), middle (18. m [60 ft] to 37 m [120 ft] below water table), and deep (37 m [120 ft] below water table to base of aquifer) portions of the unconfined aquifer. The carbon tetrachloride isopleths for the shallow portion of the unconfined aquifer in Appendix C do not exactly correspond to those shown on the plate map in Appendix A. As explained in Section 1.4.1, the Appendix A isopleths are based on annual averages of COC concentrations and activity levels in the shallow unconfined aquifer. The Appendix C isopleths are derived from a three-dimensional analysis of depth-discrete groundwater samples.

Depth-discrete data are currently available for the following 19 wells, which are referred to as "RI/FS wells" in this 200-ZP-1 RI report: 299-W10-24, 299-W11-25B (well "T1"), 299-W11-43 (well "H"), 299-W11-45 (well "T2"), 299-W13-01 (well "G"), 299-W14-11, 299-W14-13, 299-W14-14, 299-W14-19, 299-W15-42 (well "A"), 299-W15-43, 299-W15-44, 299-W15-46, 299-W15-49 (well "C"), 299-W15-50 (well "E"), 299-W15-152 (well "F"), 299-W17-01 (well "I"), 299-W18-16 (well "D"), and 699-50-74 (well "T"). Additional depth-discrete data are expected when wells "AA," "BB," "CC," "DD," and "EE" are drilled in FY06 and FY07. The additional data will be attached as an appendix to the FS.

Most of the RI/FS wells were drilled a minimum of 37 m (120 ft) below the water table. Several of the RI/FS wells were drilled deeper. Well 299-W15-49 (well "C") was drilled to the top of the Ringold Lower Mud Unit, approximately 62 m (205 ft) below the water table. Well 299-W11-43 (well "H") was drilled to approximately 55 m (180 ft) below the water table. The Lower Mud Unit was not present at this location. Well 299-W15-46 was drilled approximately 92 m (300 ft) below the water table. This well was drilled near the 216-Z-9 Trench, through the Lower Mud Unit to the top of basalt at the base of the unconfined aquifer. All depth-discrete groundwater samples from the 19 RI/FS wells were analyzed for VOCs and, in some cases, a variety of other analytes. Depth-discrete groundwater samples from wells 299-W15-49 (well "C"), 299-W15-46, and 299-W11-43 (well "H") were also analyzed for the parameters identified in Tables 1-1 and 2-1. The results are described in Sections 4.4, 4.5, 4.6, and 4.7.

Depth-discrete groundwater samples from six of the 19 RI/FS wells were analyzed for four VOCs (i.e., carbon tetrachloride, TCE, chloroform, and tetrachloroethylene [PCE]). These four VOCs were used as indicator parameters to estimate the three-dimensional distribution of dissolved VOC contaminants within the unconfined aquifer. Five of the six wells were drilled to

approximately 36.6 m (120 ft) below the water table and four depth-discrete samples were collected from each well: 299-W18-16 (well "D"), 299-W15-50 (well "E"), 299-W15-152 (well "F"), 299-W17-1 (well "I"), and 699-50-74 (well "T"). The sixth well, 299-W13-1 (well "G"), was drilled to the top of basalt at a depth of 160.8 m (527.3 ft). Nine depth-discrete groundwater samples were collected during the drilling of this well (FH 2004).

2.3 MODELING INPUT PARAMETERS FOR SEDIMENT

The *Data Quality Objectives Summary Report Supporting the 200-ZP-1 Operable Unit Remedial Investigation/Feasibility Study Process* (FH 2003c) and the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) identify a number of specific modeling input parameters that are required to evaluate contaminant migration. The 200-ZP-1 RI/FS work plan identified the geotechnical (i.e., physical), hydraulic, and geochemical parameters in Table 2-1 as required data for modeling potential contaminant migration within the saturated zone. Sediment samples for geotechnical, hydraulic, and geochemical analysis were collected during the drilling of three wells: 299-W15-49 (well "C"), 299-W11-43 (well "H"), and 299-W15-46. These three wells are positioned such that data from these locations should generally be representative of the OU as a whole. The approximate well locations are shown on the plate map in Appendix A.

Wells 299-W15-49 and 299-W15-46 provide data for the carbon tetrachloride and other plumes that might have originated from the 218-W-4B/218-W-2 Burial Grounds and Z Plant, respectively. Well 299-W15-46 was drilled on the south side of the 216-Z-9 Trench to define the distribution of COCs at this source location and to determine if DNAPL is present. Well 299-W11-43 is positioned near the center of several of the COC groundwater plumes in the vicinity of T Plant, including the uranium, iodine-129, tritium, TCE, and nitrate plumes.

Because the 216-Z-9 Trench is suspected to be one of the primary sources for carbon tetrachloride contamination, additional sediment samples were collected from well 299-W15-46. As shown in data tables that are discussed in Section 4.6, a total of 37 sediment samples were collected during the drilling of well 299-W15-46, ranging in depth from 1.4 m (4.5 ft) below ground surface (bgs) to 159.1 m (521.5 ft) bgs at the top of the Elephant Mountain Member of the Saddle Mountains Basalt. The samples are also listed in Table 2-9 of the borehole summary report for well 299-W15-46 (FH 2005c). Section 4.6 also describes six sediment samples from well 299-W15-49 and the single sediment sample from well 299-W11-43. Groundwater was encountered at 67.9 m (222.7 ft) bgs. The sediment samples were analyzed for the COC concentration parameters identified in Table 1-5 and the geotechnical, hydraulic, and geochemical parameters in Table 2-1. Section 4.5 provides a summary of the geotechnical, hydraulic, and geochemical analytical results from wells 299-W15-49, 299-W11-43, and 299-W15-46.

Similar sets of chemical, geotechnical, hydraulic, and geochemical data were obtained during the drilling of three 200-UP-1 wells, including the following: 699-30-66 (well "R"), 699-36-70B (well "P"), and 299-W19-48 (well "K"). The 200-UP-1 data were collected to further define the vertical and lateral extent of groundwater contaminant plumes and to provide data needed to support risk modeling and evaluation of remedial alternatives for that adjacent operable unit. The analytical results for sediment samples from the 200-UP-1 OU are considered applicable to the adjacent 200-ZP-1 OU and are contained in the Hanford Environmental Information System (HEIS) database. The results from sorption-desorption studies are published in *Characterization*

of 200-UP-1 Aquifer Sediments and Results of Sorption-Desorption Tests Using Spiked Uncontaminated Groundwater (Um et al. 2005).

PNNL analyzed 13 sediment core samples and 13 depth-discrete groundwater samples from three 200-UP-1 wells: 299-W19-48 (well "K"), 699-30-66 (well "R"), and 699-36-70B (well "P"). Section 4.5 provides a summary of the 200-UP-1 data for the parameters listed in Table 2-1.

2.3.1 Geotechnical Parameters

The 200-ZP-1 RI/FS work plan (DOE-RL 2004c) identifies the six geotechnical (i.e., physical) parameters listed in Table 2-1: particle-size distribution, calcium carbonate content, geophysical borehole surveys, mineralogy, bulk density, and lithology. Sieve analyses were completed for particle-size distribution, calcium carbonate analyses, bulk density tests, lithology descriptions, and other geotechnical analyses for three 200-ZP-1 wells: 299-W15-49 (well "C"), 299-W11-43 (well "H"), and 299-W15-46 (see plate map in Appendix A). Geophysical borehole surveys were performed in 13 of the 19 RI/FS wells identified in Section 2.2. Geophysical survey data for well 299-W11-43 had not yet been processed at the time that this RI report was prepared. Laboratory mineralogy data also were not available when this RI report was prepared, except for that described in the borehole log. The following geotechnical sediment samples were analyzed from the 200-ZP-1 boreholes: 20 samples from well 299-W15-46, 5 samples from well 299-W15-49, and one sample from well 299-W11-43. While many attempts were made to collect additional sediment samples from well 299-W11-43 for geotechnical analysis, the presence of gravel and cementation prevented adequate sediment recovery. Section 4.5 describes the available 200-ZP-1 data.

Geotechnical data from sediment samples collected from the 200-UP-1 OU supplement the data collected from the 200-ZP-1 OU. The 200-UP-1 sediment cores were analyzed for four of the geotechnical parameters listed in Table 2-1: particle-size distribution, calcium carbonate content, mineralogy, and lithology. Particle-size distributions in the 200-UP-1 samples were measured using the dry sieve and hydrometer methods of the American Society for Testing and Materials (ASTM) Method D422-63 (ASTM 2002a). The calcium carbonate content of the 200-UP-1 intact sediment cores was measured by ASTM Method D4373 (ASTM 2002b). A geologist described the lithology of each sediment core when the core liners were opened.

The four geotechnical parameters that are listed in Table 2-1 (e.g., particle-size distribution, calcium carbonate content, geophysical borehole surveys, and lithology) were collected during other well drilling activities in the 200 West Area. The geotechnical data for specific 200 West Area wells are available in various Hanford Site databases and are summarized in *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington* (Williams et al. 2002) and *Hanford Borehole Geologic Information System (HBGIS)* (Last et al. 2005).

2.3.2 Hydraulic and Transport Parameters

As shown in Table 2-1, the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) identified effective porosity, total porosity, and bulk density as "hydraulic and transport" parameters that need to be run on sediment samples. Section 4.5 provides a summary of the measurements for these parameters.

2.3.3 Geochemical Parameters

The 200-ZP-1 RI/FS work plan (DOE-RL 2004c) identified six geochemical parameters as key to better understanding how contaminant interactions with soil particles will influence transport. Table 2-1 lists the following six parameters: major cations (i.e., sodium and calcium), cation exchange capacity (CEC), K_d for carbon tetrachloride, total organic carbon (TOC), total inorganic carbon (TIC), and pH. The major cations, CEC, TOC, TIC, pH, and other geochemical data were obtained from soil samples collected during the installation of the three 200-ZP-1 wells (299-W15-49 [well "C"] 299-W11-43 [well "H"], and 299-W15-46 (see plate map in Appendix A). The K_d data for well 299-W15-46 are presented in *Carbon Tetrachloride and Chloroform Partition Coefficients Derived from Aqueous Desorption of Contaminated Hanford Sediments* (Riley et al. 2005), as described in Section 3.1.4. While K_d analyses were also planned to be performed on sediment samples collected from wells 299-W11-43 (well "H") and 299-W15-49 (well "C"), inadequate sediment recovery prevented this. Additional sampling for K_d analysis is scheduled for later in FY06 from wells drilled between the Old Laundry Facility and T Plant. The following numbers of geochemical sediment samples were analyzed from the 200-ZP-1 boreholes: 37 samples from well 299-W15-46, 6 samples from well 299-W15-49, and one sample from well 299-W11-43. As noted in Section 2.3.1, the presence of gravel and cementation in well 299-W11-43 prevented adequate sediment recovery to support geochemical analyses. The available 200-ZP-1 data are summarized in Section 4.5.

Geochemical analysis of sediment samples from the 200-UP-1 OU supplement the data collected from the 200-ZP-1 OU. Table 2-1 identifies the six geochemical parameters that were analyzed for the 200-UP-1 sediment cores. PNNL measured the CEC of five 200-UP-1 sediment cores by a radiotracer procedure (Routson et al. 1973).

PNNL measured desorption and adsorption K_ds for the following eight COCs in 200-UP-1 samples: technetium-99, uranium (VI), strontium-90, cesium-137, neptunium, hexavalent chromium, selenium, and iodine-129. The desorption K_d values for the contaminated sediments were generally greater than the adsorption values. Section 4.5 summarizes the recommended K_d values for risk transport modeling for three tested lithologic units: Ringold Unit E, Ringold gravel, and the Ringold Lower Mud Unit.

The total and inorganic carbon contents were measured in sediment cores from 200-UP-1 according to ASTM Method E1915-01 (ASTM 2005). The organic carbon content was calculated as the difference between the total and inorganic carbon content. The pH was measured in 1:1 sediment to water extracts from the same samples for the 13 sediment cores. Section 4.5 summarizes the 200-UP-1 results.

2.4 MODELING INPUT PARAMETERS FOR GROUNDWATER

The 200-ZP-1 RI/FS work plan (DOE-RL 2004c) identified saturated zone modeling input parameters required to be run on groundwater samples. Table 2-1 lists the hydraulic, transport, and geochemical parameters applicable to groundwater samples. Depth-discrete groundwater samples from wells 299-W15-49 (well "C"), 299-W11-43 (well "H"), and 299-W15-46 were analyzed for these parameters. The results from these analyses are presented in Sections 4.7.1 and 4.7.2. The plate map in Appendix A shows the approximate well locations.

Depth-discrete groundwater samples collected from 200-UP-1 wells 699-30-66 (well "R"), 699-36-70B (well "P"), and 299-W19-48 (well "K") were analyzed for hydraulic, transport, and geochemical analyses, which supplement the data collected from the 200-ZP-1 OU. The results of these analyses are also presented in Sections 4.7.1 and 4.7.2.

2.4.1 Hydraulic and Transport Parameters

The 200-ZP-1 RI/FS work plan (DOE-RL 2004c) identified the following six hydraulic parameters for groundwater modeling and/or evaluation of remedial alternatives: hydraulic gradient, hydraulic conductivity (K_h) measured during slug tests, groundwater production rates, water-level drawdown, groundwater pumping performance during well development, and longitudinal and transverse dispersivity. The hydraulic parameter results from wells 299-W15-49 (well "C"), 299-W11-43 (well "H"), and 299-W15-46 are discussed in the following sections of this RI report:

- Hydraulic gradient (Section 4.1.3.2)
- Hydraulic conductivity (K_h) (Section 4.6.1)
- Groundwater production flow rate (Section 4.6.1)
- Water-level drawdown (Section 4.6.1)
- Groundwater pumping performance (Section 4.6.1)
- Dispersivity (Sections 3.1.5 and 4.6.1).

Section 4.1.3.2 presents the results for hydraulic gradient, groundwater flow rates, and water table changes. Horizontal K_h was measured during a series of unconfined aquifer slug tests conducted in the following three 200-ZP-1 wells during FY05: 299-W11-43 (well "H"), 299-W15-50 (well "E"), and 299-W18-16 (well "D"). The methods used to perform the slug tests are presented in *Slug Test Characterization Results for Multi-Test/Depth Intervals Conducted During the Drilling of CERCLA Operable Unit OU 200-ZP-1 Wells 299-W11-43, 299-W15-50, and 299-W18-16* (PNNL 2005b). Section 4.6.1 summarizes the horizontal K_h results from the slug tests.

The *Borehole Summary Report for Six CERCLA Wells Drilled in the 200-UP-1 and 200-ZP-1 Operable Units, and Six RCRA Wells Drilled in the A-AX, B-BX, and U WMA; CY 2004-2005* (FH 2005b) presents well development information for well 299-W15-49. Similar well development information for well 299-W15-46 is provided in the *Borehole Summary Report for Well 299-W15-46 (C3426) Drilled at the 216-Z-9 Trench* (FH 2005c). Well development data for well 299-W11-43 were obtained from a draft borehole summary report (FH 2006a [in publication]). Section 4.6.1 provides a summary of the groundwater production rates, drawdown, etc., for wells 299-W15-49 and 299-W15-46.

Dispersivity is discussed in a study of carbon tetrachloride modeling parameters in *Assessment of Carbon Tetrachloride Groundwater Transport in Support of Hanford Carbon Tetrachloride Innovative Technology Demonstration Program* (Truex et al. 2001). Section 3.1.5 summarized the conclusions from this study. The longitudinal and transverse dispersivity parameters that were developed in the study are summarized in Section 4.6.1.

2.4.2 Geochemical Parameters

The 200-ZP-1 RI/FS work plan (DOE-RL 2004c) lists the following 10 geochemical parameters as those required for groundwater modeling and/or evaluation of remedial alternatives: major cations (i.e., sodium and calcium), CEC, specific conductance, TOC, TIC, pH, temperature, alkalinity, dissolved oxygen (DO), and turbidity. Nine of the 10 specified geochemical parameters were measured in groundwater samples from 200-ZP-1 wells 299-W15-49 (well "C"), 299-W11-43 (well "H"), and 299-W15-46. The CEC was measured in sediment samples but not in groundwater samples because the analysis is not applicable to water samples. As shown in Table 2-1, TOC and TIC were measured with different methods than those specified in the 200-ZP-1 RI/FS work plan. The substituted methods are commonly accepted analyses for TOC and TIC. Section 4.6.2 provides a summary of the parameters, groundwater sampling intervals, and analytical results.

Table 2-1. Geotechnical, Hydraulic, and Geochemical Analytical Methods for Sediment and Groundwater Samples. (2 sheets)

Property	Parameter	Method	CRDL	Precision Required	Accuracy Required
Aquifer Sediments					
Geotechnical	Particle-size distribution (by dry sieve, wet sieve, and hydrometer methods)	ASTM D422	N/A	N/A	N/A
	Calcium carbonate content	ASTM D4373			
	Borehole geophysics (neutron probe, natural gamma, spectral gamma, and gamma-gamma density[a])	[b]	N/A	N/A	N/A
	Mineralogy	XRD	N/A	N/A	N/A
	Bulk density	ASTM D2937	N/A	N/A	N/A
	Lithology	Geologist description	N/A	N/A	N/A
Hydraulic and transport	Effective porosity	Field and laboratory measurement			
	Bulk density	ASTM D2937	N/A	N/A	N/A
	Total porosity	[b]	N/A	N/A	N/A
Geochemical	Major cations (e.g., sodium and calcium)	ASTM D4327	N/A	N/A	N/A
	CEC[c]	Routson et al. (1973)	N/A	N/A	N/A
	TOC	ASTM E1915[d]	N/A	±25%	±25%
	K_d (carbon tetrachloride)	ASTM 3987	N/A	N/A	N/A
	TIC	ASTM E1915[d]	25,000 µg C/kg sample	±25%	±25%
	pH	9045[e]	0.1 pH unit	±0.1 pH unit	±0.1 pH unit
Water					
Hydraulic and transport	Hydraulic gradient	Field measurement	N/A	N/A	N/A
	Slug test, slug interference test, constant rate discharge test, or tracer test	Field test	N/A	N/A	N/A
	Water production flow rate	Well development	N/A	N/A	N/A
	Water-level changes (drawdown)	Well development	N/A	N/A	N/A
	Groundwater pumping performance	Well development	N/A	N/A	N/A
	Dispersivity	Field tracer measurement	N/A	N/A	N/A

Table 2-1. Geotechnical, Hydraulic, and Geochemical Analytical Methods for Sediment and Groundwater Samples. (2 sheets)

Property	Parameter	Method	CRDL	Precision Required	Accuracy Required
Geochemical	Major cations (e.g., sodium and calcium)	ASTM D4327	N/A	N/A	N/A
	CEC[c]	Routson et al. (1973)	N/A	N/A	N/A
	K_d (e.g., carbon tetrachloride)	ASTM 3987	N/A	N/A	N/A
	Specific conductivity	Field screening	N/A	N/A	N/A
	TOC	ASTM E1915[d]	1,000 µg/L	±25%	±25%
	TIC	ASTM E1915[d]	1,000 µg/L	±25%	±25%
	pH	9045[e]	0.1 pH unit	±0.1 pH unit	±0.1 pH unit
	Temperature	Field screening	N/A	±1°C	1°C
	Alkalinity	310.1[f] or 310.2[f]	10 mg/L as CO_3	±20%	±25%
	Dissolved oxygen	Field screening	N/A	0.1 mg/L	±1%
	Turbidity	Field screening	<5 NTU	N/A[g]	N/A[g]

[a] If gamma-gamma density probe is not available at the time of logging, proceed running only natural and neutron-induced capture gamma-ray spectroscopy.
[b] Method will be defined by technical support prior to implementation.
[c] The CEC was included in Table A2-2 of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) but it is not applicable to water samples.
[d] TOC and TIC were analyzed by the ASTM methods shown above rather than the methods (415.1 and 415.1M) listed in Table A2-2 of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c).
[e] Method from U.S. Environmental Protection Agency's SW-846 (EPA 1999).
[f] Method from *Standard Methods for Examination of Water and Wastewater* (Eaton et al. 1995).
[g] Requirements are "yes/no" above or below 5 NTU; precision and accuracy do not apply.

ASTM = American Society for Testing and Materials
CEC = cation exchange capacity
CRDL = contract-required detection limit
K_d = distribution coefficient
N/A = not applicable
NTU = nephelometric turbidity unit
TIC = tentatively identified compound
TOC = total organic carbon
XRD = x-ray diffraction

3.0 OTHER SUPPORTING STUDIES PERFORMED OUTSIDE OF THE 200-ZP-1 REMEDIAL INVESTIGATION/FEASIBILITY STUDY PROCESS

3.1 SPECIAL CARBON TETRACHLORIDE STUDIES

A variety of special studies were conducted on different aspects of the carbon tetrachloride contamination within the 200 West Area. The following sections present summaries of the study findings that are pertinent to the 200-ZP-1 RI/FS process. A brief summary is included for the interim action soil vapor extraction (SVE) system that is operating near the three primary carbon tetrachloride disposal facilities.

3.1.1 Dense Nonaqueous Phase Liquid Investigations Within the 200-ZP-1 Operable Unit

In FY03, EPA and RL agreed upon a comprehensive DNAPL carbon tetrachloride investigation strategy for the 200 West Area (DOE-RL 2004b). The DNAPL investigation strategy includes the elements listed below:

- If the dispersed carbon tetrachloride vadose zone plume investigation identifies a continuing source, a DNAPL investigation should be conducted at that location.
- In addition to any DNAPL investigations at dispersed plume locations, a DNAPL investigation should be conducted at the 216-Z-9 Trench.
- At the 216-Z-9 Trench, the DNAPL investigation should be conducted just above the water table and below the water table.
- If no DNAPL is detected either just above or below the water table, the DNAPL investigation at the 216-Z-9 Trench would be considered complete. The planned investigation would not rule out the possibility that DNAPL might be present in the Cold Creek unit.
- In addition, through the Alternatives for Carbon Tetrachloride Source Term Location (ACTSTL) Project, the DNAPL investigation will include (1) development of a viable conceptual model for the presence/absence of DNAPL in the unconfined aquifer, (2) evaluation/proposal of characterization technologies to validate the model, and (3) performance of the selected characterization activities to confirm the conceptual model that will describe the nature, extent, and mass of the assumed DNAPL (DOE-RL 2004e).
- Any data obtained during the investigations of the dispersed carbon tetrachloride plume and the 216-Z-9 Trench site will be shared with the ACTSTL Project.

The sampling design developed during the DQO process for the DNAPL investigation included collection and analysis of sediments during drilling of two wells at the 216-Z-9 Trench (FH 2003d). The representative waste site SAP provides requirements for sampling during drilling of the slant well under the 216-Z-9 Trench as part of the 200-PW-1 OU representative waste site RI report (DOE-RL 2004b, Appendix B). The DNAPL investigation SAP provides requirements for sampling during drilling of the vertical well adjacent to the 216-Z-9 Trench as part of the 200-ZP-1 OU investigation (DOE-RL 2004b, Appendix E).

The Step II SAP addresses the potential for DNAPL investigations at locations of the Step II sampling for the dispersed carbon tetrachloride vadose zone plume (DOE-RL 2004b, Appendix D). The DNAPL investigations that were identified above will be implemented for the 216-Z-9 Trench site and the potential Step II locations. The ACTSTL Project will conduct any additional DNAPL investigations that are required to support the RI/FS processes for carbon tetrachloride contamination in the vadose zone and aquifer.

The ACTSTL Project was initially funded by DOE's Environmental Management Office of Cleanup and Acceleration. Phase I of the project, which included development of the conceptual model for the absence/presence of DNAPL in the aquifer and proposed technologies to validate the conceptual model, was initiated in FY03. Phase II of the project, which includes the use of the proposed technologies to describe the nature, extent, and mass of DNAPL in the subsurface, was initiated in FY04 and was scheduled to be completed in June 2006.

Completion of the ACTSTL Project, in conjunction with the 216-Z-9 Trench investigation, satisfies the requirements of EPA (action item 2002) in the CERCLA 5-year review to investigate applicable DNAPL detection technologies (EPA 2001). Investigation of DNAPL at the 216-Z-9 Trench satisfies the requirement in the 200-ZP-1 OU interim ROD (EPA et al. 1995) to investigate DNAPL in the area of the trench.

Although the focus of the DNAPL investigation is primarily on the unconfined aquifer, the results also will benefit the vadose zone investigation. For example, identification of DNAPL in the aquifer may assist in the determination of contaminant sources or pathways for contaminant migration in the vadose zone.

A vertical borehole (C3426) was drilled and sampled adjacent to the south side of the 216-Z-9 Trench from October 2003 to January 2005 and was subsequently completed as monitoring well 299-W15-46. Sample results indicated high concentrations of carbon tetrachloride vapors in the vadose zone that were associated with a silt layer within the Hanford formation at the 20.1 to 20.4 m (66 to 67 ft) depth and in the Cold Creek unit silt at the 33.4 to 34.1 m (109.5 to 112 ft) depth. Just above the upper silt layer, a very fine-to-fine sand sample at the 19.7 m (64.5 ft) depth showed positive results for a carbon tetrachloride DNAPL field screening test. This was the only sample interval in the borehole that showed positive results for the DNAPL field test (FH 2005c). Prior to obtaining the sample results from this borehole, the presence of carbon tetrachloride DNAPL in the subsurface near the 216-Z-9 Trench was an element of the conceptual contamination model at this site, but this was the first hard evidence for DNAPL presence in the vadose zone. The results of the depth-discrete groundwater sampling collected during drilling of this well are presented in Section 4.3.1. The slant well under the 216-Z-9 Trench is scheduled to be drilled and sampled in early 2006.

During FY05, the CERCLA RI report for the 200-PW-1 OU focused on the dispersed carbon tetrachloride vadose zone plume. The investigation is being conducted in two steps. The study area for Step I (which is completed) was the portion of the shallow vadose zone overlying the observed highest concentrations in the carbon tetrachloride groundwater plume. The study area for the Step II investigation includes the vadose zone overlying the entire carbon tetrachloride groundwater plume. The Step II study extends deeper into the vadose zone than the Step I investigation.

The Step II field investigation activities conducted in FY05 included soil vapor sampling using the Enhanced Access Penetration System to access the deep vadose zone, soil vapor and groundwater sampling from existing wells, passive soil vapor sampling, and vapor sampling from burial ground vent risers. The next step in the RI/FS process for the 200-PW-1 OU is the preparation of a separate RI report, which will document these field activities and will summarize and report the data collected. This report will be prepared in FY06.

Vista Engineering Technologies, LLC (VET), completed the *Alternatives for Carbon Tetrachloride Source-Term Location* (VET 2004) project (Phase I) and is currently working on the Phase II *Integrated Approach for Carbon Tetrachloride Source-Term Location in the 200 West Area of the Hanford Site* (Bratton et al. 2004). The current project goal is to select and deploy innovative, reliable technologies for characterizing and quantifying carbon tetrachloride that exists as a DNAPL in the subsurface of the 200 West Area.

Specific locations for the investigation were selected using the conceptual model that was developed by a VET team, and these locations are presented in the Phase I report (Bratton et al. 2004). The conceptual model postulates that the majority of the carbon tetrachloride remains in the vadose zone as DNAPL in the fine-grained units of both the Cold Creek unit and the overlying Hanford formation. Some DNAPL might also exist within the unconfined aquifer on top of the Ringold Lower Mud Unit (Unit 8). The location of the DNAPL is governed by gravity-driven transport along the surface topography of the fine-grained layers. Characterization of the subsurface topography of the fine-grained layers is a key component to locating the DNAPL sources.

The characterization methods developed in Phase I for the 216-Z-9 Trench region will be applied in an adaptive and graded approach to the remainder of the site, as described in the Phase II work plan (DOE-RL 2004e). Several key analyses are summarized below:

- Coarse application of a passive soil gas methodology to evaluate the broad surface expression of the subsurface contaminants in the vadose zone across the likely source-term area. Subsequent, more detailed surveys will be conducted to focus on likely source areas.
- Further detailed geophysical characterization of the subsurface structure with particular focus on fine-grained units and likely retention features.
- Geophysical analysis of the Ringold Lower Mud Unit to identify potential topological features that could influence density-driven movement of the DNAPL beneath the disposal sites.
- Focused intrusive sampling, using effective access technologies, to collect samples and quantify the source mass distribution.
- Collection of depth-discrete groundwater samples in existing wells to better define groundwater sources.
- Continued groundwater flow analysis and modeling to evaluate source regions and confining layer topological effects in the unconfined aquifer.
- Quantify the potential fraction of carbon tetrachloride released to the atmosphere, with further analysis of carbon tetrachloride heating and evaporation due to decay heat from co-disposed radionuclides.

The results of the Phase II investigation will be presented in a separate report in June 2006.

The VET team held a project technical workshop in October 2005 to review the available evidence on whether carbon tetrachloride as DNAPL is present within the unconfined aquifer. The interim findings from that workshop are summarized below:

- Depth-discrete groundwater sampling from 24 existing wells centered around the high-concentration portion of the carbon tetrachloride groundwater plume showed that the highest detected concentration (4,152 μg/L) is significantly less than the carbon tetrachloride solubility limit (800,000 μg/L).
- The total calculated mass of carbon tetrachloride in the groundwater plume decreased from 1991 to the present.
- Groundwater modeling indicates that if carbon tetrachloride DNAPL sources were present at mid-depth in the aquifer, they would produce concentrations in monitoring wells above those measured to date. A carbon tetrachloride DNAPL source at the bottom of the aquifer could produce concentrations in monitoring wells similar to those measured to date. This modeling study included assumptions about the mass of a presumed DNAPL source in the aquifer that is greater than indicated so far from the results of the other groundwater activities conducted for the Source Term Project. The available evidence is inconclusive with regard to the presence of some quantity of DNAPL that may be responsible for persistent decreasing dissolved carbon tetrachloride concentrations. The existing data do not support the emplacement of a deep source without leaving a residual detectable trace higher in the aquifer. A deep-well pumping and sampling test is planned to investigate the presence of a carbon tetrachloride DNAPL source at the bottom of the aquifer beneath the 216-Z-9 Trench.
- The available evidence indicates that there is not a significant carbon tetrachloride DNAPL source within the aquifer beneath the 216-Z-9 Trench.
- High-concentration carbon tetrachloride vapors that were found in the deep vadose zone during a 1993 drilling program likely contaminated the shallow aquifer prior to startup of the interim action SVE system around the 216-Z-9 Trench.

Liquid waste disposal sites near the primary carbon tetrachloride waste disposal sites likely provided sufficient perched water above the Cold Creek unit to contact carbon tetrachloride in the vadose zone and subsequently transport dissolved phase carbon tetrachloride into the unconfined aquifer. There may have been some lateral movement of the contaminated perched water on the Cold Creek Unit, but the sampling results from the 200-PW-1 OU dispersed carbon tetrachloride vadose zone plume investigation (*Remedial Investigation Report for the Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit: Includes the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units* [DOE-RL 2006b]) indicate that infiltration was within approximately 150 m (492 ft) of the primary carbon tetrachloride waste disposal sites.

The carbon tetrachloride groundwater plume is found deeper in the aquifer as it migrates downgradient from the primary carbon tetrachloride waste disposal sites. This is likely the result of combined artificial and natural recharge that resulted in higher vertical gradients when liquid wastes were disposed. Another contributing factor may be changes in groundwater flow directions during waste disposal operations.

In order to confirm the interim findings (i.e., that there is not a significant carbon tetrachloride DNAPL source within the unconfined aquifer beneath the 216-Z-9 Trench), VET will be conducting a deep-well pumping and sampling test in FY06 to investigate carbon tetrachloride concentrations at the bottom of the aquifer beneath the trench. Groundwater will be pumped and sampled for 3 to 4 months from deep well 299-W15-6, which is screened at the base of the unconfined aquifer. If the carbon tetrachloride concentrations obtained bi-weekly from the pumped groundwater during the test period remain below 1% of the dissolution limit for carbon tetrachloride (8 parts per million [ppm]), this would corroborate previous sampling and modeling results that there is not a DNAPL source beneath the 216-Z-9 Trench near the base of the unconfined aquifer. If the test results show increasing carbon tetrachloride concentrations at or above the 8 ppm limit, it would suggest a deep DNAPL source, and further sampling, pumping and testing may be recommended. The results of the pumping test are not yet available and may be more difficult to interpret than suggested above.

3.1.2 Geostatistical Analysis of the Persistence of Carbon Tetrachloride in the 200 West Area

PNNL conducted a geostatistical analysis of the persistence of carbon tetrachloride groundwater concentration for eight areas of interest in the 200 West Area that were identified by FH (Murray and Chien 2005). The results of the report are summarized below.

The available carbon tetrachloride data for the period 1994 to 2004 were reviewed to identify a set of wells that were sampled regularly through the 10-year period. Data sets were initially selected from 53 wells for which carbon tetrachloride data were consistently available from 1996, 1998, 2000, and 2002. Consistent well locations were selected for each time period so variations in concentration in a given area would not be due to changes in well configurations. A fifth data set was added to represent conditions in 37 wells during 2004 and 11 wells during 2003; 5 wells from the initial four data sets were excluded. Although the results for 2004 generally agreed with results for earlier time periods, the missing five well locations increased the degree of uncertainty. No significant differences were seen in the overall distribution of carbon tetrachloride concentrations over the 10-year time period. A slight decrease in concentrations was observed during the last two time periods.

The carbon tetrachloride concentration data were highly skewed, so concentration mapping was performed on normal-score data transforms. Experimental variograms were fit with isotropic models that showed a slight decrease in range from 1,200 m (3,937 ft) in 1996 and 1998 to 1,000 m (3,280.8 ft) in 2000 and 2002. The variogram range in 2004 was further reduced, but that may be an artifact of the missing well locations for last time period. The decrease in range might also be due to a slight decrease in the size of the plume.

Murray and Chien (2005) generated 1,000 simulations of carbon tetrachloride concentration for each time period and found that 500 simulations were sufficient to characterize the spatial variability. The modeling summarized carbon tetrachloride spatial distribution in several ways, including calculation of median simulated values, the probability of exceeding several cut-off values, and calculation of percentiles of local distributions. Maps were prepared from the statistics to identify areas of high and low concentration for each time period and to provide measures of the uncertainty in carbon tetrachloride concentrations. Figure 3-1 provides a summary map of the sub-areas that were identified by FH. The sub-areas are ranked in terms of the likelihood for containing persistent carbon tetrachloride sources.

The simulations of the individual sub-areas identified important differences. The differences suggest that some of the sub-areas might contain ongoing carbon tetrachloride sources. The simulations include the following notable results:

- Several of the northern sub-areas had relatively high median concentrations with low variability and little variation with time. The sub-areas with the highest median concentrations and lowest variability were sub-areas #3 and #4. Sub-areas #2 and #5 are also candidates for ongoing carbon tetrachloride sources, but they display greater variability over time. If the concentration reported for well 299-W10-1 in 1998 is not representative, then the median concentrations for sub-areas #2 and #5 are higher and less variable. Concentrations for sub-areas #2 and #5 would then resemble sub-areas #3 and #4.
- Sub-area #7 exhibited a significant decrease in median concentration during the last two time periods. The substantial concentration decrease could result from nearby pump-and-treat operations.
- Sub-areas #1 and #6 exhibited significant decreases in median concentration and are unlikely to contain ongoing sources for carbon tetrachloride release.
- Sub-area #8 showed an increasing median carbon tetrachloride concentration at a level that is significantly lower than all of the other sub-areas; it is unlikely to contain a significant continuing carbon tetrachloride source.

The geostatistical analysis did not include factors such as changes in water table elevations, groundwater flow over time, and the influence of the 200-ZP-1 pump-and-treat system. The uncertainties of these factors on the outcome of the study will be considered in the revised conceptual model that is presented in the FS.

3.1.3 Particle-Tracking Analysis Related to Carbon Tetrachloride

Updated 200-ZP-1 Particle Tracking Analysis and Animations Depicting Movement of the Carbon Tetrachloride Plume Report (McMahon 2005) discusses a particle-tracking analysis depicting movement of the carbon tetrachloride plume in the 200-ZP-1 OU. The report is summarized below. The purpose of this analysis was to evaluate the hydraulic flow fields during and after the carbon tetrachloride disposal at known waste sites to determine whether the distribution of carbon tetrachloride in groundwater is reasonable based on hydraulics alone. It was not intended to model the three-dimensional flow field in the unconfined aquifer and was used as a screening-level analysis to evaluate the need to identify other potential source locations.

The purpose of the hydraulic particle-tracking animation files is to illustrate potential pathways for carbon tetrachloride to migrate from known discharge facilities to groundwater and likely starting locations for carbon tetrachloride that is currently observed in the aquifer. These analyses support the 200-PW-1 efforts to identify potential sources for carbon tetrachloride groundwater contamination. The animation files showed travel paths for hypothetical carbon tetrachloride particles in groundwater. The travel paths represent carbon tetrachloride movement at the average groundwater-flow velocity. The particle simulation is an estimate of the carbon tetrachloride travel path and does not indicate or imply carbon tetrachloride groundwater concentrations.

Hydraulic gradients and velocity vectors were calculated using annual computations of the water table elevation and K_h of the unconfined aquifer. The data obtained were linearly interpolated onto a square grid with 75-m (246.1-ft) spacing and extended across the entire 200 West Area. The hydraulic derivatives (dH/dx and dH/dy) and hydraulic velocities [K*(dH/dx)/n and K*(dH/dy)/n] were calculated for every year at each point in the grid using an internal algorithm in the Tecplot® software package. Travel paths for each year were then calculated using a numerical integration scheme, the hydraulic velocity field, and a retardation factor (R) that represents the ratio of groundwater velocity to contaminant velocity (e.g., a retardation factor of 2 means the groundwater travels at twice the velocity of the contaminant, or that the contaminant travels at one-half the velocity of the groundwater). The end points of travel paths for a given year were input as starting points of travel paths for the following year.

The forward travel path simulations are initiated with hypothetical carbon tetrachloride particles in a circular distribution in groundwater around the known discharge sites. The simulation starts approximately 7 to 8 years following the carbon tetrachloride discharge for each site. Discharge to 216-Z-9, 216-Z-1A, and 216-Z-18 began in 1955, 1964, and 1969, respectively; the carbon tetrachloride particles around the facilities start traveling in 1962, 1971, and 1977, respectively. The circumference of the circle of particles approximates the perimeter of the facility. The radius is 23.0 m (75.5 ft) at 216-Z-9, 72.2 m (236.9 ft) at 216-Z-1A, and 136 m (446.2 ft) at 216-Z-18. The movement of the hypothetical carbon tetrachloride particles is calculated, tracked, and displayed each half year until 2002. The simulations add a new circle of particles around the facilities each year to represent how carbon tetrachloride from a continuing source might move through the aquifer.

The backward travel path simulation begins with hypothetical carbon tetrachloride particles positioned where the high-concentration portion of the groundwater plume existed in 2002. The reverse movement of the hypothetical carbon tetrachloride particles is calculated, tracked, and displayed backward in time each year from 2002 to the year when the carbon tetrachloride may have entered the aquifer.

The forward particle tracks provide estimations of the distance from the source sites that the advective front of the plume traveled since the carbon tetrachloride entered the aquifer. The reverse particle tracks provide an indication of where the carbon tetrachloride that was observed in 2002 might have originated. Both the forward and reverse particle track simulations indicate that most of the carbon tetrachloride is apparently retarded in the groundwater. The reverse particle track analyses resulted in very little movement from the mid-1980s to 1996. The forward-tracking animations for non-retarded carbon tetrachloride indicate much greater movement than observed in groundwater monitoring programs. Furthermore, the high-concentration area of the plume (e.g., greater than 2,000 µg/L) would not remain limited in area and near the source sites. The reverse-tracking animations indicate that a "zero" retardation value for existing groundwater contamination results in carbon tetrachloride sources that are farther away than the known source locations. A retardation factor of 4 produced both forward and reverse particle tracks representative of the current carbon tetrachloride distribution in groundwater. Selected examples of the animations from McMahon (2005) are shown in Figures 3-2, 3-3, and 3-4.

Tecplot® is a registered trademark of Amtec Inc. Engineering Corporation., Bellevue, Washington.

The particle tracks also indicate that there is not a continuing carbon tetrachloride source capable of sustaining the observed maximum concentrations where the plume centroid was found in 1996. Before initiation of 200-ZP-1 Phase II pump-and-treat operations in 1996, the high-concentration area of the plume was centered near PFP and was offset to the north of known discharge sites. If a continuing source existed at the discharge sites, then the maximum carbon tetrachloride concentrations in groundwater would occur around the discharge sites and not to the north. Drilling and sampling of PFP well 299-W15-42 did not reveal greatly elevated carbon tetrachloride concentrations in the vadose zone or groundwater. Therefore, it does not appear as though the elevated carbon tetrachloride concentration in groundwater beneath PFP results from contaminants entering the aquifer from the vadose zone in that area. A continuing source of carbon tetrachloride groundwater contamination is not likely.

Well 299-W13-1 is located approximately 470 m (1,542 ft) east of the 200 West Powerhouse and beyond the extent of the particle-tracking figures. Carbon tetrachloride concentrations in well 299-W13-1 were greater than 1,200 μg/L at specific depths in the aquifer when sampled in December 2003. The well is located in the approximate path of carbon tetrachloride particles that originate from 216-Z-9 for simulation with a retardation factor less than 4. The agreement between the particle tracks and the well sampling results validates the flow paths and velocities calculated by the model.

As illustrated in Figure 3-4, the reverse particle track simulations that start with particles distributed along the leading edge of the groundwater plume, where the carbon tetrachloride concentrations are 1,000 and 2,000 μg/L, indicate that the particles converge toward a common source area to the west of the 216-Z-1A, 216-Z-12 and 216-Z-18 Cribs. The cause of the offset is uncertain but could result from the model grid spacing and discharge inputs. The 216-U-14 Ditch received approximately 1.9×10^9 L of discharge during a short period in 1991, resulting in a reversed hydraulic gradient. The 216-Z-19 and 216-Z-20 unlined ditches also received large volumes of discharged water. The 216-T-19 Crib received 4.5×10^8 L of discharge during operation.

The carbon tetrachloride source status (i.e., continuous or non-continuous) and mobility (i.e., retarded or non-retarded) may be considered in a simplified "truth table" format. The actual environment may contain elements of all four of the logical outcomes combining source and mobility options. The intent of the truth table is to address the carbon tetrachloride source and movement in a general sense. For the purpose of the truth table, "continuous source" refers to ongoing, nonattenuating contaminants that enter groundwater and are capable of sustaining concentrations at the levels currently observed in the high-concentration area of the carbon tetrachloride plume.

1. If the source of carbon tetrachloride remained continuous and the movement was non-retarded, the extent of the high-concentration area would be much larger than currently observed. The origin of the plume would remain fairly obvious and would include the known source areas. The carbon tetrachloride distribution within the plume area would be more uniform than is currently observed. The fact that the high-concentration area appears to have remained fairly restricted in size and near the known discharge sites contradicts the hypothesis that there is a continuous source and a non-retarded contaminant.

2. If the source of carbon tetrachloride remained continuous and the movement was retarded, the high-concentration area would be restricted in area and encompass the known source areas. Such a scenario would be consistent with current data if the location where the carbon tetrachloride enters the groundwater is offset from the known discharge sites. The PFP well did not substantiate such a hypothesis.
3. If the source of carbon tetrachloride was non-continuous and the movement was non-retarded, the high-concentration area would be much larger, extend much farther than currently observed, and consist of lower concentration values. The fact that the high-concentration area appears to have remained fairly restricted in size close to the known discharge sites seems to dispute this hypothesis. The effects of dispersion on the carbon tetrachloride in the aquifer would reduce the concentration, and cause greater spreading of a more uniform plume.
4. If the source of carbon tetrachloride was non-continuous and the movement was retarded, the high-concentration area would be restricted in area and remain at or near the source areas. Such a scenario is the best description of current observations, unless the carbon tetrachloride arrived at the water table much later than 8 years after disposal began. The animations including a retardation factor of 2 and 4 appear to best approximate the currently observed in groundwater conditions.

3.1.4 Partitioning Coefficient Studies

Carbon Tetrachloride and Chloroform Partition Coefficients Derived from Aqueous Desorption of Contaminated Hanford Sediments (Riley et al. 2005) calculated the carbon tetrachloride and chloroform groundwater/sediment partition coefficients (K_d values) for contaminated aquifer sediments that were collected from well 299-W15-46, adjacent to the 216-Z-9 Trench. The K_d study is summarized below.

Realistic K_d values are critical to predict future movement of carbon tetrachloride in groundwater. It is best to obtain such values from contaminated sediments because the values will reflect the long sediment/contaminant contact times that are difficult to mimic in laboratory experiments. The K_d values for modeling carbon tetrachloride are crucial to a more accurate estimate of whether compliance limits may be exceeded outside the Central Plateau waste management area (WMA).

Carbon tetrachloride and chloroform K_ds for groundwater and sediment were determined in contaminated aquifer sediments of the Ringold Formation at depths in the range of 70 to 131 m (230 to 430 ft) from the borehole for well 299-W15-46. The contaminants were in contact with the sampled sediments for 30 years or less. Carbon tetrachloride and chloroform K_ds measured in this study are summarized in Table 3-1. The K_d for carbon tetrachloride ranged from 0.106 to 0.367 L/kg. The K_d for chloroform ranged from 0.084 to 0.432 L/kg. The carbon tetrachloride and chloroform K_d values are 3 to 8 times and 12 to 23 times larger, respectively, than the low organic carbon content of the sediments (0.017 to 0.059%) would indicate.

The concentration of carbon tetrachloride in sediments was estimated for the calculated K_ds and the carbon tetrachloride and chloroform groundwater concentrations. In some cases, predicted values were significantly higher than the observed carbon tetrachloride sediment concentrations (e.g., 904 µg/kg calculated versus 31.8 µg/kg observed). A likely rationale for the difference is degradation of carbon tetrachloride in the sediments. A significant fraction of chloroform

(i.e., 61% to 70% of the total solute mass) was resistive to desorption from some of the sediments. The apparent sequestering properties of the sediments suggest that a portion of the chloroform in aquifer sediments is migrating more slowly in groundwater than predicted by simple partitioning between groundwater and sediment.

Previous carbon tetrachloride transport modeling in the Hanford groundwater aquifer was based on a conservative contaminant partitioning value of "zero" with no degradation. The resulting model predicted that carbon tetrachloride concentrations would exceed compliance limits on the 200 Area Plateau and at the Columbia River within a 1,000-year timeframe. The K_d values determined by Riley et al. (2005) would result in slower predicted carbon tetrachloride and chloroform migration rates and reduced uncertainty. Significant concentrations of chloroform in the presence of lower-than-expected concentrations of carbon tetrachloride indicate a carbon tetrachloride degradation process in sediments that is not accurately represented in previous transport modeling.

3.1.5 Basis for Abiotic Degradation Rates

Groundwater modeling was performed in support of the Hanford Carbon Tetrachloride Innovative Treatment Remediation Demonstration (ITRD) Program (Truex et al. 2001). The following information is summarized from that report.

As a first step toward implementation of innovative technologies for remediation of the carbon tetrachloride groundwater plume, modeling was performed to provide an indication of the potential source impact on the compliance boundary at a distance of approximately 5,000 m (16,404 ft). The primary objective of the carbon tetrachloride modeling was to bracket the source amount that would most likely result in noncompliance at the boundary. The relative influence of the various model input parameters was also evaluated.

The modeling was based on the assumption that approximately 750,000 kg of carbon tetrachloride were discharged to the soil in the 200 West Area. Previous work indicated that the final disposition of approximately 65% of the 750,000 kg is assumed as the vadose zone. The previous calculations included atmospheric losses of 21%; an unsaturated zone inventory in soil gas, soil moisture, and adsorbed phases of 12%, as well as a dissolved phase portion of 2%. Model simulations were performed using 65%, 30%, 10%, and 1% of the 750,000 kg as possible source amounts that could reach groundwater. Approximately 1% to 2% of the original carbon tetrachloride inventory now exists in the distal plume.

The model sensitivity to other input parameters was evaluated by Monte Carlo methods. The input parameters included groundwater Darcy velocity, inlet concentration (i.e., carbon tetrachloride concentration leaving the source area), porosity, soil/water equilibrium K_d, abiotic degradation (K_a) rate, dispersivity, and stream tube cross-sectional area. Parameter limit ranges for K_a and K_d were determined by methods detailed in Appendix C of Truex et al. (2001). The modeling produced 1,000 Monte Carlo simulations for estimating the portion of the source area where remediation is required.

Porosity, K_d, and K_a were the input parameters with the greatest impact on the model results. The K_a and K_d modeling parameters are summarized in Appendix C of Truex et al. (2001). The modeling was based on carbon tetrachloride K_a values that ranged from 2.7×10^{-7} to 4.6×10^{-5} day^{-1}, with a "most probable" value of 4.6×10^{-5} day^{-1}. The carbon tetrachloride K_d modeling values ranged from 0.016 to 0.83 L/kg, with a "most probable" value of 0.12 L/kg. At the end of

Appendix C in Truex et al. (2001), a determination of site-specific K_a and K_d values was recommended. PNNL initiated a 6-year study of K_a values at the Hanford Site in 2006. The study is planned to estimate K_a for a temperature range of 70°C to 20°C (158°F to 68°F). The initial data results are expected in the fourth quarter of 2006; the available K_a data will be utilized in the FS, as needed. Appendix C in Truex et al. (2001) included a literature review of "Natural Attenuation Mechanisms and Rates for Chloromethane Subsurface Contamination at Hanford."

3.1.6 Use of Abiotic Degradation and Partition Coefficients

The importance and use of both K_a and sorption or K_d values in groundwater contaminant transport modeling in the 200 West Area was discussed in *Recent Site-Wide Transport Modeling Related to the Carbon Tetrachloride Plume at the Hanford Site* (Bergeron and Cole 2005). The following summary is based on the report.

The Hanford ITRD Program completed an initial evaluation of the nature and extent of carbon tetrachloride contamination in the unconfined aquifer in the 200 West Area. Subsequent studies more closely examined the transport of carbon tetrachloride in the unconfined aquifer system. Those studies were undertaken to support strategic planning and provide guidance for the more robust modeling to obtain a final ROD for the carbon tetrachloride plume.

The ITRD modeling study examined carbon tetrachloride concentrations at an arbitrary boundary between the 200 East and 200 West Areas (Truex et al. 2001). After that work was completed, questions arose concerning the concentrations reaching the Columbia River and the impact of remediation options involving source removal or absence. To address those questions, additional modeling studies were conducted using the groundwater model with the modeling domain extended to the Columbia River. The modeling results are described below for each case.

A continuing carbon tetrachloride source with no sorption or K_a was assumed for Case 1a:

- A substantial carbon tetrachloride plume developed and migrated from source areas in the 200 West Area to the Columbia River. Predicted concentrations reached approximately 200 μg/L at the arbitrary boundary chosen for the analysis and approximately 34 μg/L along the Columbia River during a 1,000-year timeframe. Both of these values exceed the benchmark MCL of 5 μg/L.
- The equilibrium carbon tetrachloride release estimate in the source area was approximately 73 kg/yr.
- Initial conditions yielded an initial mass of approximately 542 kg of carbon tetrachloride in the aquifer, which grew to 58,050 kg after 1,000 years (i.e., the year 3000).

A continuing source with median value estimates of sorption and K_a was assumed in Case 1b:

- A limited carbon tetrachloride plume developed and migrated from source areas within the general vicinity of the 200 West Area. Predicted concentrations reached approximately 4.5 μg/L at the arbitrary boundary. Concentrations at discharge areas along the Columbia River did not reach substantial levels during the 1,000-year analysis period.

- The combination of sorption and K_a processes significantly limited carbon tetrachloride source loading of the aquifer and reduced the aquifer area and volume that is affected by the carbon tetrachloride plume migration. The K_a rate was more important than the sorption rate. Retardation through sorption without K_a did not reduce concentrations, except through dilution that results from hydrodynamic dispersivity.

In Cases 2 and 3, it was assumed that there was not a continuing carbon tetrachloride source and that no sorption or K_a occurred. The source area with the highest carbon tetrachloride concentrations in the plume (i.e., above 3,000 µg/L) was assumed to be removed from the aquifer in Case 2. The existing plume was considered as an initial condition of aquifer contamination in Case 3. The model results were similar for both Cases 2 and 3 and are summarized below:

- A limited carbon tetrachloride plume developed outside of the 200 West Area and migrated toward the Columbia River. The extent of the carbon tetrachloride plume migration was less than in Case 1a when a continuing carbon tetrachloride source was assumed.
- The carbon tetrachloride concentration increased to approximately 6.5 µg/L at the arbitrary boundary during a period of approximately 600 years, between 2100 and 2700. In Case 1a, the carbon tetrachloride concentrations rapidly increased to an asymptotic level that was lower than the maximum concentrations in Cases 2 and 3.
- Carbon tetrachloride concentrations at discharge areas along the Columbia River were substantially below the benchmark MCL of 5 µg/L during the 1,000-year period of analysis.

In summary, the results illustrate the importance of developing field-scale estimates of K_d and K_a for carbon tetrachloride. For K_d and K_a of "zero," the model projected that carbon tetrachloride concentrations would exceed the compliance limit of 5 µg/L outside of the 200 Area Plateau WMA. The model also predicted that aquifer source loading and the associated contaminated portion of the aquifer would continue expanding until equilibrium of approximately 73 kg/yr is reached for river arrival and source release rates. Modeling analyses demonstrate that natural attenuation parameters K_d and K_a are critical in predicting the future movement of carbon tetrachloride from the 200 West Area. As described in Section 3.1.4, K_d values were calculated for carbon tetrachloride in sediment samples from well 299-W15-46, adjacent to the 216-Z-9 Trench in the 200-ZP-1 OU. The calculated K_d values for carbon tetrachloride ranged from 0.016 to 0.367 L/kg. Additional K_d calculations are expected for sediment samples from five wells that are planned in the vicinity of the Old Laundry Facility.

3.1.7 Soil Vapor Extraction

The process of SVE is used to remove carbon tetrachloride from the vadose zone at the 200-PW-1 OU (formerly designated as the 200-ZP-2 OU). A general overview is provided in *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Carbon Tetrachloride Site, Fiscal Year 2004* (Rohay 2005), which discusses system operation and effectiveness from February 25, 1992, through October 31, 2004. The following summary is derived from the report.

Carbon tetrachloride was found in the unconfined aquifer beneath the 200 West Area in the mid-1980s. Groundwater monitoring indicated that the carbon tetrachloride plume was widespread and that concentrations were increasing. Carbon tetrachloride removal from the vadose zone was initiated in 1992 using SVE and vapor treatment with GAC. Three SVE systems with a total capacity of 85 m^3/min were located near each of the three primary carbon tetrachloride disposal sites in March 1993. The three primary carbon tetrachloride disposal sites are the 216-Z-9, 216-Z-1A, and 216-Z-18 subsurface infiltration facilities that were used from 1955 through 1973 for disposal of carbon tetrachloride aqueous and organic liquid wastes. The SVE and monitoring wells are shown in Figure 3-5.

A 14.2-m^3/min SVE system was operated at the 216-Z-1A/Z-18 well field during April, June, July, and September 2004, and at the 216-Z-9 well field during October 2004. The SVE system was not operated during May 2004, when it was evaluated and repositioned to address a safety concern. The FY04 period of operation was extended for one month through October 2004. Operation at the 216-Z-9 well field was delayed until October 2004 to avoid interfering with vadose zone sampling during the installation of characterization borehole C3426 for well 299-W15-46, which is located on the south side of the 216-Z-9 Trench.

Carbon tetrachloride concentrations in the extracted soil vapor decreased significantly at all three sites during operation of the SVE systems. Initial carbon tetrachloride concentrations in extracted soil vapor were approximately 30,000 parts per million by volume (ppmv) at the 216-Z-9 well field and 1,500 ppmv at the 216-Z-1A/Z-18 well field. In sharp contrast, carbon tetrachloride concentrations in extracted soil vapor were approximately 41 ppmv at the 216-Z-9 well field in October 2004 and 14 ppmv at the 216-Z-1A/Z-18 well field in September 2004.

The primary source of the remaining carbon tetrachloride is apparently the relatively low-permeability Cold Creek unit (formerly the Plio-Pleistocene unit) that is approximately 38 to 45 m (124.7 to 147.6 ft) bgs. Carbon tetrachloride is removed by the SVE system as it migrates from the lower permeability zone into the overlying and underlying higher permeability zones. The rate of removal is controlled by the carbon tetrachloride desorption and diffusion rates. At many monitoring locations, including locations within the higher permeability zones, the relatively low carbon tetrachloride rebound concentrations indicate that the readily available mass is removed (i.e., carbon tetrachloride already in the vapor phase or volatizing directly from residual nonaqueous phase liquid [NAPL]). The availability of additional mass for removal is controlled by desorption and diffusion kinetics for carbon tetrachloride that is adsorbed within soil particle micropores.

The operating strategy was modified in FY98 based on the results of the *Rebound Study Report for the Carbon Tetrachloride Soil Vapor Extraction Site, Fiscal Year 1997* (Rohay 1997) and the declining rate of carbon tetrachloride removal during continuous extraction operations. The 14.2-m^3/min SVE system was the only SVE unit operated during FY98, FY99, FY01, FY02, FY03, and FY04. The system typically operated from April through September, and alternated between the 216-Z-9 and the 216-Z-1A/Z-18 sites in approximately 3-month periods. The system was maintained in standby mode from October through March to allow time for carbon tetrachloride vapor concentrations to rebound. System operation was temporarily suspended during the entire period of FY00 as a result of higher priority remediation activities that competed for limited funding. The 28.3-m^3/min and 42.5-m^3/min SVE systems were no longer maintained in standby mode beginning in FY03.

The SVE system was operated at an average 68% availability. Approximately 78,348 kg of carbon tetrachloride were removed from the vadose zone between April 1991 and October 2004. The total includes 53,888 kg from the 216-Z-9 well field and 24,461 kg from the 216-Z-1A/Z-18 well field. The extracted mass of carbon tetrachloride declined from 644 kg in FY02 to 294 kg in FY03, and then to 256 kg in FY04. The extracted mass decrease was partially due to a reduced extraction time for the high-production area around 216-Z-9 in FY04 and FY03 to avoid interfering with drilling activities.

Passive SVE systems were installed on eight wells in FY99 and operated from FY00 through FY04 to remove carbon tetrachloride from the vadose zone. Passive SVE is a natural process driven by barometric pressure fluctuations and is often referred to as "barometric pumping." The eight wells are located in the 216-Z-1A/Z-18 well field. Approximately 10 kg of carbon tetrachloride were removed from the vadose zone by passive SVE in FY04; approximately 60 kg of carbon tetrachloride were removed between October 1999 and September 2004.

An estimate was prepared in 1993 for the disposition of carbon tetrachloride that was discharged between 1955 and 1990 to the three primary disposal sites. It was estimated that 21% of the original carbon tetrachloride inventory discharged to the three primary disposal sites was lost to the atmosphere; 12% was partitioned into the vadose zone as vapor, dissolved, and adsorbed phases; 2% was dissolved in groundwater; and 1% was biodegraded. The remaining 64% of the carbon tetrachloride inventory was assumed to be in residual saturation and non-equilibrium sorption sites within the vadose zone and aquifer, and possibly as DNAPL in groundwater.

The total mass of removed carbon tetrachloride represents an estimated 10.4% of the original carbon tetrachloride inventory that was discharged to the soil column. Approximately 74,851 kg, or 10% of the inventory, was removed from 1991 through 1997. Only 0.4% of the original carbon tetrachloride inventory was removed from FY98 through FY04.

Recommendations for SVE operations include (1) continuing operation of active and passive extraction systems, and (2) continuing development of a final remedial action through the CERCLA RI/FS process that began in FY02.

An additional SVE system was operated at the 218-W-4C Burial Ground from November 2003 through April 2004. Elevated carbon tetrachloride concentrations were detected at the east end of Trench T-04 during the RI for the 200-PW-1 OU. The SVE system was operated to remove the carbon tetrachloride from the burial ground trench and minimize the release of carbon tetrachloride to the environment. Approximately 11 kg of carbon tetrachloride were removed from Trench T-04 in the 218-W-4C Burial Ground during FY04. The system was dismantled permanently to allow for removal of the soil overburden that covered the drums at the east end of Trench T-04.

3.1.8 STOMP Modeling of the 216-Z-9 Crib Releases

FH contracted with PNNL to improve the conceptual model for carbon tetrachloride distribution in the 200 West Area subsurface through numerical flow and transport modeling. The following summary is derived from the subsequent PNNL report, *Three-Dimensional Modeling of DNAPL in the Subsurface of the 216-Z-9 Trench at the Hanford Site* (Oostrom et al. 2004).

Three-dimensional fate and transport modeling was conducted to enhance the conceptual model of carbon tetrachloride vertical and lateral distribution beneath the 216-Z-9 Trench. Simulations targeted the migration of carbon tetrachloride and co-disposed DNAPL contaminants in the

subsurface beneath the 216-Z-9 Trench. The DNAPL migration was simulated as a function of sediment stratigraphy and also the properties and distribution of disposed waste. The geological aspects of the computer model were extracted from a larger Earthvision® geologic model of the 200 West Area that was developed during FY02. PNNL simulated carbon tetrachloride migration using the STOMP multi-fluid flow and transport model.

A total of 23 three-dimensional simulations were conducted to examine carbon tetrachloride subsurface infiltration and redistribution prior to implementation of SVE remediation activities in 1993. The simulations consisted of one base case simulation and 22 sensitivity analysis simulations. The sensitivity simulations investigated the effects of eight variables on the movement and redistribution of DNAPL: (1) fluid composition; (2) disposal rate, area, and volume; (3) fluid retention; (4) permeability; (5) anisotropy; (6) sorption; (7) porosity; and (8) residual saturation. Additional simulations were conducted to investigate the effects of the SVE system.

The simulations indicated that substantial quantities of carbon tetrachloride accumulated in the Cold Creek unit and that the Cold Creek unit is the primary determinant of DNAPL movement and distribution in the vadose zone. The Cold Creek unit is a relatively thin, laterally continuous unit comprised of a silt layer and a cemented carbonaceous layer that is located approximately 40 m (131 ft) bgs and approximately 50 m (164 ft) above the water table. The simulations also showed that the lateral extent of the vapor-phase plume in the vadose zone was much more extensive than the lateral extent of the DNAPL. Vapor-phase carbon tetrachloride moved downward until it contacted either relatively impermeable units (e.g., the Cold Creek unit) or the water table, and then moved laterally. The vapor plume also partitioned into the groundwater and onto the solid phase. The carbon tetrachloride in the Cold Creek unit is expected to continue volatilizing and moving downward to relatively impermeable layers, where it could be removed through SVE or deeper to the water table. The simulations clearly demonstrate that "free-phase" carbon tetrachloride has not moved laterally from the footprint of the disposal facility. In most simulations, free-phase or dissolved carbon tetrachloride was predicted to enter the water table directly beneath the disposal area or through gaseous transport and subsequent partitioning into the aqueous phase over a widespread area.

In summary, the modeling results led to the following conclusions for updating the conceptual carbon tetrachloride distribution model:

- *Where is carbon tetrachloride expected to accumulate?* Free-phase carbon tetrachloride accumulates in the finer grained layers of the vadose zone but does not appear to pool on top of these layers.
- *Where are continuing liquid carbon tetrachloride sources of groundwater contamination suspected?* Free-phase carbon tetrachloride migrates preferentially vertically downward below the disposal area. Lateral movement of free-phase carbon tetrachloride is not likely; however, significant lateral migration of vapor-phase carbon tetrachloride is expected.
- *Where would DNAPL contamination in groundwater be suspected?* Sufficient carbon tetrachloride and other liquid wastes were disposed for free-phase carbon tetrachloride to migrate as a DNAPL through the Cold Creek unit and, in some sensitivity cases, across

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the water table. For the base case simulation, 43% of the original free-phase inventory (i.e., 450,000 kg) was still present in the vadose zone as a DNAPL in 1993. Most of the DNAPL was located just above and within the Cold Creek unit. Approximately 27,000 kg (i.e., 6% of the inventory) of DNAPL moved across the water table through the end of 1993.

- *What is the estimated distribution and state of carbon tetrachloride in the vadose zone?* The amount of carbon tetrachloride that accumulated in the vadose zone as a DNAPL through 1993 ranges from 19% to 65% of the total disposed in the sensitivity simulations. The majority of the mass in 1993 was typically present in a free-phase DNAPL or sorbed phase. The center of mass for carbon tetrachloride in the vadose zone was typically directly beneath the disposal area and within the Cold Creek unit.
- *How does SVE affect the distribution of carbon tetrachloride in the vadose zone?* SVE effectively removes carbon tetrachloride from the permeable layers of the vadose zone. The SVE that was previously applied to the 216-Z-9 Trench area likely removed a large portion of the carbon tetrachloride initially present in the permeable layers within the large radius of influence of the extraction wells. Finer grained layers with more moisture content are less affected by SVE and contain the remaining carbon tetrachloride in the vadose zone.

3.1.9 Geostatistical Analysis of the Carbon Tetrachloride Inventory in the Unconfined Aquifer

Carbon Tetrachloride Atmospheric Losses and Residual Inventory Beneath 200 West Area (Rohay 1993) included an initial "order-of-magnitude" estimate of the carbon tetrachloride inventory within the unconfined aquifer in the 200 West Area. The initial estimate of 15,740 kg was based on summing the calculated area of groundwater plume concentration contour intervals (based on well data from January 1988 through May 1991), multiplied by the median carbon tetrachloride concentration for each contour interval, a constant plume depth of 10 m (32.8 ft), and an aquifer porosity of 30%.

In order to re-evaluate the inventory of carbon tetrachloride in the unconfined aquifer in the 200 West Area, FH requested that PNNL perform a three-dimensional geostatistical study of the deep carbon tetrachloride groundwater concentration values. The results of that study, *Geostatistical Analysis of the Inventory of Carbon Tetrachloride in the Unconfined Aquifer in the 200 West Area of the Hanford Site* (Murray et al. 2006), are summarized in this section.

The geostatistical analysis was based primarily on deep carbon tetrachloride and chloroform data from depth-discrete sampling at 141 intervals in 26 boreholes. Data were obtained from 1999 to 2005; 134 of the 141 concentration values were measured in the period from 2002 to 2005. Plots of the discrete carbon tetrachloride data in 10-m (32.8-ft)-depth intervals show that there is significant carbon tetrachloride from the water table to the base of the unconfined aquifer, an interval of approximately 60 m (197 ft). The carbon tetrachloride concentrations are especially high to the east of the known source areas, which supports the results previously reported in *Characterization of the Vertical Distribution of Carbon Tetrachloride Contamination in Hanford Site Groundwater* (Williams et al. 2005).

The deep carbon tetrachloride data were insufficient for defining a reliable three-dimensional variogram model due to the relatively sparse distribution. A horizontal variogram was calculated

and modeled using a normal-score transform of the most recent annual average (from FY03 to FY05). The selected concentration values were assumed to be representative of conditions in the upper portions of the aquifer, and these values were used as supplementary data for the geostatistical mapping. The more widely distributed FY03 to FY05 two-dimensional data from the top of the aquifer were used to calculate isotropic two-dimensional experimental variograms for carbon tetrachloride and chloroform. Isotropic two-dimensional variogram models were fit to the experimental variograms. Both variables have a relatively small "nugget effect" and were fit using spherical models with a correlation range of 1,200 to 1,300 m (3,937 and 4,265 ft). In both cases, the variogram model for the normal scores was set to level off at a value of 1.0, as required by the sequential Gaussian simulation algorithm that was used.

The range of the vertical variogram model was assumed to be 30 m (98.4 ft), based on analysis of the thickness of the carbon tetrachloride plume using borehole data. A sensitivity analysis could be conducted to determine the effect of the uncertainty in the assumed variogram models (both horizontal and vertical) on the calculated carbon tetrachloride inventory, but this was not part of the study.

Sequential Gaussian simulation (using sequential Gaussian simulation) was used to generate 1,000 simulations of the carbon tetrachloride and chloroform concentrations for every node in the three-dimensional grid. Each simulation honors the available data, the variogram model, and the histogram of the concentration data. Tecplot® was used to create a series of three-dimensional visualizations of the median-simulated carbon tetrachloride and chloroform value at each node of the simulation grid. The three-dimensional visualizations are shown in Figures 3-6 through 3-12.

Figures 3-6 and 3-7 present cutaway three-dimensional visualizations of the median carbon tetrachloride and chloroform concentrations in the unconfined aquifer. The cutaway is approximately through the main north-south and east-west centers of the carbon tetrachloride plume. Further visualization of the plume is provided by a series of horizontal and vertical slices through the median carbon tetrachloride concentration grid. Figures 3-8 through 3-10 present six horizontal slices at 10-m (32.8-ft) increments through the grid, from depths of 5 to 55 m (16.4 to 180.4 ft) below the water table. Figures 3-11 and 3-12 present four east-west vertical cross-sections through the plume. The four cross-sections are spaced 1 km (0.62 mi) apart, along northing orientations of 134000 m, 135000 m, 136000 m, and 137,000 m. The plume visualizations in Figures 3-6 through 3-12 include a buffer zone approximately 1,600 m (5,249 ft) wide around the entire 200 West Area. As a result, the figures illustrate both the 200-ZP-1 and 200-UP-1 OUs.

An analysis of the visualizations suggests that there is a southeast area of high uncertainty (as shown in Figures 3-8, 3-9, and 3-10) where data are sparse and the edge of the plume is not well defined. The lower boundary of the plume is also marginally defined by high median carbon tetrachloride concentrations (i.e., greater than 100 µg/L) at the base of the simulation grid, 60 m (196.8 ft) below the top of the unconfined aquifer.

The inventory of carbon tetrachloride and chloroform were estimated within the geostatistical simulation grid using a Monte Carlo approach. The inventory represents carbon tetrachloride and chloroform in groundwater and sorbed to sediments. The chloroform is assumed to result from degraded carbon tetrachloride. The inventory was based solely on aqueous concentration data, and no free-phase DNAPL is included in the inventory estimates. An attempt to account

for the uncertainty in carbon tetrachloride and chloroform porosity and K_d values was implemented in the Monte Carlo approach by estimating those parameters from probability distributions.

The results indicate that the mean carbon tetrachloride inventory in the study area is approximately 114,000 kg at a 95% confidence interval of 73,900 to 174,000 kg. The Monte Carlo carbon tetrachloride result is about 7.2 times larger than the initial 15,740 kg inventory estimated by Rohay (1993), which was 2% of the approximately 750,000 kg of carbon tetrachloride that was disposed to the subsurface. An analysis of the individual simulation results indicates that an average of approximately 49% of the carbon tetrachloride inventory in the aquifer is dissolved in the groundwater, 39% is sorbed to the aquifer sediments, and 12% is now present as chloroform. The largest amount of the carbon tetrachloride inventory (39%) is associated with the 100 to 1,000 µg/L contour interval, with 23% in the 1,000 to 2,000 µg/L interval, and 28% associated with the 2,000 to 4,000 µg/L interval.

The effect of hydrolysis on the carbon tetrachloride that entered the aquifer was also estimated. The calculations indicated that an average initial condition of approximately 149,000 kg of dissolved carbon tetrachloride was required to result in the estimated 114,000 kg of carbon tetrachloride that currently resides in the unconfined aquifer. The required initial condition would approximate 20% of the average estimated 750,000 kg of released carbon tetrachloride.

In summary, this study used a geostatistical analysis approach to update the estimated mass of carbon tetrachloride in the unconfined aquifer. The study is based on depth-discrete groundwater sampling results from 26 boreholes that have been drilled between 1999 and 2005. These results have also been used to refine the conceptual model of carbon tetrachloride contamination in the groundwater within the OU (summarized in Section 4.4) that shows there is significant carbon tetrachloride present from the water table to the base of the unconfined aquifer (and deeper into the confined aquifer unit where the Ringold Lower Mud Unit is not present). The study results show that there is an estimated 114,000 kg of carbon tetrachloride currently residing in the unconfined aquifer. This amount means that approximately 149,000 kg (20%) of the average estimated 750,000 kg of carbon tetrachloride that was initially disposed to the liquid waste disposal sites entered the groundwater and was subsequently degraded by hydrolysis.

Additional drilling of five deep wells, depth-discrete groundwater sampling, and aquifer sediment characterization are planned to help confirm the conceptual model of the carbon tetrachloride concentrations within the aquifer (FH 2006b).

3.2 RESOURCE CONSERVATION AND RECOVERY ACT OF 1976 GROUNDWATER MONITORING AND STATE WATER DISCHARGE PERMIT PROGRAM

The 200-ZP-1 OU underlies portions of the LLBG and SST system TSD units that are regulated according to the requirements of RCRA for hazardous waste constituents through Ecology's delegated program for dangerous constituents in WAC 173-303; locations above the OU also are regulated under the *Atomic Energy Act of 1954* (AEA) for radionuclides (e.g., source, special nuclear, and byproduct material). Data collected for groundwater monitoring requirements to meet WAC 173-303-645 and AEA compliance are described in the following subsections for five 200-ZP-1 OU facilities (PNNL 2005a). This RI report has used available data from sources including, but not limited to, CERCLA monitoring, RCRA monitoring, and AEA compliance

activities. However, the data presented in this report are not intended to replace or negate requirements for RCRA monitoring.

3.2.1 Low-Level Waste Management Area 3

Groundwater at LLWMA-3 is monitored in accordance with WAC 173-303, AEA, and CERCLA requirements. All wells in the monitoring network are sampled semi-annually for RCRA indicators (i.e., pH, specific conductance, TOC, and total organic halides) and site-specific parameters (i.e., alkalinity, anions, metals, phenols, and VOCs), as required by *Interim Status Groundwater Monitoring Plan for Low-Level Waste Management Areas 1 to 4, RCRA Facilities, Hanford Washington* (PNNL 2004a), 40 *Code of Federal Regulations* (CFR) 265.93(b), and WAC 173-303-400. The LLWMA-3 monitoring well network currently consists of six wells that are sampled semi-annually: 299-W7-3, 299-W7-4, 299-W7-12, 299-W8-1, 299-W10-14, and 299-W10-20. The network previously included five other wells that are now dry due to a declining water table; wells 299-W10-19, 299-W7-1, and 299-W7-7 went dry in FY04, and wells 299-W7-5 and 299-W10-21 went dry in FY05. New downgradient well locations were identified and prioritized as part of the Tri-Party Agreement Milestone M-24 (Ecology et al. 2003). Wells 299-W10-25, 299-W10-29, and 299-W10-30 are scheduled for installation in the southern LLWMA-3 in early FY06. Two additional wells are proposed on the Tri-Party Agreement priority list for installation in upgradient locations. A changing groundwater flow direction resulted in no upgradient wells for LLWMA-3. The current groundwater flow direction is east-northeast (approximately 75 degrees) at a gradient of 0.0012 and an estimated flow rate of 0.00008 to 0.12 m/day (0.00026 to 0.39 ft/day).

The data evaluation process that was described in Section 1.4 was applied to 9 of the 11 wells in the original monitoring network; wells 299-W7-3 and 299-W10-14 were excluded. The nine evaluated LLWMA-3 wells are identified in Table 1-2. As described in Section 1.4, contaminant concentrations in groundwater samples that were collected beginning in 1988 were evaluated. Although not required by the 200-ZP-1 RI/FS work plan (DOE-RL 2004c), historical Group B data that were available from the wells were included in the evaluation.

An application to Ecology was submitted in June 2002 to incorporate the LLBG into the Hanford Facility RCRA Permit (Ecology 1994). If the application is approved, the groundwater monitoring requirements for the burial grounds would change from interim status monitoring to final status monitoring. New groundwater monitoring wells, constituents, and statistical evaluations were proposed in the application.

Analytical data indicate that nitrate and carbon tetrachloride routinely exceed the DWS in wells 299-W10-19 and 299-W10-20. The two wells are located upgradient of the eastern portion of LLWMA-3 but are downgradient of the southwestern portion of the WMA. Groundwater flow and monitoring data since RCRA monitoring began in the 1980s indicate that the nitrate and carbon tetrachloride originate from sources to the south. There are no monitoring wells on the west (upgradient) side of LLWMA-3. Carbon tetrachloride concentrations on the west side of LLWMA-3 were less than 10 µg/L in well 299-W9-1 until it went dry and was no longer sampled.

Performance assessment monitoring of radionuclides at LLWMA-3 was designed to complement RCRA detection monitoring and is aimed specifically at monitoring radionuclide materials that are not regulated by RCRA. The performance assessment monitoring goals were to gather data for evaluating concentration changes in downgradient wells with statistical tests and to provide

sufficient supporting information from upgradient wells for interpreting the observed changes. Technetium-99, iodine-129, and uranium are monitored specifically for performance assessment under the current monitoring plan (DOE-RL 2000).

Contaminant characteristics in the groundwater at LLWMA-3 include the following:

- Technetium-99 concentrations are less than 100 pCi/L and are generally stable or declining. The highest technetium-99 concentration in FY05 was 44 pCi/L in well 299-W10-21 on the southern edge of the WMA. Although well 299-W10-21 is currently downgradient of the burial ground, it was likely impacted by activities to the south that temporarily imposed a northward groundwater flow. Well 299-W10-21 went dry prior to the second FY05 sampling event. Technetium-99 was also detected in wells 299-W7-4 and 299-W10-20 in FY05.
- Uranium concentrations are less than 2 μg/L.
- Iodine-129 was not detected in any of the RCRA wells. The minimum detectable activity level is approximately 0.3 pCi/L.
- Tritium was not detected in most wells in LLWMA-3 and was less than the EPA's DWS. The maximum tritium concentration in FY05 was 522 pCi/L in well 299-W10-21.
- Carbon tetrachloride, TCE, and chloroform concentrations in groundwater are consistent with regional plume values. The highest carbon tetrachloride concentration detected during routine monitoring was 140 μg/L in well 299-W7-4. The TCE and chloroform concentrations were below the EPA's DWS in FY05.
- Nitrate distribution in groundwater is consistent with regional plumes. The maximum nitrate concentration was 116 mg/L in well 299-W10-21.

3.2.2 Low-Level Waste Management Area 4

The groundwater at LLWMA-4 is monitored in accordance with WAC 173-303, AEA, and CERCLA requirements. All wells in the monitoring well network are sampled semi-annually for RCRA indicators (i.e., pH, specific conductance, TOC, and total inorganic halides) and site-specific parameters (i.e., alkalinity, anions, metals, phenols, turbidity, and VOCs), as required by the *Interim Status Groundwater Monitoring Plan for Low-Level Waste Management Areas 1 to 4, RCRA Facilities, Hanford Washington* (PNNL 2004a); 40 CFR 265.93(b), and WAC 173-303-400. The LLWMA-4 monitoring well network consisted of the following six wells until FY04: 299-W15-15, 299-W15-16, 299-W15-17, 299-W18-21, 299-W18-22, and 299-W18-23.

The water level in downgradient well 299-W15-16 was too low for sampling in June 2004 due to a declining water table, and it was replaced with well 299-W15-30. Well 299-W15-16 was originally an upgradient well under previous groundwater flow conditions. The total organic halides in well 299-W15-16 consistently exceeded the "statistical comparison value" until its final sample event in January 2004. The anomalous analytical results were initially reported to EPA and Ecology in August 1999. The elevated total organic halide concentrations are consistent with carbon tetrachloride concentrations attributed to PFP operations. Carbon tetrachloride and other VOCs were detected in the LLWMA-4 trenches and vadose zone during FY02. The LLWMA-4 vadose zone was investigated as part of the 200-PW-1 OU.

New downgradient well locations were identified and prioritized as part of Tri-Party Agreement Milestone M-24 (Ecology et al. 2003). Well installations were scheduled to begin in calendar year 2005. As previously noted, an application was submitted to Ecology in June 2002 to incorporate the LLBG into the Hanford Facility RCRA Permit (Ecology 1994). As previously described for LLWMA-3, the application includes proposed new groundwater monitoring wells, constituents, and statistical evaluations.

Groundwater flow is generally to the east (approximately 90 degrees) with a calculated gradient of 0.002 and an estimated flow rate of 0.02 to 0.5 m/day (0.07 to 1.6 ft/day). The flow direction is affected to a large degree by the 200-ZP-1 pump-and-treat system. Extraction wells are located to the east, and injection wells are located west of LLWMA-4.

The data evaluation process that was described in Section 1.4 was applied to four of the six wells in the monitoring network: 299-W15-15, 299-W15-16, 299-W15-17, and 299-W18-23. These four LLWMA-4 wells are identified in Table 1-2. As described in Section 1.4, contaminant concentrations in groundwater samples that were collected beginning in 1988 were evaluated. Although not required by the 200-ZP-1 RI/FS work plan (DOE-RL 2004c), historical Group B data that were available from the wells were included in the evaluation.

Performance assessment monitoring of radionuclides at LLWMA-4 is designed to complement RCRA detection monitoring by gathering additional data to assess downgradient concentration changes using statistical tests and to provide sufficient supporting information from upgradient wells to interpret the changes. Technetium-99, iodine-129, and uranium are monitored specifically for performance assessment under the current monitoring plan (DOE-RL 2000).

Contaminant characteristics at LLWMA-4 include the following:

- Technetium-99 concentrations are slightly elevated in two wells (299-W15-15 and 299-W18-23) on the western, upgradient side of LLWMA-4.
- Uranium concentrations are elevated in upgradient well 299-W18-21 in the southwest corner.
- Iodine-129 was not detected. The minimum detectable activity level is approximately 0.3 pCi/L.
- Tritium concentrations were less than the DWS.
- Nitrate concentrations exceed the DWS in many monitoring wells. The nitrate contamination could partially result from treated water that is reinjected upgradient of the burial ground because the 200-ZP-1 treatment system does not remove nitrate. Nitrate is slowly increasing in monitoring well 299-W18-21 in the upgradient, southwestern corner of LLWMA-4; the well is not associated with the large nitrate plumes in the 200 West Area.
- Carbon tetrachloride, TCE, and chloroform concentrations in groundwater are consistent with regional plume values. Investigation of carbon tetrachloride in the vadose zone at LLWMA-4 is continuing.

3.2.3 Single-Shell Tank System Waste Management Area T

WMA-T is located in the north-central portion of the 200 West Area and consists of the T Tank Farm, pipelines, diversion boxes, and other equipment. The tank farm contains 12 tanks with a capacity of 2 million L (528,344 gal) each and 4 tanks with a capacity of 208,000 L (approximately 54,948 gal) each that were constructed between 1943 and 1944. Leaks are known or suspected at 7 of the 16 tanks.

Groundwater is monitored in accordance with the requirements of WAC 173-303, AEA, and CERCLA. The monitoring well network consisted of 13 wells through FY04; 11 wells are sampled quarterly (299-W10-1, 299-W10-4, 299-W10-8, 299-W10-23, 299-W10-24, 299-W10-28, 299-W11-12, 299-W11-39, 299-W11-40, 299-W11-41, and 299-W11-42), and 2 wells are sampled semi-annually (299-W10-22 and 299-W11-7). The well locations are shown on the plate map in Appendix A.

Two additional RCRA monitoring wells (299-W11-25B and 299-W11-45 [well "T2"]) were planned for 2005. The borehole for well 299-W11-25B was drilled during February and March 2005 to assess the vertical extent of contamination to a depth of 36 m (118.1 ft) below the water table near the northeastern corner of WMA-T. However, this well was abandoned due to well installation problems. Well 299-W11-46 is a replacement well that was installed immediately adjacent to abandoned well 299-W11-25B. Well 299-W11-45 was installed approximately 75 m (246 ft) downgradient of WMA-T to assess the vertical and horizontal extent of contamination. Trend surface analyses indicate that groundwater flow is generally to the east (Spane et al. 2001a, 2002). The calculated average groundwater flow velocity ranges from 0.017 to 0.28 m/day (0.056 to 0.92 ft/day).

The objective of RCRA groundwater monitoring is to assess the extent and migration rate of wastes that originated from WMA-T. The monitoring wells are sampled for RCRA indicators (i.e., pH and specific conductance) and site-specific parameters (i.e., alkalinity, anions, DO, metals, oxidation-reduction potential, and turbidity), as required by 40 CFR 265.93(d) and WAC 173-303-400. The current groundwater assessment plan is described in *RCRA Assessment Plan for Single-Shell Tank Waste Management Area T at the Hanford Site* (Hodges and Chou 2001a) and *RCRA Assessment Plan for Single-Shell Tank Waste Management Area T at the Hanford Site, Interim Change Notice 1* (Horton 2002a).

The data evaluation process that was described in Section 1.4 was applied to 13 wells in the monitoring network. Wells 299-W11-45 and 299-W11-46 were excluded because analytical data from the two wells were not available when the evaluations were performed. The 13 evaluated WMA-T wells are identified in Table 1-2. As described in Section 1.4, contaminant concentrations in groundwater samples that were collected beginning in 1988 were evaluated. Although not required by the 200-ZP-1 RI/FS work plan (DOE-RL 2004c), historical Group B data that were available from the wells were included in the evaluation.

WMA-T was originally placed in RCRA assessment monitoring due to an elevated specific conductance measurement in downgradient well 299-W10-15 (PNNL 2004a). The RCRA assessment continued when contaminants were identified in downgradient well 299-W11-27 (Hodges 1998). Chromium and nitrate were identified as dangerous waste constituents in groundwater beneath WMA-T. Carbon tetrachloride, TCE, tritium, and technetium-99 were detected as non-RCRA groundwater contaminants. The carbon tetrachloride and TCE groundwater plumes are attributed to PFP operations. The tritium plume is believed to be part of

a large regional plume that is not associated with the WMA-T. The technetium-99 groundwater plume is located downgradient and east of WMA-T and is attributed to the tank farm. A DQO process is underway to better define the lateral and vertical distribution of the technetium-99 groundwater plume.

Chromium concentrations in groundwater exceed the DWS of 100 μg/L in several wells, including upgradient well 299-W10-28, well 299-W10-4 (located south of WMA-T) and two downgradient wells (299-W11-41 and 299-W11-42). The chromium concentrations are increasing in wells that exceed the DWS.

Average fluoride concentrations exceeded the primary DWS of 4 mg/L in FY03 but decreased to less than 4 mg/L during 2004. The fluoride concentration in groundwater continues to exceed 4 mg/L in wells 299-W10-23 and 299-W10-8.

The nitrate concentration exceeds the DWS of 45 mg/L in all WMA-T wells. The groundwater nitrate plume is shown on the Figure 1-2 and the plate map in Appendix A. Nitrate concentrations are increasing in well 299-W10-4 and downgradient wells 299-W11-41 and 299-W11-42.

Tritium exceeds the interim DWS of 20,000 pCi/L in one well, 299-W11-12, which is located in the southwestern corner of WMA-T. The source of the tritium is assumed to be near the TX-TY Tank Farms.

Technetium-99 exceeds the interim DWS of 900 pCi/L in seven downgradient wells: 299-W10-24, 299-W11-39, 299-W11-40, 299-W11-41, 299-W11-42, 299-W11-45, and 299-W11-46. The following summary of the technetium-99 groundwater contamination is derived from *RCRA Assessment Plan for Single-Shell Tank Waste Management Area T* (Horton 2005). Technetium-99 began to increase in well 299-W11-27 at the northeastern corner of T Tank Farm in late 1995, coincident with the cessation of surface water disposal in the 200 West Area. Concentrations reached a peak level of 21,700 pCi/L in February 1997. The technetium-99 concentrations in well 299-W11-27 subsequently decreased to 6,000 pCi/L in March 1999 when the well went dry. Hodges (1998) suggested that technetium-99 arrived at well 299-W11-27 by the early 1990s but was diluted with water from a leaking water line located immediately adjacent to the well. The water line carried cooling and ventilation steam condensate, process cooling water, and evaporator condensate from the 207-T retention basin to the 216-T-4-2 Ditch until 1995. Elimination of water discharge to the 216-T-4-2 Ditch in June 1995 allowed contaminants to reach the well. The subsequent decrease in technetium-99 in well 299-W11-27 since 1997 may be a result of changing groundwater flow direction. Technetium-99 began to increase in well 299-W11-23, which is east of well 299-W11-27, during November 1997 when groundwater flow changed to a more eastward direction. It increased to a high of 8,540 pCi/L in November 1998. Subsequent technetium-99 values fluctuated between 7,110 and 840 pCi/L. The last sample from this well, in December 2000, resulted in a technetium-99 concentration of 4,470 pCi/L. Sampling of replacement well 299-W11-39 in 2001 detected technetium-99 concentrations between 4,160 and 5,010 pCi/L, indicating contamination of the upper portion of the aquifer at this well. The technetium-99 concentration in this well rose to a high of 21,400 pCi/L in August 2004. In early 2002, the technetium-99 concentration began to increase in well 299-W11-42, which is south of well 299-W11-39, and in early 2003, technetium-99 began to increase in well 299-11-41, which is south of 299-W11-42. These increases suggest that a second technetium-99 plume or a portion of the technetium-99

plume first detected in the northeastern corner of T Tank Farm is being detected along the entire eastern and downgradient side of the WMA.

Sampling during drilling of well 299-W10-24 in 1998 showed that the highest technetium-99 concentrations were at or very near the water table, at the northeastern corner of the WMA, and concentrations decreased rapidly with increasing depth in the aquifer at the time the well was drilled. This suggested a nearby source for the technetium-99 because the contaminant had not traveled far enough to disperse vertically in the aquifer (Hodges 1998). However, in February and March 2005, well 299-W11-25B was drilled to the Ringold Lower Mud Unit and encountered extremely high concentrations of technetium-99, nitrate, and chromium at 10.7 m (35.1 ft) below the water table and deeper. (Well 299-W11-25B was damaged during construction and was replaced by well 299-W11-46.) Such high levels of contaminants at these depths below the water table is contrary to what had been observed at well 299-W10-24 and at well 299-W14-13 at WMA-TX/TY (PNNL 2004b), where the highest concentrations of technetium-99 were at or near the water table. The reason for the high concentrations at depth in well 299-W11-25B is not fully understood. Part of the explanation may be the broken pipeline near well 299-W11-27 and/or permeability differences in WMA-T wells (i.e., 299-W10-24, 299-W11-39, and 299-W11-47).

Hodges (1998) applied tritium/technetium-99 and nitrate/technetium-99 ratios to WMA-T groundwater samples in 1998 to distinguish contaminants from the cribs and trenches, evaporator condensate, and PFP. Technetium-99/chromium ratios were calculated in a similar 2004 study (Serne et al. 2004) to compare contaminant concentrations in groundwater, tank fluids that leaked from tanks T-106 and T-101, and effluent compositions disposed to cribs and trenches in the T Tank Farm area. The estimated ratios for two tank leaks and past-practice disposal facilities near WMA-T were later updated in the FY05 annual groundwater report (PNNL 2006, Section 2.8.3.3, p. 2.8-17). The revised interpretations of the technetium-99/chromium ratios are described as follows:

> *As was previously concluded (PNNL-15070, PNNL-14849), the figure shows that groundwater in the northeast part of the waste management area, and probably the more recent samples from the east part of the waste management area, have technetium-99/chromium concentration ratios similar to those in the fluids leaked from tank T-101 and T-106. However, the groundwater in the southwest, west, and north parts of the waste management area now do not appear to have been influenced to any great extent by waste disposed to the nearby cribs and trenches located upgradient of the waste management area as was previously concluded* (PNNL 2006).

When monitoring began in 1997, the technetium-99/chromium ratios in wells east of WMA-T were the same as those from upgradient wells and the northeastern corner of WMA-T. Recent data indicate that the tank waste migrated from the northeastern corner to the eastern edge of WMA-T and mixed with crib waste that was initially found in the eastern WMA-T wells. The groundwater flow direction shifted from a northern direction before 1997 to an east-southeast direction after 1997. Further characterization of the technetium-99 contamination at WMA-T to understand the lateral and vertical distribution of the plume is currently being developed through the DQO process.

3.2.4 Single-Shell Tank System Waste Management Area TX-TY

The WMA-TX/TY is located in the north-central portion of the 200 West Area and consists of the TX and TY Tank Farms and associated facilities. The tank farms contain 24 tanks (each 2.9 million L [766,099 gal] in capacity) that were constructed between 1944 and 1952. Leaks are known or suspected at 12 of the 24 tanks.

Groundwater is monitored in accordance with the requirements of WAC 173-303, AEA, and CERCLA. The monitoring well network through FY04 consisted of 15 wells that are sampled quarterly: 299-W10-26, 299-W10-27, 299-W14-6, 299-W14-13, 299-W14-14, 299-W14-15, 299-W14-16, 299-W14-17, 299-W14-18, 299-W14-19, 299-W15-40, 299-W15-41, 299-W15-44, 299-W15-763, and 299-W15-765. Well 299-W14-5 (located southeast of WMA-TX/TY) was removed from the monitoring network in May 2004 when it went dry. The monitoring network was expanded to 16 wells in May 2005 when well 299-W14-11 was installed downgradient of WMA-TX/TY to assess the vertical extent of contamination to 36 m (118.1 ft) below the water table. Three monitoring wells in the WMA-TX/TY network (299-W15-40, 299-W15-44, and 299-W15-765) were converted to extraction wells and connected to the 200-ZP-1 pump-and-treat system in July 2005 (DOE-RL 2005d). Monitoring well 299-W15-43 was also connected to the system in July 2005. The well locations are shown on the plate map in Appendix A.

WMA-TX/TY was originally placed in RCRA assessment monitoring due to an elevated specific conductance measurement in downgradient wells 299-W10-27 and 299-W14-12 (PNNL 2004a). The objective of RCRA groundwater monitoring at WMA-TX/TY is to assess the extent and migration rate of groundwater contaminants that originated in WMA-TX/TY. The monitoring wells are sampled for RCRA indicators (i.e., pH and specific conductance) and site-specific parameters (i.e., alkalinity, anions, DO, metals, oxidation-reduction potential, and turbidity), as required by 40 CFR 265.93(d) and WAC 173-303-400. The current groundwater assessment plan is described in *RCRA Assessment Plan for Single-Shell Tank Waste Management Area TX-TY at the Hanford Site* (Hodges and Chou 2001b) and *RCRA Assessment Plan for Single-Shell Tank Waste Management Area TX-TY at the Hanford Site, Interim Change Notice 1* (Horton 2002b).

The groundwater flow direction varies across WMA-TX/TY. In the northeast area near the TY Tank Farm, groundwater flows east-southeast (108 degrees) according to trend analysis (Spane et al. 2001a). The flow direction varies from 108 to 133 degrees along the downgradient, southern side of the TX Tank Farm (Spane et al. 2001a, 2002, 2003). Water-level measurements in wells south of WMA-TX/TY indicate that groundwater is flowing south-southwest. Groundwater flow in the southern portion of WMA-TX/TY is influenced by the 200-ZP-1 pump-and-treat system extraction wells. The northern WMA-TX/TY groundwater flow direction of east-southeast represents original conditions. The groundwater flow velocity ranges from 0.191 to 1.1 m/day as measured during aquifer tracer tests (Spane et al. 2001a, 2001b, 2002, 2003). The calculated average linear flow velocity ranges from 0.0007 to 2.46 m/day (0.0023 to 8.1 ft/day).

The data evaluation process that was described in Section 1.4 was applied to 15 wells in the monitoring network. Well 299-W14-11 was excluded because analytical data from the well were not available when the evaluations were performed. The 15 evaluated WMA-TX/TY wells are identified in Table 1-2. As described in Section 1.4, contaminant concentrations in groundwater

samples that were collected beginning in 1988 were evaluated. Although not required by the 200-ZP-1 RI/FS work plan (DOE-RL 2004c), historical Group B data that were available from the wells were included in the evaluation.

Chromium, nitrate, carbon tetrachloride, and TCE were identified as dangerous waste constituents in groundwater beneath WMA-TX/TY. Tritium, technetium-99, and iodine-129 were detected as non-RCRA groundwater contaminants. The carbon tetrachloride and TCE are attributed to PFP operations.

Nitrate concentrations exceed the DWS of 45 mg/L in all WMA-TX/TY monitoring network wells. The highest nitrate concentration is found in well 299-W14-13. The nitrate groundwater contamination is primarily the result of PFP operations and waste disposal in cribs and trenches. A smaller portion of the nitrate contamination may originate from WMA-TX/TY. Chromium was detected above the DWS of 100 µg/L in well 299-W14-13. The most likely chromium source is assumed to be WMA-TX/TY because no other sources were identified.

Tritium exceeds the interim DWS of 20,000 pCi/L in two wells: 299-W14-13 and 299-W14-15. Both wells are located approximately 50 m (164 ft) south of well 299-W14-13. Potential sources for the tritium include one or more of the following: WMA-TX/TY, the 242-T evaporator, the 216-T-19 Crib and tile field (which received evaporator condensate from the 242-T evaporator), and the 216-T-26 through 216-T-28 Cribs. Technetium-99 exceeds the interim DWS of 900 pCi/L in one well (299-W14-13). The technetium-99 could originate from WMA-TX/TY.

Iodine-129 was detected in two wells at WMA-TX/TY: 299-W14-13 and 299-W14-15. Interpretation of the iodine-129 data is difficult due to changing laboratory sample preparation methods and resulting high laboratory detection limits. The Groundwater Project is working to resolve the laboratory problems.

3.2.5 State Waste Discharge Permit Groundwater Monitoring

The Hanford Site's 200 Area Effluent Treatment Facility processes contaminated aqueous waste. The treated wastewater occasionally contains tritium that is not removed during the treatment process. The wastewater is discharged to the 200 Area SALDS in accordance with the requirements of the Washington State waste discharge permit (WAC 173-216). The discharge permit was approved in June 1995, and the site began operating in December 1995.

Permit requirements for groundwater monitoring are described in the *Groundwater Monitoring and Tritium-Tracking Plan for the 200 Area State-Approved Land Disposal Site* (Barnett 2000). The discharge permit establishes enforcement limits for maximum concentrations of nine contaminants (i.e., acetone, benzene, cadmium, chloroform, copper, lead, mercury, sulfate, and tetrahydrofuran) and two other parameters (i.e., pH and total dissolved solids). Groundwater is also sampled for four AEA parameters: gross alpha, gross beta, strontium-90, and tritium. Numerical flow-and-transport modeling of the SALDS is conducted as required by the permit.

The 15 total compliance parameters are monitored quarterly in three wells near the SALDS perimeter: 699-48-77A, 699-48-77C, and 699-48-77D. Three additional wells are sampled semi-annually (299-W7-3, 299-W7-5, and 699-51-75), and another eight wells are sampled annually (299-W6-6, 299-W6-11, 299-W6-12, 299-W7-12, 299-W8-1, 699-48-71, 699-49-79, and 699-51-75P). Five wells formerly in the tritium-tracking network south of SALDS were dry before or during FY04: 299-W7-1, 299-W7-6, 299-W7-7, 299-W7-9, and 299-W6-7. The

continuing wastewater discharges at SALDS result in a mound in the water table under the facility. Groundwater flows outward in all directions away from the SALDS discharge points.

The data evaluation process described in Section 1.4 was applied to 15 of the 19 wells in the tritium-tracking network. Wells 299-W6-6, 299-W7-3, 699-48-77C, and 699-51-75P were excluded. The 15 evaluated SALDS wells are identified in Table 1-2. As described in Section 1.4, contaminant concentrations in groundwater samples that were collected beginning in 1988 were evaluated. Although not required by the 200-ZP-1 RI/FS work plan (DOE-RL 2004c), historical Group B data that were available from the wells were included in the evaluation.

The average tritium activity level is decreasing in all three SALDS perimeter wells. The maximum tritium activity levels during FY04 were 116,000 pCi/L in well 699-48-77A, 229,000 pCi/L in well 699-48-77C, and 95,000 pCi/L in well 699-48-77D. The fluctuating tritium activity level in well 699-48-77A is presumably the result of varying amounts of tritium in the wastewater discharge.

All monitored parameters are within the permitted limits. Benzene, tetrahydrofuran, copper, and mercury were below MDLs in all FY04 samples. Lead and cadmium were detected in well 699-48-77A during FY04. Major cation and anion groundwater concentrations during FY04 were below background concentrations that were observed prior to operation of the facility due to dilution by the discharged wastewater.

3.3 INTERIM ACTION PUMP-AND-TREAT PERFORMANCE

The 200-ZP-1 OU pump-and-treat system was implemented in a three-phased approach. Phase I operations consisted of a pilot-scale treatability test between August 29, 1994, and July 19, 1996, around the 216-Z-12 Crib. During this phase, contaminated groundwater was removed through a single extraction well (299-W18-1) at a rate of approximately 151 L/min (40 gpm), treated using GAC, and then returned to the aquifer through an injection well (299-W18-4). For more detailed information about operations during the treatability test, refer to the *200-ZP-1 Operable Unit Treatability Test Report* (DOE-RL 1995a).

Concurrent with Phase I operations, the interim ROD for the 200-ZP-1 OU (EPA et al. 1995) was issued in June 1995. The selected remedy was to use groundwater pump-and-treat technology to minimize further migration of carbon tetrachloride, chloroform, and TCE in the groundwater and remove contaminant mass.

Phase II operations commenced August 5, 1996, in accordance with the interim ROD (EPA et al. 1995) and Tri-Party Agreement Milestone M-16-04A (Ecology et al. 2003) The 1996 groundwater plume was the basis for the interim ROD. The well field configuration during Phase II operations consisted of three extraction wells (299-W15-33, 299-W15-34, and 299-W15-35), pumping at a combined rate of approximately 567.8 L/min (150 gpm), and a single injection well (299-W15-29). Groundwater was treated using an air stripper to release carbon tetrachloride into a vapor phase, and GAC was used to collect the vapor. For a detailed description of the treatment system setup and operation, refer to the *200-ZP-1 Phase Interim Remedial Measure Quarterly Report, October – December 1996* (BHI 1997a). Phase II operations were terminated on August 8, 1997, to transition to Phase III operations.

Phase III operations began on August 29, 1997, satisfying Tri-Party Agreement Milestone M-16-04B (Ecology et al. 2003). The well field for Phase III operations was expanded to include six extraction wells (existing wells, plus new wells 299-W15-32, 299-W15-36, and 299-W15-37) and five injection wells (existing wells, plus wells 299-W18-36, 299-W18-37, 299-W18-38, and 299-W18-39). The total pumping rate was increased to more than 800 L/min (>200 gpm), versus a total treatment system capacity of 1,893 L/min (500 gpm). The treatment process for the Phase III system uses the same air-stripping and GAC systems for remediating contaminated groundwater. Extraction wells were installed to contain the high-concentration portion of the carbon tetrachloride plume located near PFP, as required by the interim ROD (EPA et al. 1995). The southernmost extraction well, 299-W15-37, was converted to a monitoring well in January 2001 because of its limited impact on hydraulic capture of the high-concentration portion of the plume (DOE-RL 2002b).

Two new extraction wells were drilled and brought on-line in FY04. Well 299-W15-45 replaced 299-W15-33, and well 299-W15-47 replaced 299-W15-32. Both new wells have been drilled deeper into the aquifer and were constructed with 15.2-m (50-ft) screens, starting 1.5 m (5 ft) below the water table in the upper, unconfined aquifer. The old wells have been reconfigured to monitor water levels.

The key achievement for the 200-ZP-1 pump-and-treat system in FY05 was the expansion of the five-well extraction system to a total of nine wells with the addition of four new extraction wells north of the existing baseline plume area. Extraction pumps were installed in existing monitoring wells 299-W15-40, 299-W15-43, 299-W15-44, and 299-W15-765; connected to the 200-ZP-1 treatment building; and formally started groundwater extraction on July 27, 2005. Since startup, the extraction system pumping rates have increased to between 946 to 1,230 L/min (250 to 325 gpm). The 200-ZP-1 pump-and-treat system wells are shown in Figure 3-13.

The FY05 hydraulic capture analysis shows that the pump-and-treat system continues to capture the high-concentration levels of carbon tetrachloride (greater than 2,000 to 3,000 µg/L) at the extraction wells. Groundwater monitoring results for FY05 also show that carbon tetrachloride concentrations continue to decline in the unconfined aquifer (DOE-RL 2005a). Carbon tetrachloride contamination in the groundwater was reduced in the area of highest concentrations through mass removal. Over 322.3 million L (85.1 million gal) of contaminated groundwater were treated in FY05 at an average flow rate of 715 to 1,116 L/min (190 to 295 gpm). Treatment of the contaminated water resulted in the removal of 753.5 kg of carbon tetrachloride in FY05. Between the initiation of pump-and-treat operations in March 1994 and the end of FY05, approximately 2.74 billion L (725 million gal) of water has been treated, resulting in the removal of 9,262 kg of carbon tetrachloride (DOE-RL 2005d).

The reduction in carbon tetrachloride concentrations at the top of the unconfined aquifer underlying the primary carbon tetrachloride source cribs is shown by the changes in the carbon tetrachloride groundwater plume from 1990 to 2004, as illustrated in Figure 3-14. The reduction likely resulted from the dual application of SVE remediation in the vadose zone (as discussed in Section 3.1.7) and the pump-and-treat groundwater remediation in the source cribs vicinity.

3.4 SUMMARY OF VADOSE ZONE RESULTS PERTINENT TO THE 200-ZP-1 OPERABLE UNIT

Contaminants that may contribute significantly to site risk are referred to as COCs. Identification of COCs is an important process because it determines the list of contaminants for which further risk evaluations will be developed. Development of COCs in the data evaluation and risk assessment process is discussed in *Risk Assessment Guidance for Superfund (RAGS), Volume I, Human Health Evaluation Manual (Part A), Interim Final* (EPA 1989). Those contaminants that are COCs are determined by comparing contaminant concentrations with background, developing a set of data for use in risk assessment, and (if appropriate) limiting the number of contaminants to be carried through a risk assessment by risk-based screening or other methods. For the waste group OUs in the vadose zone above the 200-ZP-1 Groundwater OU, the evaluation of COCs is presented in RI reports and work plans (e.g., *Remedial Investigation Report for the 200-TW-1 and 200-TW-2 Operable Units (Includes the 200-PW-5 Operable Unit)* [DOE-RL 2003c]; *Remedial Investigation for the 200-PW-2 Uranium-Rich Process Waste Group and 200-PW-4 General Process Condensate Group Operable Units* [DOE-RL 2005e]; and *Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Units RI/FS Work Plan: Includes the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units* [DOE-RL 2004b]). The COCs identified with the potential to impact groundwater quality are of particular interest for this 200-ZP-1 Groundwater OU RI report. Maximum constituent concentrations for nonradioactive constituents in the vadose zone were compared to soil screening criteria calculated using the fixed-parameter, three-phase partitioning model described in WAC 173-340-747. Use of this model for screening soil contamination for potential groundwater impacts was performed by using Method B soil cleanup levels as published on Ecology's Internet site (https://fortress.wa.gov/ecy/clarc/Reporting/CLARCReporting/aspx).

3.4.1 Analogous Site Approach

Analogous data are used in the Hanford Site's 200 Areas to reduce the amount of investigation needed at individual waste sites by performing characterization activities for groups of similar waste sites. It is a conservative approach because waste sites generally expected to contain the most contamination are selected to represent all sites in a soils OU. This concept is advanced in *Hanford Past-Practice Strategy* (DOE-RL 1991). The basic approach is that the representative sites contain types, concentrations, and distributions of contaminants similar to those at the other sites in the OU because the sites are grouped on the basis of similar site histories, site construction, and processes. The sites, therefore, share similar risks and a similar need for remedial action. The data collected for the representative sites are considered analogous to other sites designated in the RI reports (DOE-RL 2003c, 2005e).

In the case of the 200-PW-2 and 200-PW-4 OUs, only one site in these waste group OUs (216-T-20 in the 200-PW-4 OU) is in the vadose zone above the 200-ZP-1 Groundwater OU; it was not sampled directly. In the RI report (DOE-RL 2005e), all sites within both OUs were considered analogous to all sampled sites. This is a very conservative approach in that all COCs (determined by sampling conservatively selected representative sites) for both OUs are applied to all sites within both OUs.

In the case of the 200-TW-1, 200-TW-2, and 200-PW-5 OUs, the RI report draws a correlation between each directly sampled site and its analogous site(s). One waste site above the 200-ZP-1 Groundwater OU, the 216-T-26 Crib, is a representative site that was sampled directly. Other waste sites above the 200-ZP-1 Groundwater OU were not directly sampled. Table 3-2 shows the 200-TW-1, 200-TW-2, 200-PW-1, 200-PW-2, 200-PW-4, 200-PW-5, and 200-PW-6 OU waste sites in the vadose zone above the 200-ZP-1 Groundwater OU and the representative sites that were directly sampled in support of their remediation.

3.4.2 200-PW-2 and 200-PW-4 Operable Unit Sites

The 200-PW-2 and 200-PW-4 OUs contain approximately 50 waste sites, 5 of which are RCRA TSD units. Most of the waste discharged to the soil column in the 200-PW-2 and 200-PW-4 OUs was generated at U Plant, Reduction-Oxidation (REDOX) Plant, Plutonium-Uranium Extraction (PUREX) Plant, B Plant, and C Plant (also know as the Hot Semi-Works Facility) between 1952 and 1988 (DOE-RL 2004d). Sampled representative sites were all located in the 200 East Area, near PUREX and B Plant. Contaminants that may present potential risks to groundwater were identified at all representative sites. Data for the only analogous site above the 200-ZP-1 Groundwater OU (216-T-20 Crib) are based solely on 200 East Area samples and may not include contaminants that tend to be more strongly concentrated in the 200 West Area.

3.4.2.1 Characterization. Borehole drilling and sampling, large-diameter push-hole (drive casing) installation, direct-push sampling, and sampling and analysis of soils were used to characterize the following representative sites: 216-A-10 Crib, 216-A-36B Crib, 216-A-37-1 Crib, 216-B-12 Crib, 216-A-19 Trench, and 207-A south retention basin. Data from the sites were collected during characterization efforts in FY03 and FY04. Borehole geophysical surveys were performed at the 216-A-10, 216-A-36B, 216-A-37-1, and 216-B-12 Cribs and the 216-A-19 Trench. Because of its shallow depth and concrete lining, no geophysical surveys were performed at the 207-A south retention basin.

3.4.2.2 Contaminant Distribution Models and Exposure Models. The conceptual contaminant distribution models and the conceptual exposure model developed in the *Uranium-Rich/General Process Condensate and Process Waste Group Operable Unit RI/FS Work Plan and RCRA TSD Unit Sample Plan: Includes 200-PW-1 and 200-PW-2 Operable Units* (DOE-RL 2004d) were revised based on the data obtained during the RI report and other data-collection activities. The contaminant distribution models are generally described as follows:

- Contamination associated with less-mobile COCs (e.g., cesium, plutonium, and strontium) is detected in the highest concentrations near the bottom of waste sites. Less-mobile radiological COCs have not been identified to have potential impacts to groundwater.
- Contaminant concentrations generally decrease with depth below the waste site bottom.
- Most of the contamination remains high in the vadose zone above the water table.
- Highly mobile COCs (e.g., technetium) have passed through the vadose zone and are detected sporadically across the vadose zone in low concentrations.

The exposure pathway model for the OU is generally summarized as follows:

- Potentially contaminated media are shallow-zone soils, deep-zone soils, biota, and groundwater.

- Potential receptors are mainly current and future workers (based on the current land-use assumptions) and terrestrial biota.
- Exposure pathways are ingestion, dermal contact, inhalation, and exposure to external radiation.

The contaminant distribution models were updated to better depict the nature and vertical extent of contamination relative to the physical setting. The revised models identified specific contaminants present, contaminant concentrations, and the vertical extent of contamination relative to the water table.

The conceptual model contained the following media types: surface soils or shallow-zone soils from 0 m to 4.6 m (0 to 15 ft) bgs, subsurface soils or deep-zone soils from 0 m to groundwater, groundwater, and biota. Based on current land-use assumptions, potential receptors are current workers, future workers, and terrestrial biota.

3.4.2.3 Fate and Transport Modeling and Evaluation. Table 3-3 identifies those COCs that were consistently identified and that are the most likely contaminants for future soil sampling efforts related to groundwater protection (i.e., confirmatory sampling, design sampling, and verification sampling).

Nonradioactive constituents analyzed in the RI report were screened based on detection (constituents with no detections were eliminated), comparison to background, and comparison to regulatory requirements. The initial screening of the nonradioactive contaminants for groundwater risk was performed by comparing the analytical results to the groundwater risk-based concentration (RBC) based on WAC 173-340-747 (4). The RBCs were compared to analytical results found in deep-zone soils.

Radiological constituents were screened based on detection and background. Radiological dose and cancer risk to receptors were evaluated using RESidual RADioactivity (RESRAD) dose modeling (ANL 2001) and regulatory considerations. A qualitative evaluation was performed to assess whether additional modeling was required. This included evaluation of the K_ds, frequency of detection, and location of any single detects in the soil column, and whether the constituent already has reached groundwater. Based on this evaluation, sufficient data already existed to assess the fate and transport.

The results of the fate and transport modeling and added evaluation indicate that most COCs are effectively attenuated in the vadose zone and do not pose a substantial threat to future groundwater quality during the 1,000-year simulation. Contaminants that affect groundwater in the future in significant concentrations are nitrate, uranium, tritium, iodine-129, and technetium-99. Tritium is the only radioactive contaminant that is predicted to reach groundwater within the 1,000 years. Short-lived radionuclides (e.g., cesium-137 and strontium-90) were shown to decay long before reaching groundwater.

3.4.3 200-TW-1 and 200-TW-2 Operable Unit Sites

The 200-TW-1, 200-TW-2, and 200-PW-5 OUs consist of approximately 80 RCRA past-practice and CERCLA past-practice waste sites. An evaluation of protection of groundwater indicated that contaminants currently in the vadose zone likely will impact groundwater in the future; however, the contaminants are not expected to increase groundwater concentrations above current levels.

Table 3-2 shows the 200-TW-1, 200-TW-2, and 200-PW-5 OU waste sites in the vadose zone above the 200-ZP-1 Groundwater OU and the representative sites that were directly sampled in support of their remediation. One sampled representative site, the 216-T-26 Crib, is in the vadose zone above the 200-ZP-1 Groundwater OU. The other sites that represent cribs and trenches above the 200-ZP-1 OU (i.e., 216-B-7A Crib, 216-B-38 Trench, and 216-B-5 reverse well) are located near B Plant in the 200 East Area. Results for these sites are summarized below.

The evaluation of the representative sites involved site characterization and a baseline human health risk evaluation, including identification of COCs potentially affecting groundwater quality. Contaminants that were identified as COCs for the waste sites will be carried forward into the FS for evaluation of remedial alternatives. The COCs and the contaminant distribution and exposure models are summarized below.

3.4.3.1 Contaminants of Concern and Site Risks. Nonradioactive constituents analyzed in the RI report were screened based on detection (constituents with no detections were eliminated), comparison to background, and comparison to regulatory requirements. Radiological constituents were screened based on detection and background. Radiological dose and cancer risk to receptors were evaluated using RESRAD modeling (ANL 2001). Contaminants with potential to impact groundwater were evaluated using the STOMP code (PNNL 2000). The COCs for each waste site are summarized in Table 3-3. Based on the results of the data evaluation, Table 3-3 identifies those COCs in the 200-TW-1, 200-TW-2, 200-PW-1, 200-PW-5, and 200-PW-6 OUs that the FS will consider for remedial action with respect to groundwater risk and that are the most likely contaminants for future sampling efforts (i.e., confirmatory sampling, design sampling, and verification sampling).

3.4.3.2 Contaminant Distribution Models and Exposure Models. The conceptual contaminant distribution models and the conceptual exposure model developed for the 200-TW-1 and 200-TW-2 OUs in *200-TW-1 Scavenged Waste Group Operable Unit and 200-TW-2 Tank Waste Group Operable Unit RI/FS Work Plan* (DOE-RL 2001) were refined based on the data obtained during the RI report and other data collection activities. The contaminant distribution models are generally described as follows:

- Contamination associated with less-mobile COCs (mainly cesium-137) is confined near the waste site bottom.
- Contamination associated with moderately mobile COCs (e.g., strontium-90) is found deeper in the vadose zone and, depending on the thickness of that zone, may be found throughout the vadose zone.
- Highly mobile COCs (e.g., nitrate, tritium, or technetium) have passed through the vadose zone and are concentrated in the saturated zone.

The exposure pathway model for the 200-TW-1, 200-TW-2, and 200-PW-5 OUs is generally summarized as follows:

- Potentially contaminated media include sediments, shallow-zone soils, deep-zone soils, biota, and groundwater.
- Potential receptors are mainly current and future workers (based on the current land-use assumptions) and terrestrial biota.

Exposure pathways include ingestion, dermal contact, inhalation, and exposure to external radiation.

3.4.4 200-PW-1 and 200-PW-6 Operable Unit Sites

The 200-PW-1 and 200-PW-6 OUs contain approximately 17 waste sites. The 200-PW-1 waste was generated at the Z Plant complex from 1949 to 1980. The 200-PW-6 waste, consisting of neutral/basic process waste, was generated from the Plutonium Isolation Facility from 1945 to 1949 and the head-end of the RECUPLEX process from 1955 to 1962. Sample representative sites were all located in the 200 Area core zone. Contaminants that may present potential risks to groundwater were identified at all representative sites, which were strongly concentrated in the 200 West Area. The 200-PW-3 OU waste sites are excluded from this discussion because they exclusively reside in the 200 East Area.

3.4.4.1 Characterization. Borehole drilling, soil and soil vapor sampling, and associated geophysical logging, as well as previous investigation results, are being used to characterize the 216-Z-1A and 216-Z-9 representative sites. Field investigations are planned to be completed in FY06 so the RI report can be prepared by the end of FY06. The 216-Z-9 Trench characterization includes a vertical well (completed in 2005) and a slant well (being drilled in 2006). The vadose zone results from the vertical well (299-W15-46) at the 216-Z-9 Trench are summarized in Section 3.1.1. The results from the slant well will be included as an appendix to the FS.

The dispersed carbon tetrachloride vadose zone plume was characterized in two phases. During the Step I investigation, direct-push technology was used to collect soil vapor samples from the shallow and intermediate vadose zone at potential release sites (e.g., waste disposal sites, pipelines, and burial ground trenches). Vapor samples were also collected from vent risers in the 218-W-4C Burial Ground. Relatively low concentrations of carbon tetrachloride (1 to 8 ppmv) were detected in several samples collected along some pipelines (typically from 7.6 m [25 ft] bgs) and in some samples collected at liquid waste discharge sites (the highest concentrations were typically found from 9.1 to 18.3 m [30 to 60 ft] deep). The highest carbon tetrachloride concentration (1,760 ppmv) was detected in the east end of Trench 4 in the 218-W-4C Burial Ground (FH 2003a). The Step II investigation included shallow and intermediate vadose zone soil vapor and soil sampling using direct-push technology at Step I locations that had indicated potential releases of carbon tetrachloride and at locations outside the Step I study area. Passive soil vapor samplers were also used to investigate areas near the 216-Z-9 Trench, at T Plant, and at two trenches in the 218-W-3A Burial Ground. In Step II, the deep vadose zone was also characterized by collecting soil vapor samples above the water table and shallow groundwater samples just below the water table in existing wells in the vicinity of the highest carbon tetrachloride groundwater concentrations (>1,000 µg/L). The field investigations are planned to be completed in FY06 so the RI report can be prepared by the end of FY06.

3.4.4.2 Contaminant Distribution Models and Exposure Models. The conceptual contaminant distribution models and the conceptual exposure model developed in the *Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit RI/FS Work Plan: Includes the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units* (DOE-RL 2004b) were revised based on the current understanding of physical conditions of 216-Z-1A and 216-Z-9. The contaminant distribution models are generally described as follows:

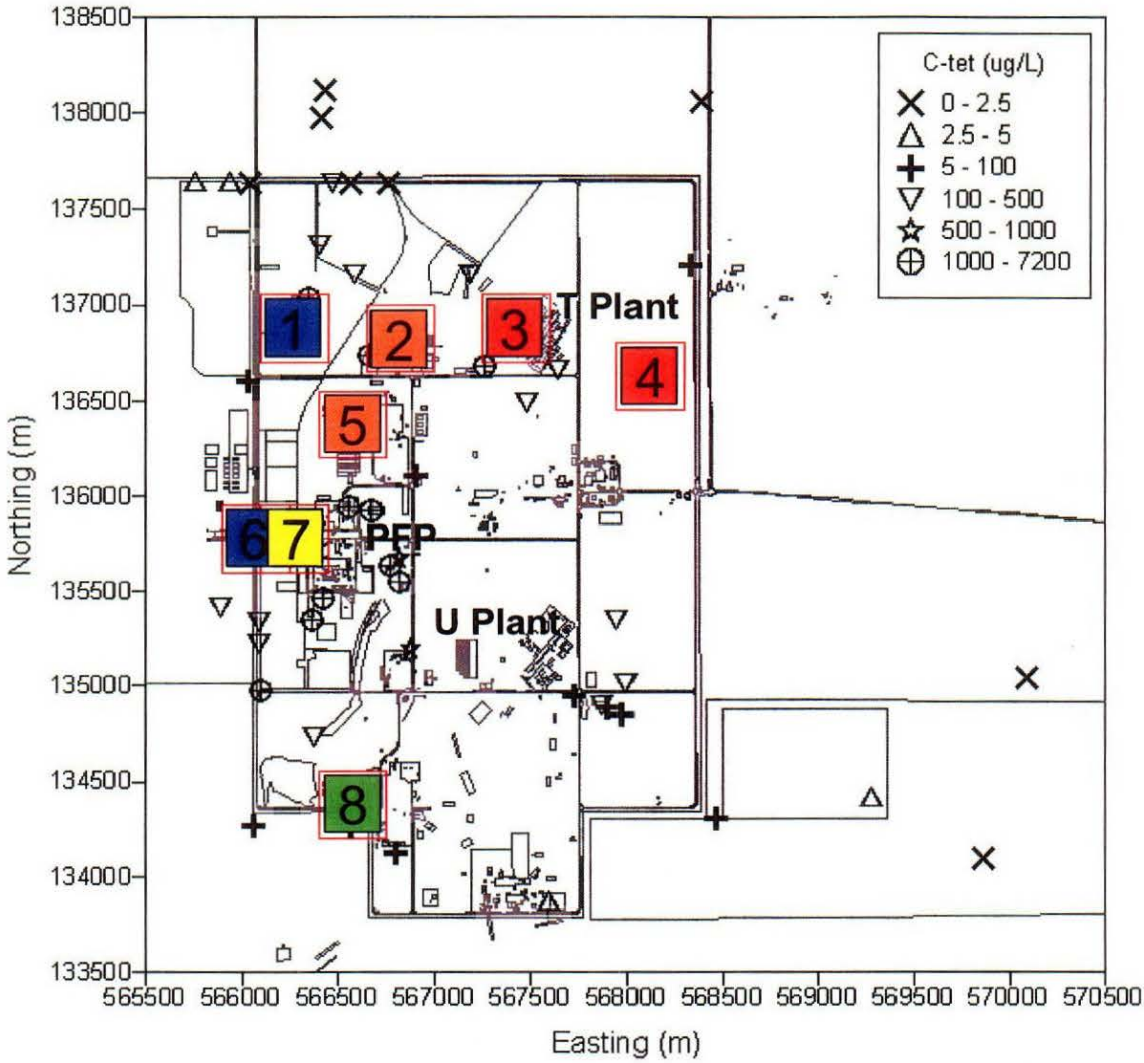
- Contamination associated with less-mobile COCs (e.g., plutonium) is in the highest concentrations near the bottom of waste sites. None of the less-mobile radiological COCs have been identified to have potential impacts to groundwater.
- Contaminant concentrations generally decrease with depth below the waste site bottom.
- Most of the contamination remains in the vadose zone above the water table.
- Mobile COCs (e.g., carbon tetrachloride) have passed through the vadose zone and are detected within groundwater.

The exposure pathway model for the OU is generally summarized as follows:

- Potentially contaminated media are shallow-zone soils, deep-zone soils, biota, and groundwater.
- Potential receptors are mainly current and future workers (based on the current land-use assumptions) and terrestrial biota.
- Exposure pathways are ingestion, dermal contact, inhalation, and exposure to external radiation.

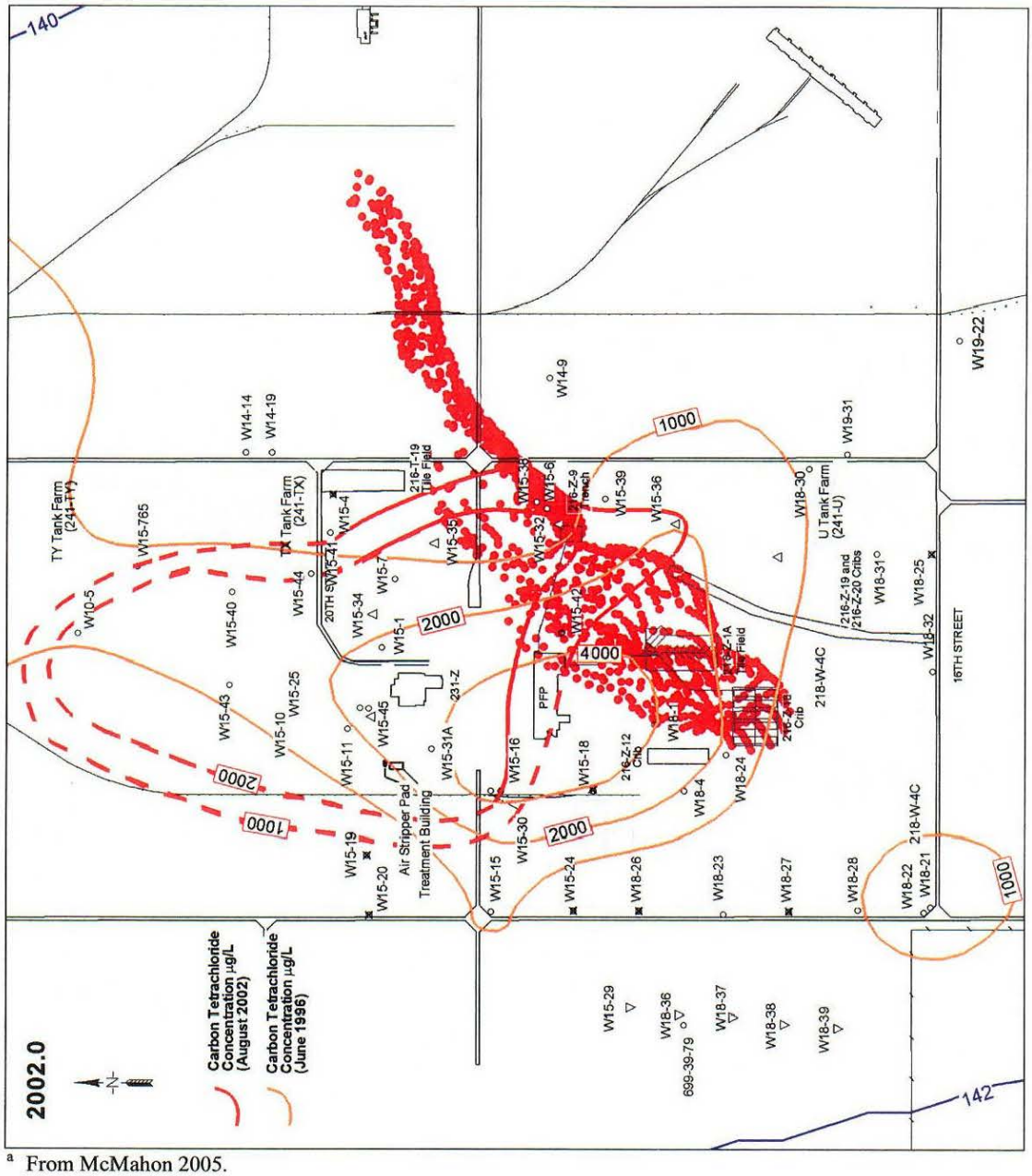
3.4.4.3 Fate and Transport Modeling and Evaluation. The RI report for the 200-PW-1, 200-PW-3, and 200-W-6 OUs will be prepared by the end of FY06, but the risk assessment for these OUs will be deferred to the FS. The COCs identified in the Table 3-3 for the 216-Z-9 and 216-Z-1A representative sites are the COCs and contaminants of interest identified in the representative SAPs for those sites (DOE-RL 2004b).

Figure 3-1. Summary Map of Classification of Sub-Areas Based on Their Likelihood of Containing Persistent Carbon Tetrachloride Sources.[a]



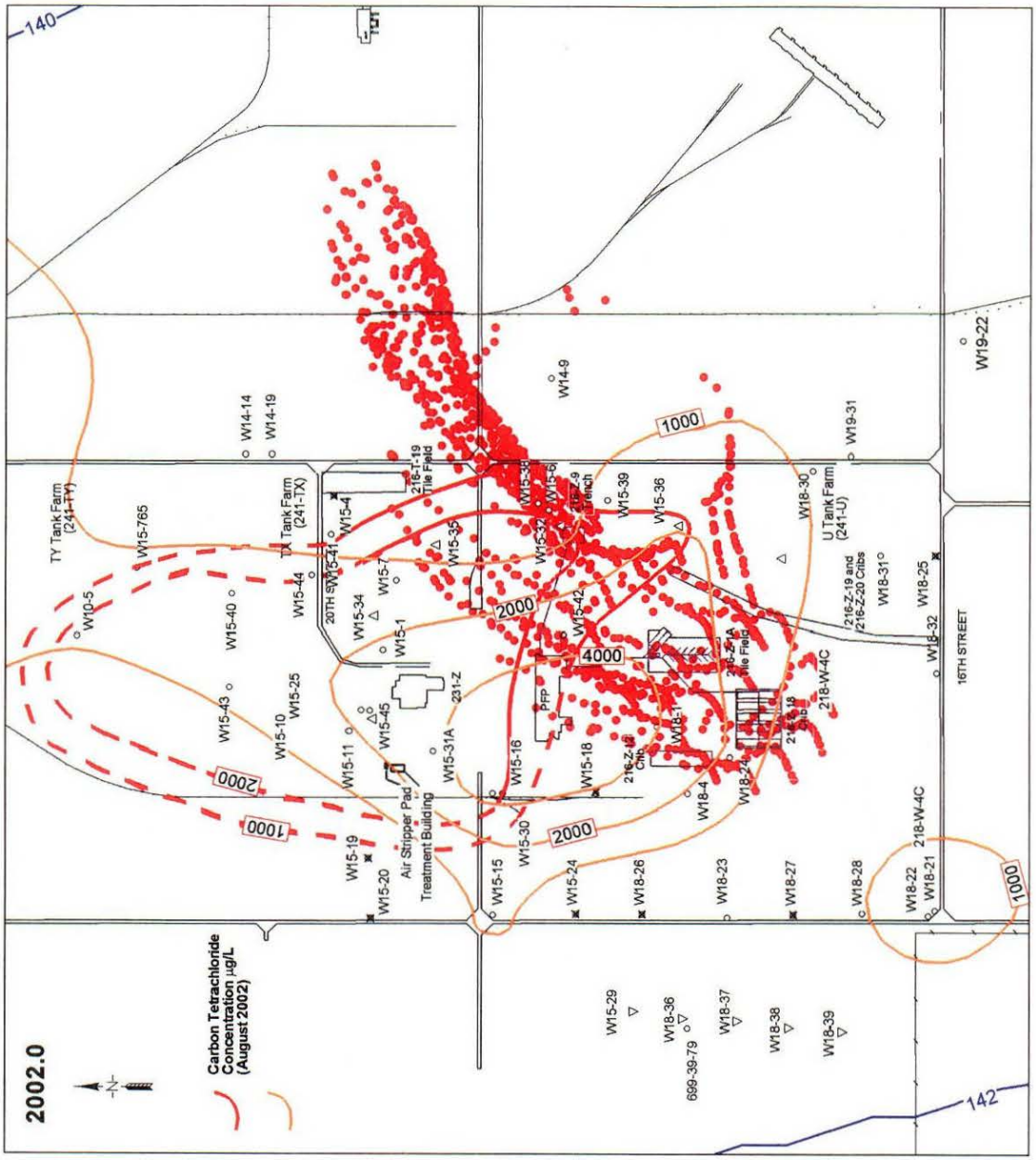
[a] Color scale ranges from red for high probability to blue for the lowest probability (from Murray and Chien 2005).

Figure 3-2. Calendar Year 2002 Locations of Particles with Retardation Factor of 4 Begun in 1962 at 216-Z-9, in 1971 at 216-Z-1A, and in 1976 at 216-Z-18.[a]



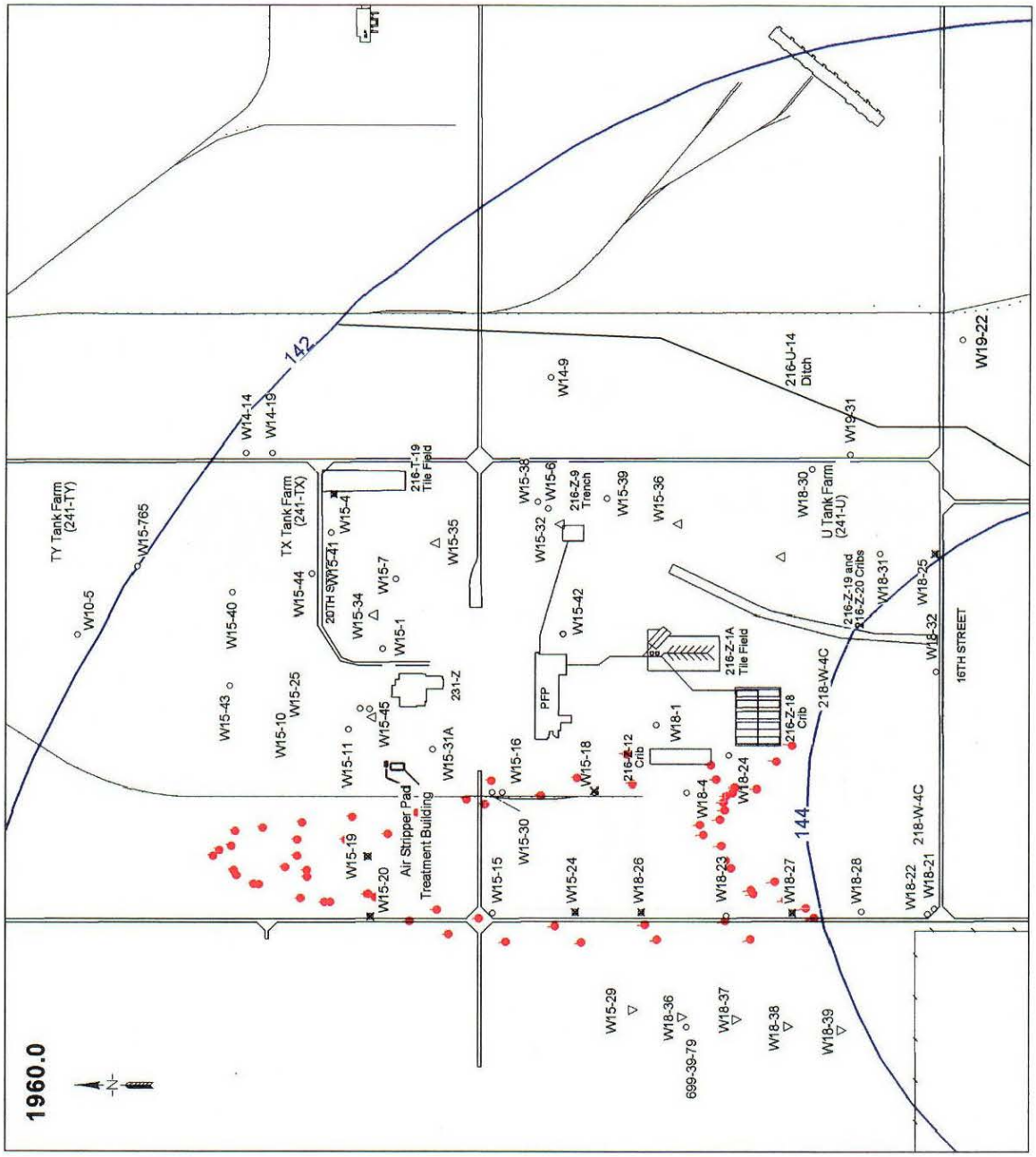
[a] From McMahon 2005.

Figure 3-3. Calendar Year 2002 Locations of Particles with Retardation Factor of 4 Begun in 1962 at 216-Z-9, in 1971 at 216-Z-1A, and in 1976 at 216-Z-18 at Approximately Twice the Facility Radius.[a]



[a] From McMahon 2005.

Figure 3-4. Year 1960 Locations of Reverse Particles Starting Along Leading Edge of Carbon Tetrachloride Plume 1,000 and 2,000 µg/L isopleths in Calendar Year 2002 with Retardation Factor of 4.[a]



[a] From McMahon 2005.

Figure 3-5. Map of Soil Vapor Extraction Well Locations.

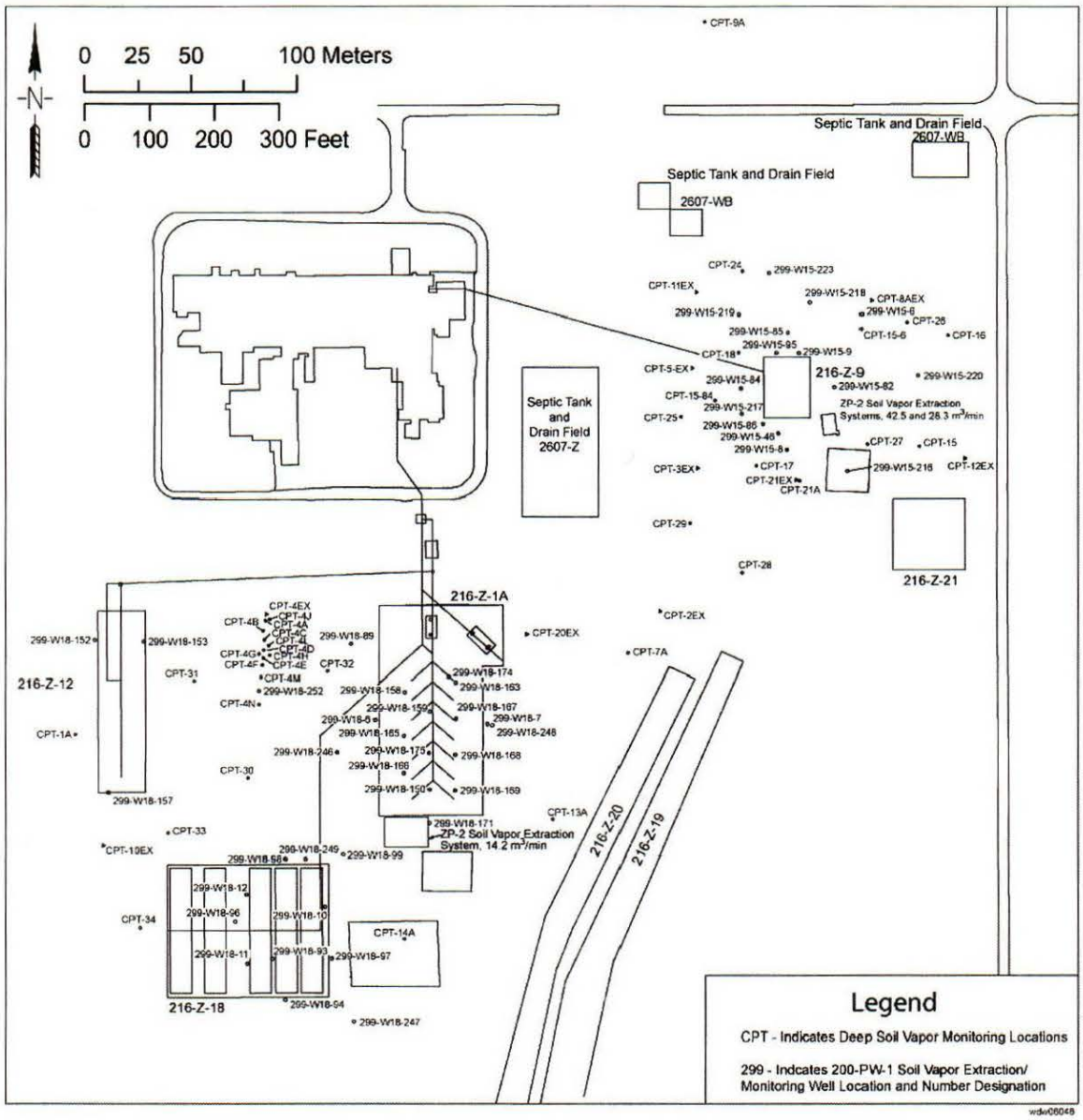
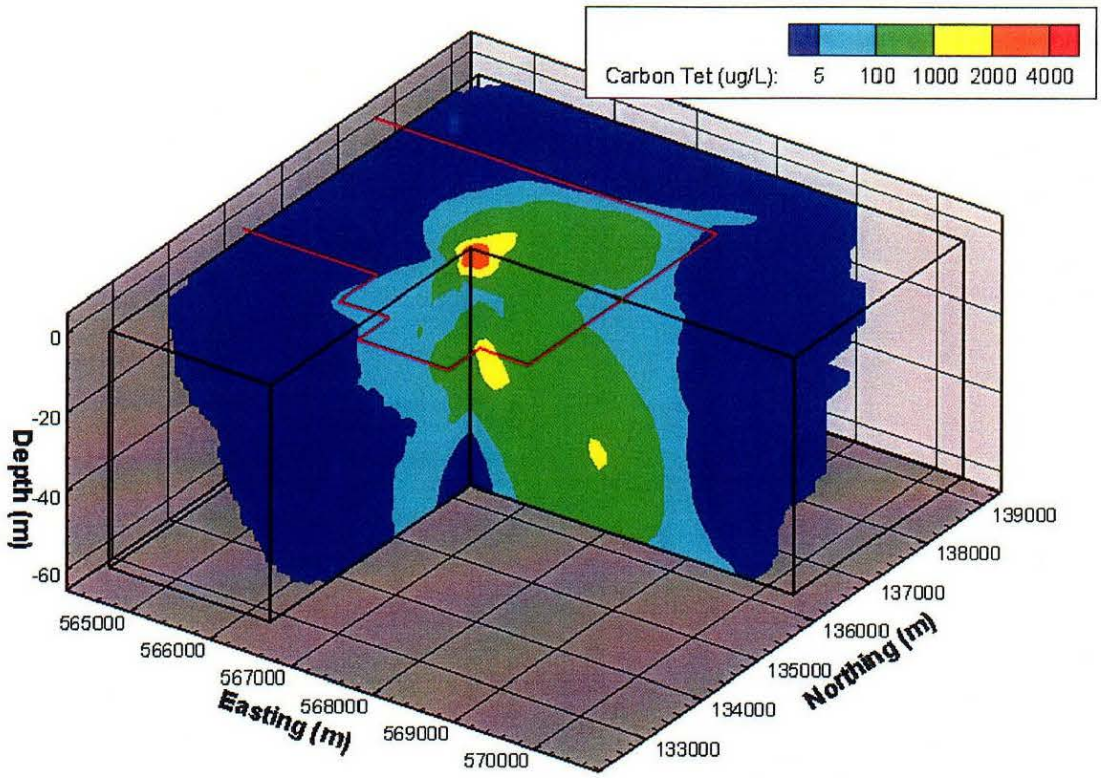
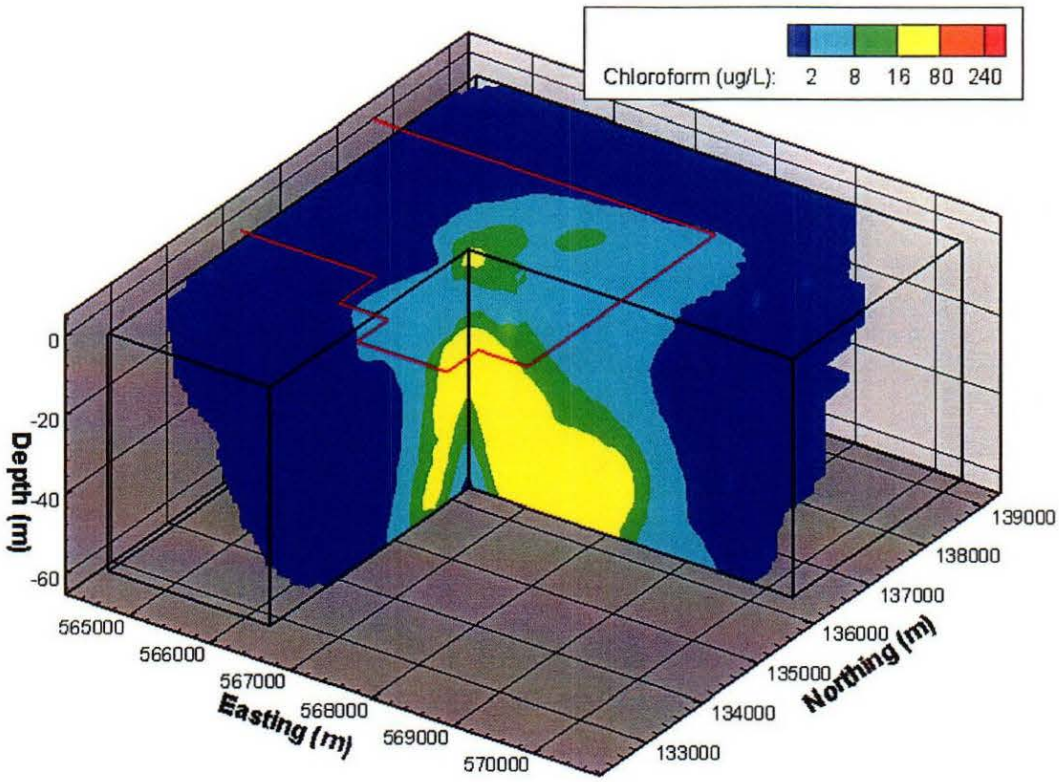


Figure 3-6. Cutaway Three-Dimensional Visualization Illustrating Median Carbon Tetrachloride Concentrations Through Main Area of the Carbon Tetrachloride Plume.[a]



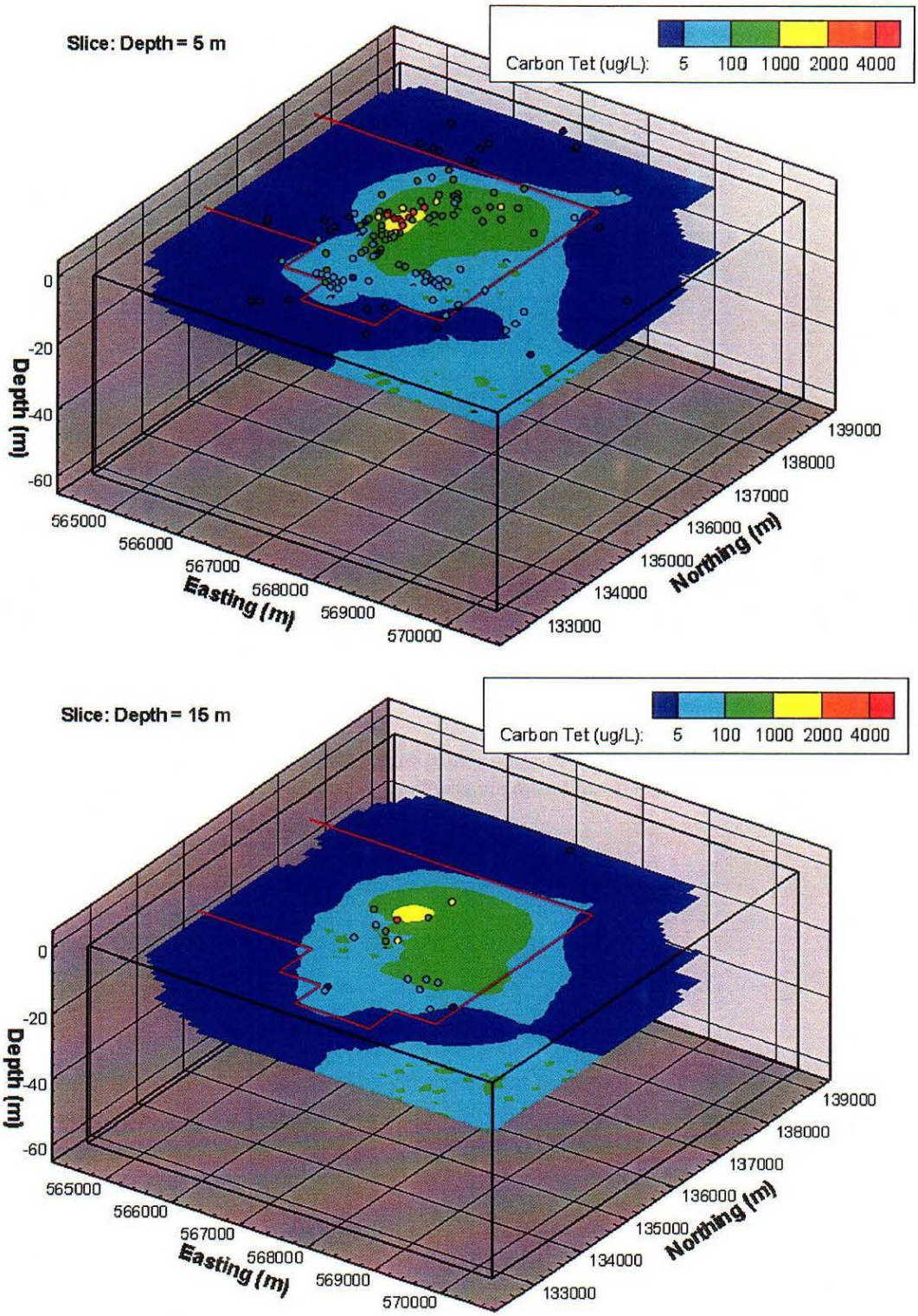
[a] Cutaway at easting from 566500 to 570500 m and northing from 132500 to 136000 m. Note large vertical exaggeration of approximately 50:1) (from Murray et al. 2006).

Figure 3-7. Cutaway Three-Dimensional Visualization Illustrating Median Chloroform Concentrations Through Main Area of the Carbon Tetrachloride Plume.[a]



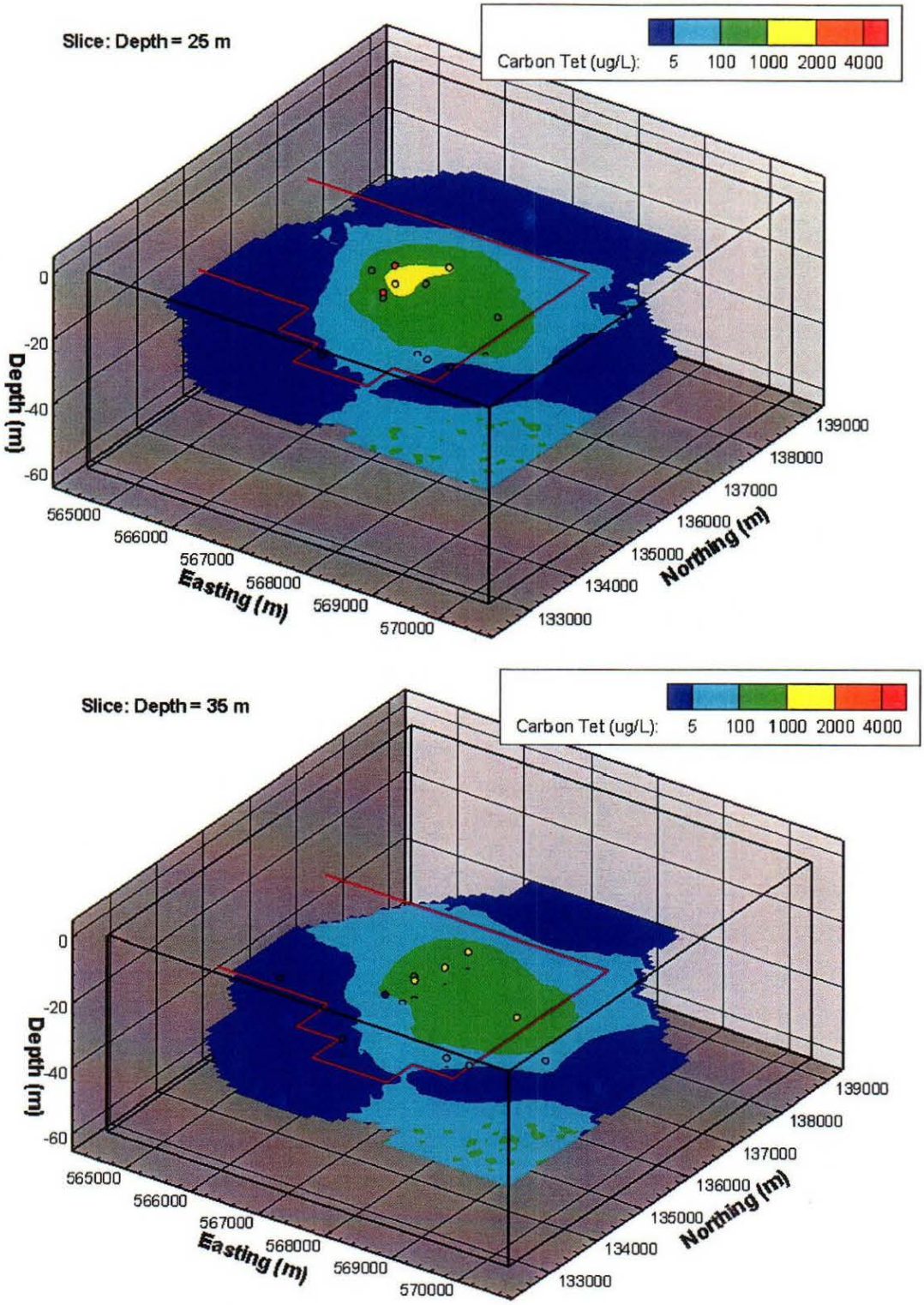
[a] Cutaway at easting from 566500 to 570500 m and northing from 132500 to 136000 m. Note large vertical exaggeration of approximately 50:1) (from Murray et al. 2006).

Figure 3-8. Horizontal Slices of Simulated Median Concentrations of Carbon Tetrachloride at Depths of 5 m and 15 m.[a]



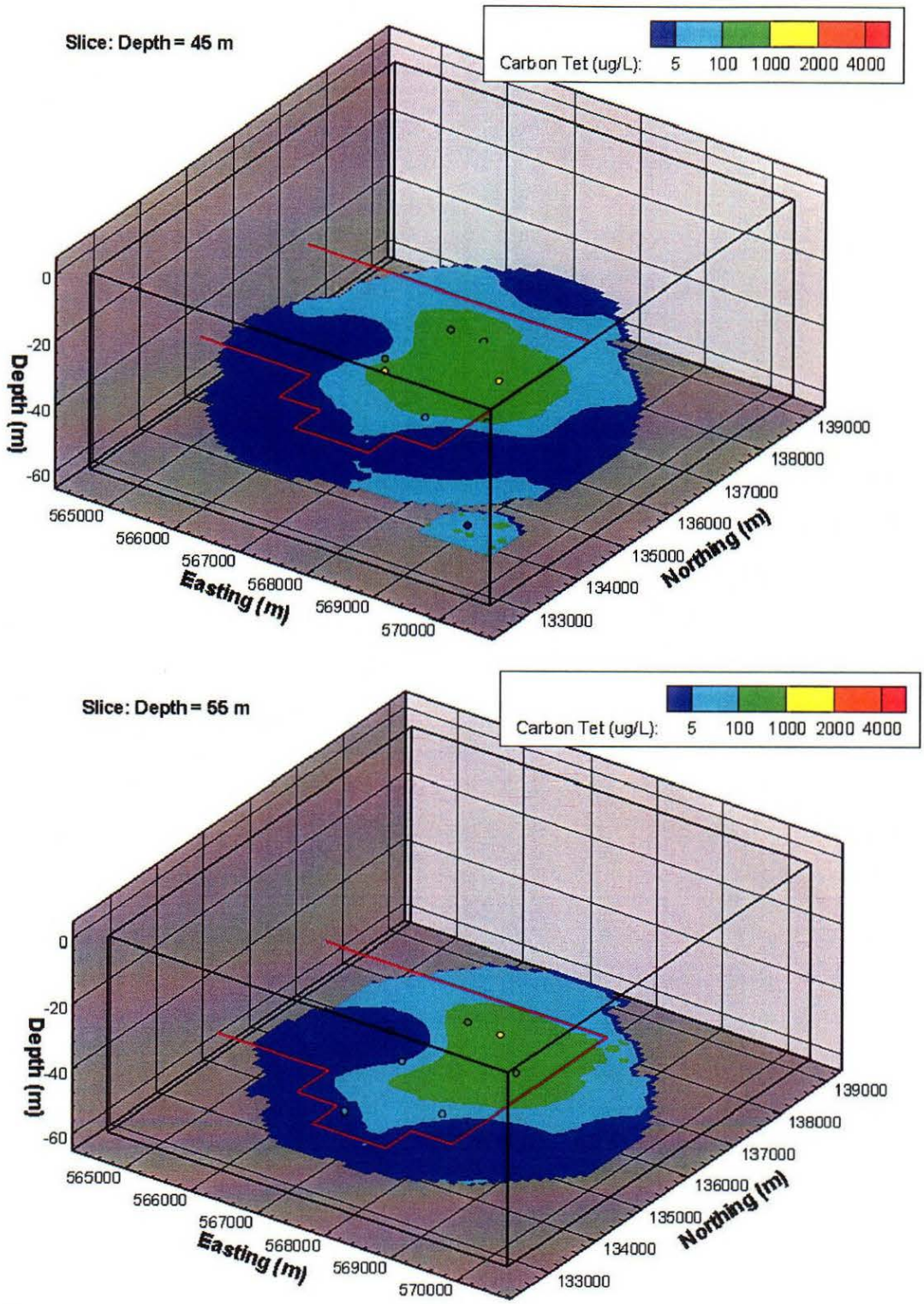
[a] From Murray et al. 2006.

Figure 3-9. Horizontal Slices of Simulated Median Concentrations of Carbon Tetrachloride at Depth of 25 m and 35 m.[a]



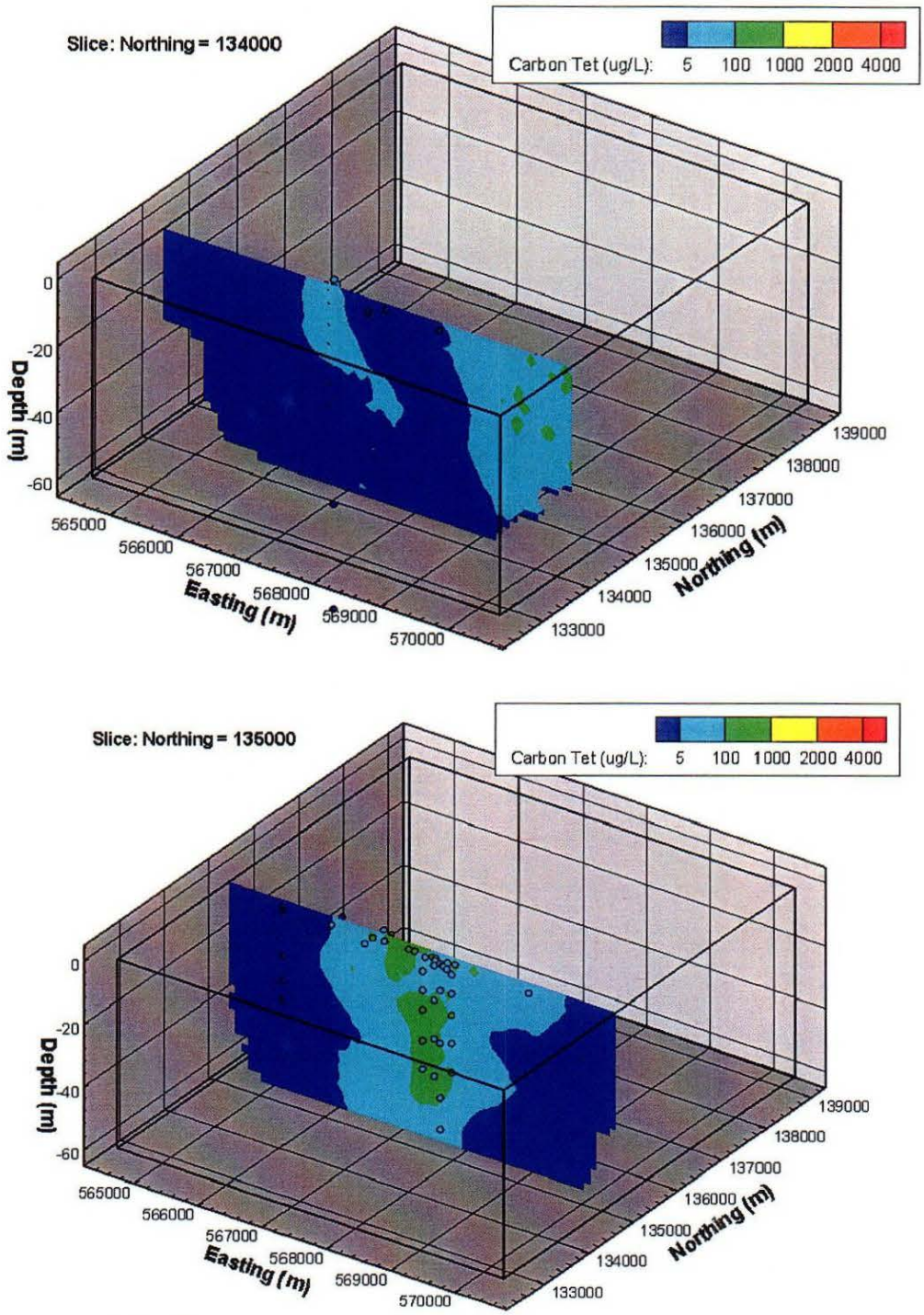
[a] From Murray et al. 2006.

Figure 3-10. Horizontal Slices of Simulated Median Concentrations of Carbon Tetrachloride at Depths of 45 m and 55 m.



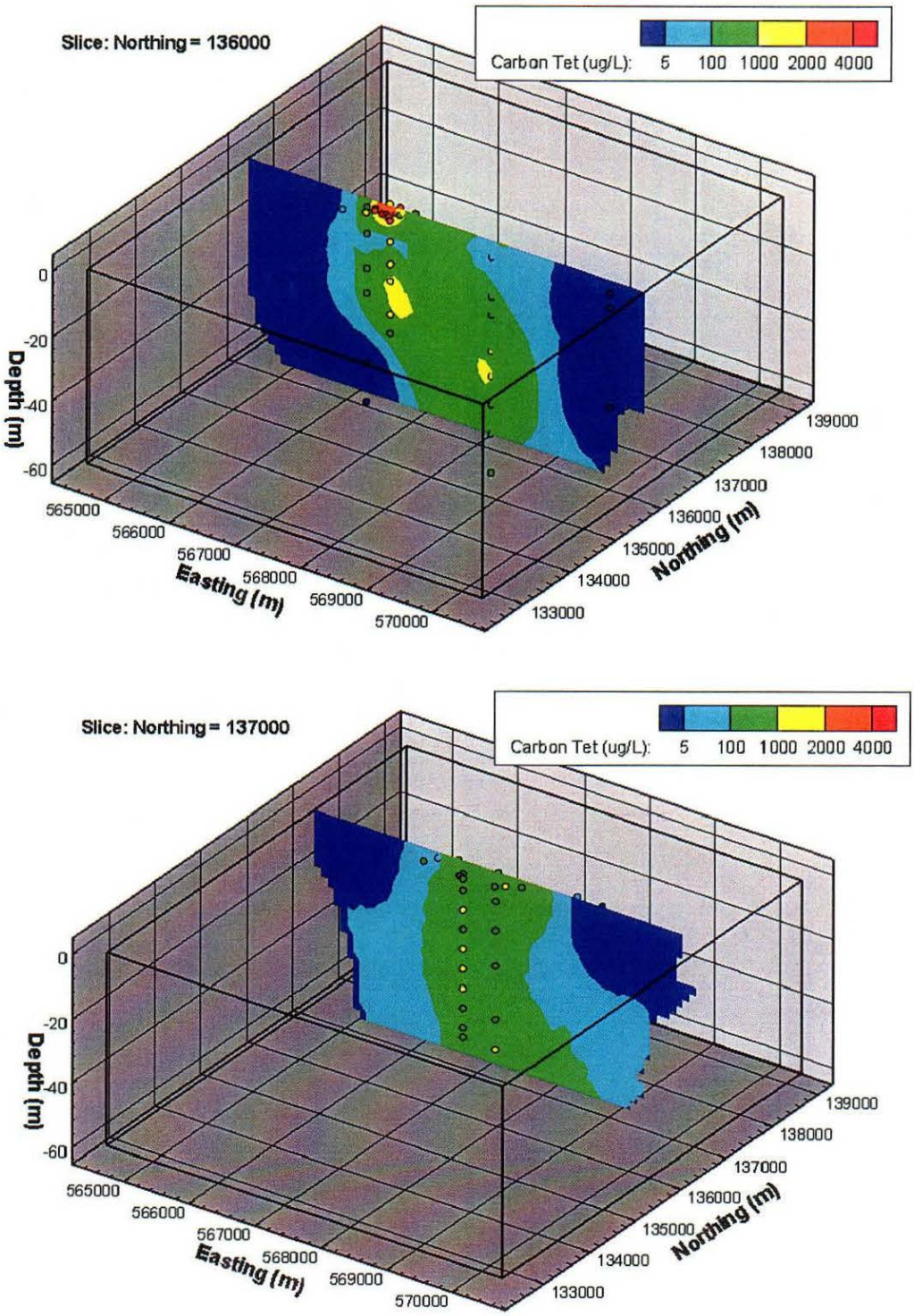
[a] From Murray et al. 2006.

Figure 3-11. Vertical Slices of Simulated Median Concentrations of Carbon Tetrachloride at Northing of 134000 m and 135000 m.[a]



[a] From Murray et al. 2006.

Figure 3-12. Vertical Slices of Simulated Median Concentrations of Carbon Tetrachloride at Northing of 134000 m and 135000 m.[a]



[a] From Murray et al. 2006.

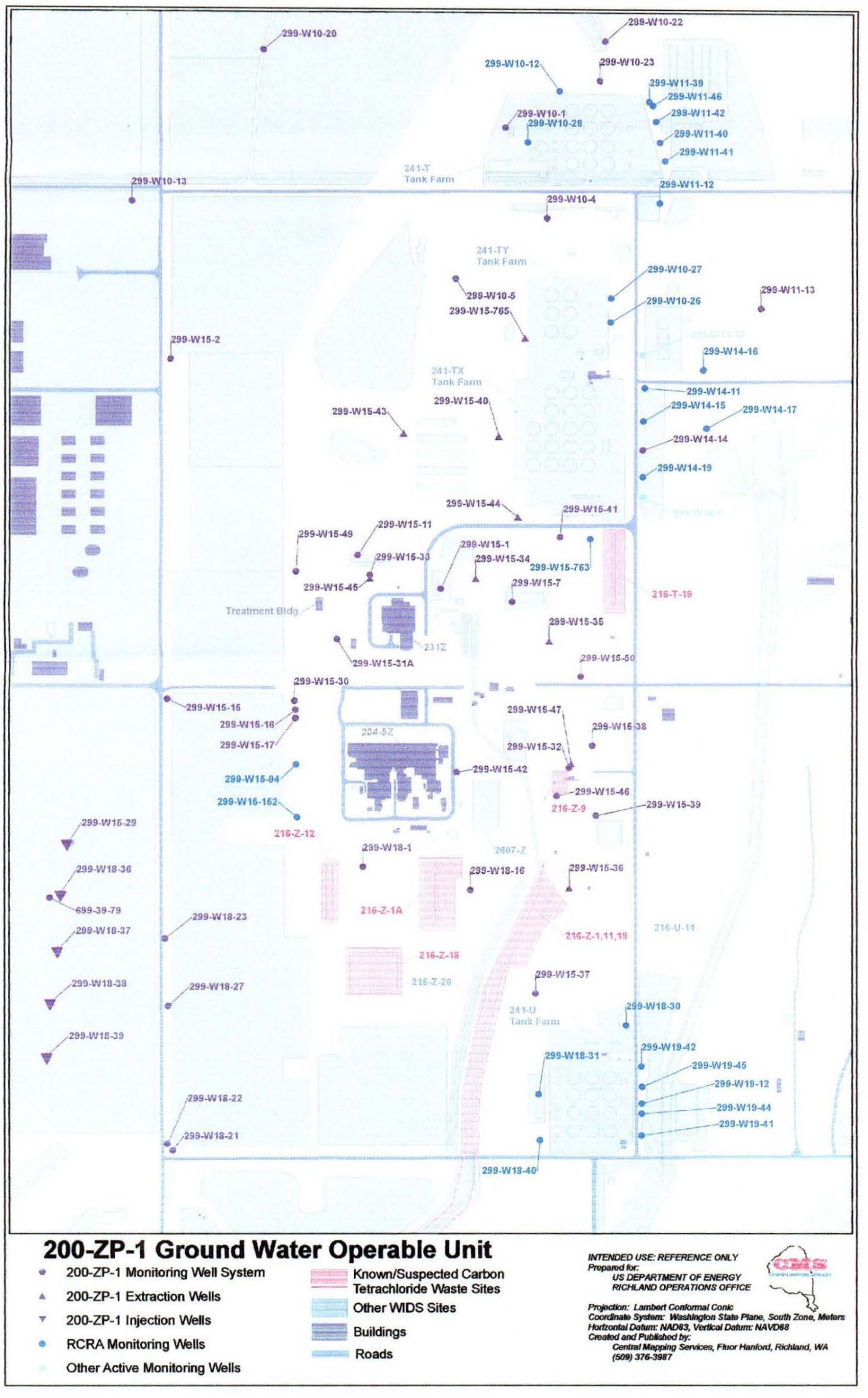
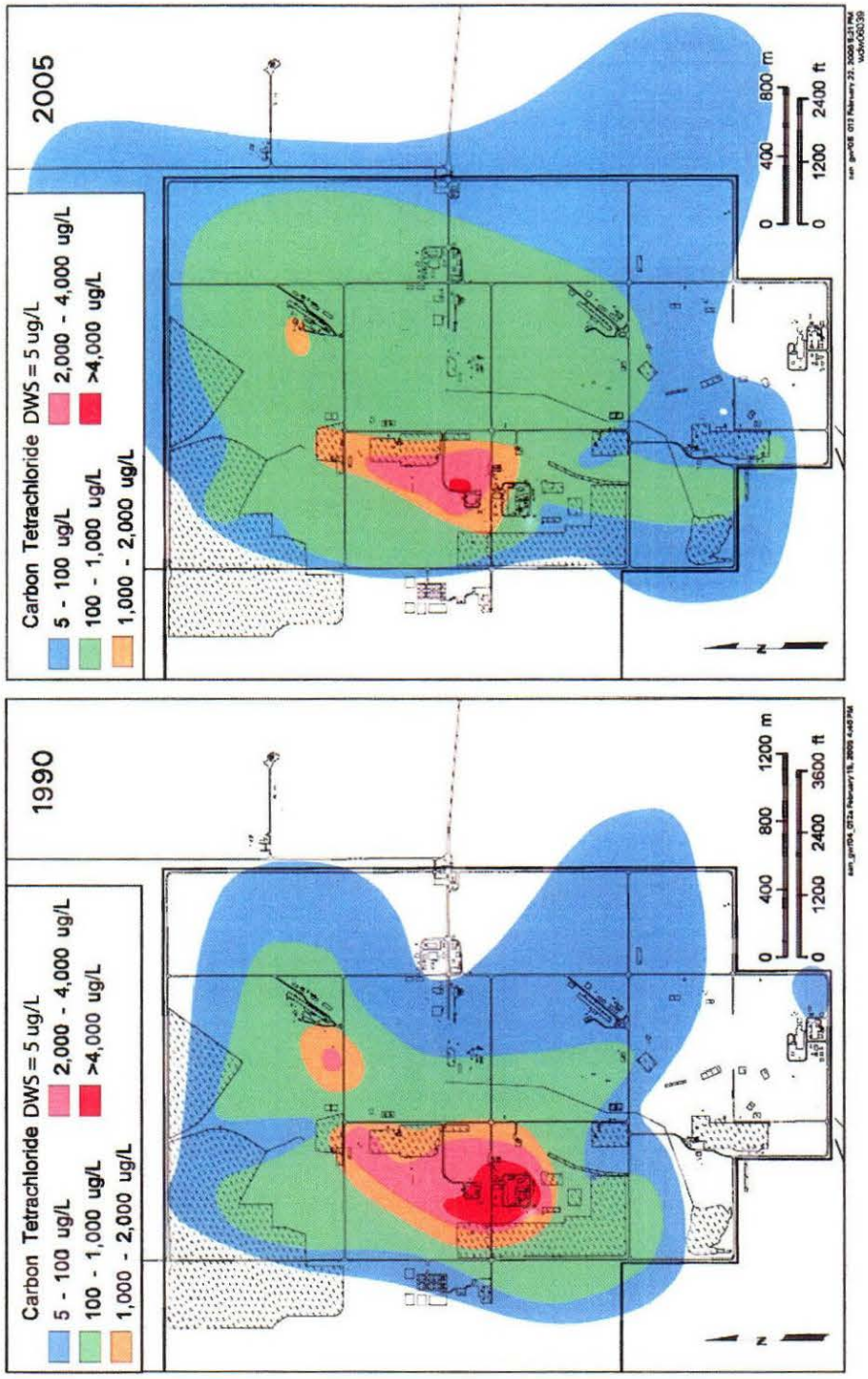


Figure 3-13. Map of Pump-and-Treat System Well Locations.

Figure 3-14. Comparison of the Carbon Tetrachloride Plume Beneath the 200 West Area at the Top of the Unconfined Aquifer.[a]



[a] From PNNL 2006.

Table 3-1. Partition Coefficients from Well 299-W15-46 Samples.[a]

Chemical	Partition Coefficient (L/kg)
Carbon tetrachloride	0.106 to 0.367
Chloroform	0.084 to 0.432

[a] From Riley et al. 2005.

Table 3-2. Waste Sites in the Vadose Zone Above the 200-ZP-1 Groundwater Operable Unit and Representative Sites That Were Directly Sampled.

Analogous Waste Sites in Vadose Zone Above 200-ZP-1 Groundwater OU	Representative Waste Sites[a]	OUs in Remedial Investigation Report
216-T-18 Crib	216-T-26 Crib	200-TW-1, 200-TW-2, and 200-PW-5 OUs
216-T-3 injection/reverse well, 216-T-5 Trench, 216-T-6 Crib, 216-T-7 Crib, 216-T-32 Crib, and 241-T-361 settling tank	216-B-7A and 216-B-7B Cribs	200-TW-1, 200-TW-2, and 200-PW-5 OUs
216-T-14, 216-T-15, 216-T-17, 216-T-21, 216-T-22, 216-T-23, 216-T-24, and 216-T-25 Trenches	216-B-38 Trench	200-TW-1, 200-TW-2, and 200-PW-5 OUs
216-T-20 Crib	216-A-10 Crib, 216-A-19 Trench, 216-A-36B Crib, 216-A-37-1 Crib, 216-B-12 Crib, and 207-A south retention basin	200-PW-2 and 200-PW-4 OUs
216-T-19, 216-Z-1&2, 216-Z-3, 216-Z-12, 216-Z-18, UPR-200-W-103, 216-Z-10 injection/reverse well, 216-Z-4 Trench, 216-Z-5 Crib, 216-Z-6 Crib, 216-Z-8 french drain, UPR-200-W-130, 241-Z-8 settling tank, and 231-W-151 receiving vault[b]	216-Z-1A Tile Field, 216-Z-9 Trench and 241-Z-361 settling tank[b]	200-PW-1 and 200-PW-6 OUs

[a] As reported in DOE-RL (2003c, 2005e).
[b] As reported in DOE-RL (2004b), Tables 2-1 and 2-3.
OU = operable unit

Table 3-3. Contaminants of Concern with Potential to Impact Groundwater for Waste Sites Above the 200-ZP-1 Operable Unit.

COC	216-T-20 Crib	216-T-26 and 216-T-18 Cribs	216-T-5 Trench, 216-T-6 Crib, 216-T-7 Crib, 216-T-32 Crib, and 241-T-361 Settling Tank	216-T-14, 216-T-15, 216-T-17, 216-T-21, 216-T-22, 216-T-23, 216-T-24, and 216-T-25 Trenches	216-Z-9 Trench
Tritium	X[a]	–	–	–	X[b]
Tc-99	X[a]	X[c]	X[d]	X[d]	X[b]
I-129	X[a]	–	–	–	X[b]
U-233/234	–	X[c]	X[d]	X[c]	X[b]
U-238	–	X[c]	X[d]	X[c]	X[b]
Pu-239	–	X[c]	–	–	X[b]
Aluminum	X[e]	–	–	–	–
Arsenic	X[e]	–	–	–	X[b]
Chromium (III)	–	X[f]	–	–	X[b]
Cyanide	–	X[f], X[c]	–	–	–
Fluoride	–	X[c]	X[f], X[c]	X[f]	X[b]
Iron	–	–	X[f]	–	–
Manganese	X[e]	–	X[f]	–	–
Nitrate	X[e]	X[f], X[c]	X[f], X[c]	X[f], X[c]	X[b]
Nitrite	X[e]	X[f], X[c]	–	X[f], X[c]	X[b]
Uranium (total)	X[a]	X[f]	X[f]	X[f]	–
B-BHC	X[a,g]	–	–	–	–
Isophorone	X[a,g]	–	–	–	–
Methylene chloride	X[a,g]	–	–	–	X[b]
Pentachloro-phenol	X[a,g]	–	–	–	–
Tributyl phosphate	X[e]	–	–	–	X[b]
Carbon tetrachloride	–	–	–	–	X[b]

[a] Breakthrough concentrations to groundwater above screening criteria (EPA-based MCLs) within 1,000 years as modeled by RESRAD and reported in DOE-RL (2005e).
[b] Source: Appendix B of *Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit Representative Sites Sampling and Analysis Plan* (DOE-RL 2004b).
[c] Breakthrough concentrations to groundwater above screening criteria (EPA-based MCLs) within 1,000 years as modeled by STOMP and reported in DOE-RL (2003c).
[d] Breakthrough concentrations to groundwater at total dose of above 10^{-6} mrem/yr as modeled by RESRAD and reported in DOE-RL (2003c).
[e] Exceeded WAC 173-340-747(4) screening criteria, as reported in DOE-RL (2005e).
[f] Exceeded WAC 173-340-747(4) screening criteria, as reported in DOE-RL (2003c).
[g] The remedial investigation report (DOE-RL 2005e) indicates that this compound is not a likely groundwater contaminant because it is a probable analytical artifact or a single detection of the substance.

COC = contaminant of concern
EPA = U.S. Environmental Protection Agency
MCL = maximum contaminant level
RESRAD = REsidual RADioactivity (dose model)
STOMP = Subsurface Transport Over Multiple Phases
WAC = *Washington Administrative Code*

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4.0 REMEDIAL INVESTIGATION RESULTS

4.1 HYDROGEOLOGIC FRAMEWORK

4.1.1 Topography

The 200-ZP-1 OU is located on the 200 Area Plateau in the Pasco Basin of the Columbia Plateau. The term "200 Area Plateau" is commonly used to describe the Cold Creek bar that was formed during the last cataclysmic flood from glacial Lake Missoula about 13,000 years ago, as shown in Figure 4-1. The cataclysmic floodwaters that deposited sediments of the Hanford formation also locally reshaped the topography of the Pasco Basin. The floodwaters deposited the thick sand and gravel deposits of the Cold Creek bar and, in the waning stages, the floodwaters eroded a channel between the 200 Areas and Gable Mountain. Most of the 200 West Area is situated on the Cold Creek bar on the southern edge of this flood channel. Figure 4-1 also shows a secondary flood channel that runs south from the main channel and bisects the 200 West Area.

The 200 Area Plateau trends generally east-west, with elevations ranging between 198 and 230 m (650 to 755 ft) above mean sea level. The plateau drops off rather steeply to the north and northwest and decreases more gently in elevation to the south into the Cold Creek Valley and to the east toward the Columbia River. Plateau escarpments have elevation changes of between 15 to 30 m (50 to 100 ft). The *200 Areas RI/FS Implementation Plan* (DOE-RL 1999, Appendix F) provides more detail on the physical setting of the 200 Areas and vicinity.

4.1.2 Geology

The 200-ZP-1 OU is located in the Pasco Basin, one of several structural and topographic basins of the Columbia Plateau. Basalts of the Columbia River Basalt Group and a sequence of suprabasalt sediments underlie the 200-ZP-1 OU. From oldest to youngest, the major geologic units of interest are the Elephant Mountain Member of the Columbia River Basalt Group, the Ringold Formation, the Cold Creek unit, the Hanford formation, and surficial deposits. Figure 4-2 provides a generalized stratigraphic column for the 200 West Area. The lithology encountered during drilling for wells 299-W15-46 and 299-W15-49 is summarized in Tables 4-1 and 4-2 and in Section 4.6.1.1.2. Table 4-3 lists references for lithologic descriptions from other 200-ZP-1 wells. The following subsections provide summary descriptions of the major geologic units that comprise the water table aquifer and vadose sediments in this area.

4.1.2.1 Elephant Mountain Member. The Elephant Mountain Member is the uppermost basalt unit (i.e., bedrock) in the OU. Except for the Gable Gap area (between Gable Butte and Gable Mountain) where it has been eroded away, the Elephant Mountain Member is laterally continuous throughout the area around the OU and is approximately 18 to 36 m (59 to 118 ft) thick. The basalt is overlain by the Ringold Formation, except in the Gable Gap area, where the basalt is directly overlain by the Hanford formation (Williams et al. 2000).

4.1.2.2 Ringold Formation. The Ringold Formation consists of an interstratified fluvial-lacustrine sequence of unconsolidated to semi-consolidated clay, silt, sand, and granule-to-cobble-size gravel deposited by the ancestral Columbia River. These sediments consist of the following four major hydrostratigraphic units (from oldest to youngest, as shown in Figure 4-2): the fluvial gravel and sand of Unit 9 (basal coarse); the buried soil horizons, overbank, and lake

deposits of Unit 8 (Lower Mud Unit); the fluvial sand and gravel of Unit 5 (upper coarse); and the lacustrine mud of Unit 4 (upper fines). Units 9 and 5 consist of silty-sandy gravel with secondary lenses and interbeds of gravelly sand, sand, and muddy sand to silt and clay. Unit 8 (Lower Mud Unit) consists mainly of silt and clay. Unit 4 (upper fines) consists of silty over-bank deposits and fluvial sand. Units 6 and 7 are not present within the 200 West and 200 East Areas (Williams et al. 2000, 2002). The Ringold Formation is overlain by the Cold Creek unit in the 200 West Area.

4.1.2.3 Cold Creek Unit. The Cold Creek unit includes several post-Ringold Formation and pre-Hanford formation units present within the central Pasco Basin (DOE-RL 2002c). The Cold Creek unit includes the units formerly referred to as the Plio-Pleistocene unit, caliche, early Palouse soil, pre-Missoula gravels, and side-stream alluvial facies described in previous reports. The Cold Creek unit has been divided into five lithofacies: fine-grained, laminated to massive (fluvial-overbank and/or eolian deposits, formerly the early Palouse soil); fine- to coarse-grained, calcium-carbonate cemented (calcic paleosol, formerly the caliche); coarse-grained, multilithic (mainstream alluvium, formerly the pre-Missoula gravels); coarse-grained, angular, basaltic (colluvium); and coarse-grained, rounded, basaltic (side-stream alluvium, formerly side-stream alluvial facies) (DOE-RL 2002c). The Cold Creek unit beneath the 200 West Area includes the overbank/eolian, calcic paleosol, and side-stream alluvial facies (DOE-RL 2002c).

4.1.2.4 Hanford Formation. The Hanford formation is the informal stratigraphic name used to describe the Pleistocene cataclysmic flood deposits within the Pasco Basin. The Hanford formation consists predominantly of unconsolidated sediments that range from boulder-size gravel to sand, silty sand, and silt. Sediment sorting ranges from poorly sorted (for gravel facies) to well sorted (for fine sand and silt facies). The Hanford formation is divided into three main lithofacies: interbedded sand- to silt-dominated (formerly Touchet beds or slackwater facies), sand-dominated (formerly sand-dominated flood facies), and gravel-dominated (formerly Pasco gravels) that have been further subdivided into 11 textural-structural lithofacies (DOE-RL 2002c). The gravel-dominated facies are cross-stratified, coarse-grained sands and granule- to boulder-sized 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 the sand. Where the silt content is low, an open-framework texture is common. Clastic dikes are common in the Hanford formation but rare in the Ringold Formation (DOE-RL 2002c). They appear as vertical to subvertical sediment-filled structures, especially within sand- and silt-dominated units. The Hanford formation is locally overlain by veneers of surficial deposits.

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

4.1.3 Hydrogeology

The hydrogeology of the 200-ZP-1 OU is presented in the hydrogeologic location map and cross-sections in Figures 4-3, 4-4, and 4-5 and is summarized in the following subsections.

4.1.3.1 Vadose Zone. In the 200 West Area, the vadose zone thickness ranges from about 48 m (157 ft) in the Cold Creek Valley area to about 100 m (328 ft) in the northwest corner. Sediments in the vadose zone include the Ringold Formation, the Cold Creek unit, and the Hanford formation. Erosion during cataclysmic flooding removed some of the Ringold Formation and the Cold Creek unit north of the 200 West Area. Perched water has historically been documented above the Cold Creek unit at locations in the 200 West Area. Because liquid waste discharges to the surface ceased in the late 1980s, most of this perched water has drained away and is now infrequently encountered during drilling.

Recharge to the unconfined aquifer is from artificial and possibly natural sources. Any natural recharge originates from precipitation. Estimates of recharge from precipitation range from 0 to 10 cm/yr (0 to 4 in/yr) and are largely dependent on soil texture and the type and density of vegetation. Artificial recharge occurred when effluent such as cooling water and liquid wastes from Hanford process operations were disposed to the ground. Non-permitted sources of artificial recharge have been halted. Drainage from past artificial recharge that remains within the vadose zone is a primary driving force for contaminant migration to groundwater. As the vadose zone moisture conditions return to the pre-disposal conditions, the potential for recharge from precipitation will become the primary driving force for any contaminant movement in the vadose zone.

4.1.3.2 Groundwater. The unconfined aquifer in the 200-ZP-1 OU occurs primarily within the Unit 5 gravels of the Ringold Formation. The depth to the water table varies from about 50 m (164 ft) bgs just south of the OU near 216-U-10 Pond to greater than 100 m (328 ft) bgs in the north. Groundwater in the unconfined aquifer flows from areas where the water table is higher (i.e., west of the Hanford Site) to lower areas near the Columbia River (Figure 4-6). In general, groundwater flow through the 200 Area Plateau occurs in a predominantly easterly direction, from the 200 West Area to the 200 East Area; from there it flows east to southeast to discharge into the Columbia River. Groundwater in the northern 200 West Area flows predominantly to the east-northeast but is locally influenced by the 200-ZP-1 groundwater pump-and-treat system in the southern portion of the OU and effluent discharges to the SALDS in the northern portion of the OU.

Flow in the central portion of the 200 West Area (i.e., southern portion of the 200-ZP-1 OU) is influenced by the operation of the 200-ZP-1 pump-and-treat system. This system extracts water from the vicinity of the 216-Z Cribs and Trenches and west of the TX-TY Tank Farms, treats the water to remove carbon tetrachloride (and other VOCs), and then reinjects the water into the aquifer to the west of the area. A small groundwater mound is associated with the injection wells and a region of drawdown is associated with the extraction wells, causing flow to converge on the extraction zone from all directions. These flow conditions are expected to continue until the end of the pump-and-treat program, at which time the flow direction will resume a west-to-east pattern.

Historical wastewater discharges greatly altered the groundwater flow regime, especially around 216-U-10 (i.e., U Pond) and the 216-T Pond system in the 200 West Area and 216-B-3 (i.e., B Pond) in the 200 East Area. Discharges to 216-U-10 Pond resulted in a groundwater mound developing in excess of 26 m (85 ft).

Pre-Hanford Site (circa 1942) groundwater flow direction was toward the east (Kipp and Mudd 1974). Groundwater flow had changed toward the south in the area by the early 1950s as a result

of the disposal of large volumes of liquid to the 216-T Pond system (Horton 2005). In 1956, groundwater flow direction changed again and started flowing towards the northeast due to the increasing influence of the groundwater mound under 216-U Pond and a decreasing influence of the mound under 216-T Pond. Discharges to 216-T Pond ended in 1976 but continued at 216-U Pond until 1984. As discharges to the 216-U Pond declined in the early 1980s, groundwater flow shifted to a more northward direction as the groundwater mound began to decrease and discharges to the 216-U-14 Ditch continued. All non-permitted discharges to the ground ceased and the influence of the 216-U Pond mound on the groundwater beneath the 200 West Area diminished until 1995. Since the elimination of artificial recharge to groundwater at the Hanford Site in 1995, the water table elevation has been steadily declining. From March 2003 to March 2004, the water table elevation in the 200 West Area declined by an average of 0.21 m (0.69 ft) (PNNL 2005a). The flow direction changed again in about 1996 and began to return toward an eastward direction where it is expected to stabilize (Horton 2005).

Discharges to B Pond in the 200 East Area created a hydraulic barrier to groundwater flow coming from the 200 West Area, deflecting it either northward through the northern 200 Areas and through Gable Gap, between Gable Mountain and Gable Butte, or to the south of B Pond. As the hydraulic effects of these discharge sites diminish, groundwater flow is expected to acquire a more easterly course through the 200 Areas, with some flow possibly continuing through Gable Gap (BHI 1997b).

Average linear groundwater flow velocities are calculated and reported annually for RCRA facilities within the 200-ZP-1 OU area (PNNL 2005a). Calculated hydraulic gradients between monitoring wells are generally in the range of 0.001 to 0.002. These low gradients produce estimated low groundwater flow rates that range from 0.0001 to 0.2 m/day (0.00033 to 0.656 ft/day) at LLWMA-3 in the northern portion of the OU; 0.017 to 0.28 m/day (0.0558 to 0.919 ft/day) at WMA-T, also in the northern portion of the OU; generally less than 0.1 and up to 2.46 m/day (0.1831 to 8.07 ft/day) at WMA-TX/TY in the central portion of the OU; and from 0.02 to 0.5 m/day (0.0656 to 1.64 ft/day) at LLWMA-4 in the southern portion of the OU.

The unconfined aquifer is separated from the lower confined Ringold Formation aquifer (Unit 9) by the Ringold Lower Mud Unit (Unit 8). The Ringold Lower Mud Unit is present throughout most of the 200 West Area, except along the northern edge where it pinches out or has been eroded. Limited information is available for the confined Ringold aquifer and deeper confined zones within the basalts. Although regionally flow is from west to east, there are few wells completed in the confined Ringold aquifer to support analysis of flow directions in that unit beneath the 200 West Area (Williams et al. 2002).

4.2 CONTAMINANTS OF CONCERN EVALUATION

Section 1.4.1 describes the logic for evaluation of the eight major plumes for the Group A analytes (i.e., chromium, carbon tetrachloride, iodine-129, nitrate, technetium-99, TCE, tritium, and radioactive/total uranium) and the Group B analytes identified in Table 1-5. The purpose of the evaluation is to assess the COCs needing risk assessment in the FS. No groundwater plumes are currently mapped for Group B COCs because they have either not been detected in the past or were detected only in low concentrations. The following subsections discuss the data preparation and the results of the evaluation.

4.2.1 Data Consolidation

Groundwater monitoring of wells that are now in the 200-ZP-1 OU was conducted at least as far back as the year 1955. The analytical data for these samples and their associated field quality control (QC) samples are maintained in the HEIS database. Data were initially consolidated from the wells listed in Table 1-2, which includes the wells listed in Table A3-2 of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) and data from wells that were documented as being part of the plumes.

Methods used to analyze data from very early groundwater monitoring results (1955 through 1987) were not well documented and detection/reporting limits were also not well documented. Since 1988, the groundwater program has consolidated data in annual groundwater reports. From 1988 through 1995, two reports were generated each year to summarize the data. From 1996 to the present, one report per year summarizes the groundwater data and the QC evaluation. The most recent of these reports is *Hanford Site Groundwater Monitoring for Fiscal Year 2005* (PNNL 2006). These reports are referred to as "annual groundwater reports." Based on improved documentation of the analytical methods and QC since 1988, data from 1988 to the present were used to support the assessment of the 200-ZP-1 OU groundwater plumes:

- Data listed below were not included in the logic used for selection of the COCs that drive risk. These were not included because there were concerns related to the quantitation and reporting limits.
- Data rejected by either the validator/reviewer or the laboratory.
- Data from samples collected prior to January 1, 1988.
- Data reported with a "null" were removed because they contained no results.
- Nonradioactive constituent data reported as "zero" are without reporting limit or detection limit.

Laboratory results were used in the COC evaluation. Field screening data were not used in the risk evaluation. The depth-discrete data augment the COC risk evaluation with respect to the location in the aquifer; however, the depth-discrete data were not used in the risk evaluation. Note that carbon tetrachloride and technetium-99 remained as COCs for future risk even without the use of the depth-discrete data.

Nondetect data for nonradioactive constituents are required to be reported with the reporting limits; therefore, analytical results reported as "zero" were reported incorrectly. There were 227 nonradioactive analyses with a value reported of "zero." This corresponds to a rate of 0.18%. These "zero" results were excluded from the calculations until such time as data may be obtained that reflect the real detection limits. Results from radiochemical analyses reported as "zero" were not excluded because there is a real potential for radiochemical analyses to be "zero" based on the counting error. A list of these results is on file with the project.

Data for many analytes were reported under various names or synonyms. Queries were initiated to produce a single set of nomenclature based on the Chemical Abstract Services (CAS) numbers. Units were made consistent for a given analyte and nitrate-containing analyses were normalized to "as nitrogen" results.

Appendix E includes an electronic copy of all of the data. Appendix F includes the data set used after the data screening was completed (as described in the previous paragraphs). There are thousands of data points; thus, printing the files is not feasible. All data for each analyte and each well from 1955 to the present are included as electronic copies of trend plots in Appendix G. Trend plots show the date on the X-axis and the concentration on the Y-axis. Note that the trend plots include data from 1955 to the present. When reviewing the trend plots, it is important to note that only data from 1988 to the present were evaluated using the COC logic.

Before the data were evaluated, original samples were tied to duplicates or splits. In many cases, the HEIS data already connected samples; however, in other cases, samples were matched by comparing the sampling dates and requested analyses. An "FD" was placed in the database to signify "field duplicate" and to ensure a connection between the real sample and the duplicate. Appendix H presents the data quality assessment (DQA). The DQA focused on the field QC samples, and the annual groundwater reports consider both the laboratory and field QC. The DQA evaluated field duplicates, equipment blanks, trip blanks, and field transfer blanks. The DQA summarizes the data that are useable for the intended purpose, as well as limitations on the data. Additional detailed laboratory QC reviews are presented in the appendices of the annual groundwater reports and include assessment of method blanks, matrix spikes, and other batch-specific laboratory QC.

The original PRG in the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) for total uranium was not based on the radioactive uranium. Data for uranium were mixed, some reported in "µg/L" and some in "pCi/L." In order to assess both radioactive and total results, the following approach was used to compare results against the PRG: for the radioactive uranium, EPA has promulgated a drinking water MCL of 30 µg/L for total uranium (40 CFR 141.66). Based on the isotopic distribution of uranium on the Hanford Site, the 30 µg/L corresponds to 21.2 pCi/L. The value was rounded down for the PRG. Mass concentration to activity calculations are documented in *Calculation of Total Uranium Activity Corresponding to a Maximum Concentration Level for Uranium of 30 Micrograms per Liter in Groundwater* (BHI 2001a).

Appendix I presents summary data from each query used in the COC evaluation logic, and Appendix J presents electronic copies of the detailed sample data from each query for the COC evaluation. Appendix K presents a summary of minimum and maximum detections and nondetects.

4.2.2 Results of Evaluation of Group A Analytes

The wells under the Group A heading in Table 1-2 are those assessed using the logic in Figure 1-3. For each of the eight major analytes, at least one sample result exceeded two times the PRG; therefore, no further analyses were required for the COCs. In other words, since the answer to question A-1 in Figure 1-3 is "yes" for all eight analytes, no subsequent questions apply. All of these COCs are recommended for evaluation in the baseline risk assessment. For informational purposes, Table 4-4 presents a list for each of the eight analytes, the number of wells and number of samples greater than two times the PRG, and the PRG from Table 1-5. The selected limit in Table 1-5 is the PRG or action limit. The source column in Table 1-5 provides the basis of the PRG, as previously detailed in the 200-ZP-1 RI/FS work plan (DOE-RL 2004c). The detailed tables supporting Table 4-4 are provided in Appendices I and J. Appendices I and J do not contain data from "A-1, no" because all analytes are recommended for baseline risk assessment in the FS.

4.2.3 Results of Evaluation of Group B Analytes

The Group B COCs include those discussed in Section 5.1.3 of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) and listed in Table 1-5 that were also detected in the wells listed in Table 1-2. All of the wells listed in Table 1-2 were used for this evaluation. The steps used in the evaluation are discussed in Section 1.4.1.2, and the outcome of the evaluation is presented here step-by-step. The question numbers from Figure 1-4 are shown below in brackets:

1. The following analytes were not detected. These analytes are removed from further consideration in the risk assessment [B-0, yes]:

   - Chlorobenzene
   - n-butylbenzene
   - Nitrogen in ammonia
   - Protactinium-231
   - Selenium-79
   - Total petroleum hydrocarbons – kerosene range
   - Total phenols.

   The analytes that were detected [B-0, no] were carried to the next question for evaluation.

2. The following analytes are detected, but no result exceeds the PRG. These analytes are removed from further consideration [B-1, yes]:

   - 2-butanone
   - Acetone
   - Carbon disulfide
   - Carbon-14
   - Cesium-137
   - Ethylbenzene
   - Lithium
   - Magnesium
   - Mercury
   - Neptunium-237
   - Nitrogen in ammonium
   - Nitrogen in nitrite and nitrate (Note that one laboratory analytical method is used to analyze nitrite and nitrate together; thus, these results cannot be separated. However, the combined total result in no case exceeded the PRG for nitrogen in nitrite [1,000 µL], which is the lower of the two.)
   - Phosphate
   - Strontium-90
   - Toluene
   - Total cresols
   - Xylenes (total).

   The analytes that were detected [B-1, no] were carried to the next question for evaluation.

3. The remaining list was evaluated for common laboratory contaminants [B-2, yes]. The only common laboratory contaminant detected is methylene chloride. Of the 1,643 methylene chloride measurements, 30% were detects. The field, trip, equipment, and transfer blanks for methylene chloride were evaluated in the DQA (Appendix H). One of the four detects in the field blanks was below the PRG and the other three were at or above the PRG. Given the large number of detects that are well above the PRG, the analyte is carried forward. Other analytes discussed in the field blank evaluations were either from Group A or were all nondetects or were not common laboratory contaminants.

   The only way to evaluate the method blanks for this extensive list of measurements is to obtain the raw data packages, which is not feasible for this many results. Thus, the analysis logic as applied to method blanks could not be used. Several observations are presented:

   - A significant number of detections occurred.
   - Results ranged from nondetects to 4,100 μg/L.
   - Under aerobic conditions, methylene chloride is a degradation product of carbon tetrachloride, which is a Group A analyte that will be evaluated in the baseline risk assessment.

   Based on the above, it is recommended that the FS include additional evaluation of laboratory contaminants and degradation byproducts. The initial recommendation is to map the carbon tetrachloride degradation products in wells with high carbon tetrachloride levels. These degradation products include chloroform, chloromethane, and methylene chloride. Further evaluation will allow a determination as to whether the methylene chloride is a degradation product or laboratory artifact and whether it will be included in the baseline risk assessment.

   Analytes that are not common laboratory contaminants and have any detect above the PRG were carried forward for additional evaluation [B-2, no].

4. The analytes that are not common laboratory solvents, but were detected above the PRGs at a frequency of less than 10%, were evaluated statistically, as discussed in Section 1.4.1.2 [B-3, no]. Data from wells sampled from 1988 to 2005 for analytes falling into the "question B-3, no" logic category were analyzed and are summarized below. Table 4-5 presents summary statistics for the 18 analytes. Sample sizes and number of detects are presented first, followed by the detection frequency, minimum nondetect, maximum nondetect, minimum detect, median, mean, maximum detect, and standard deviation.

Table 4-6 presents other statistics, including the Shapiro Wilk p-value, "bootstrapped" UCL, PRG, and a comparison between the bootstrapped UCL and the PRG. The Shapiro Wilk p-value is used to evaluate the distributional form of the data. Because all of the Shapiro Wilk p-values are small, the normality assumption is rejected for all analytes. The nonparametric bootstrapped UCL is calculated and compared to the PRG (Davidson and Hinkley 1997, EPA 2002a).

Bootstrapping is a resampling technique that provides a nonparametric approach to calculating UCLs when strong distributional assumptions cannot be made about the data set of interest. In these instances, bootstrapping allows for UCLs on the mean to be calculated by using the data

itself to find the UCL. The 95% bootstrapped UCL for the mean is calculated by resampling the data 1,000 times and computing the mean for each of those 1,000 resamples. A resample consists of a random sample of the same size and taken with replacement from the original data set. The value of the UCL is then the 95th percentile of the distribution of the resampled means (Davidson and Hinkley 1997, EPA 2002a).

For statistical calculations, including the median, mean, standard deviation, Shapiro Wilk p-value, and bootstrapped UCL, the detection limit is used for values reported as nondetects. This approach produces conservative values for each of the statistical calculations performed and is consistent with that discussed in Section 1.4.1.2, step 5d.

Comparisons between the bootstrapped UCL and PRG show three (antimony, 1,2-dichloroethane, and tetrachloroethylene) of the 95% UCLs are larger than their respective PRGs. Based on this information, these three analytes will be recommended for further evaluation in the baseline risk assessment for human health.

Table 4-7 lists the analytes that are not common laboratory solvents and are detected above the PRGs at a frequency of more than 10%, along with the sample sizes, number of detects, the detection frequency, minimum nondetect, maximum nondetect, minimum detect, median, mean, maximum detect, and standard deviation [B-3, yes]. The following concerns must be noted:

- Under aerobic conditions, chloroform is also a degradation product of carbon tetrachloride, which is a Group A analyte that will be evaluated in the baseline risk assessment.
- Based on the above, it is recommended that additional evaluation be performed in the FS. The initial recommendation is to map the carbon tetrachloride degradation products in wells with high carbon tetrachloride levels. These degradation products include chloroform, chloromethane, and methylene chloride.
- The use of hexavalent chromium is well documented at Hanford, and PRGs for hexavalent chromium are much lower than the PRG for total chromium (i.e., see CLARC numbers used as PRGs in Table 1-5).

Additional statistical assessments were conducted on the Group B analytes, excluding the common laboratory contaminants, to better assess the distribution. This additional evaluation is beyond that agreed upon by RL and EPA, and is documented in an attachment to the October 2005 200 Area Unit Managers' Meeting minutes (FH 2005a); thus, it is not in Figure 1-4 for the Group B contaminants.

The same statistical approach that was used for the "B-3, no" analytes was also used on those that exceeded the PRG more than 10% of the time. Table 4-8 presents other statistics, including the Shapiro Wilk p-value, bootstrapped UCL, PRG, and a comparison between the bootstrapped UCL and the PRG. Because all of the Shapiro Wilk p-values are small, the normality assumption is rejected for all analytes. Therefore, the nonparametric bootstrapped UCL is calculated and compared to the PRG. For statistical calculations, including the median, mean, standard deviation, Shapiro Wilk p-value, and bootstrapped UCL, the detection limit is used for values reported as nondetects. This approach produces conservative values for each of the statistical calculations performed. Comparisons between the bootstrapped UCL and PRG show three of the 95% UCLs (hexavalent chromium, iron, and chloroform) are larger than their respective PRGs.

4.3 OPERABLE UNIT CONTAMINATION

The groundwater COCs described below and listed in Table 1-5 are defined in the 200-ZP-1 RI/FS work plan (DOE-RL 2004c). The COCs consist of the eight Group A analytes discussed in Sections 1.4.1 and 4.2 (i.e., chromium, carbon tetrachloride, iodine-129, nitrate, technetium-99, TCE, tritium, and total and radioactive uranium), and the Group B analytes discussed in Sections 1.4.1 and 4.2 that exceed PRGs and are not common laboratory contaminants. Potential waste source locations and quantities for the Group A COCs are summarized in Table 1-9. Appendix G includes time-series trend plots of the Group A and Group B COCs that are evaluated in groundwater samples from 200-ZP-1 wells. Trend plots are included in Figures 4-7 through 4-35 for specific COCs and are referenced in Sections 4.3.1 to 4.3.10. The initial year in the trend plots varies for each COC, depending on when specific wells were sampled for specific constituents. Furthermore, data from earlier than 1988 is not shown on the trend plots because it is not evaluated, as explained in Section 4.2. The well locations are shown on the plate map in Appendix A and on the 200 West Area map in Figure 4-36.

4.3.1 Carbon Tetrachloride

Carbon tetrachloride contamination is found in the groundwater under most of the 200 West Area at concentrations greater than the DWS (5 µg/L). The main sources for carbon tetrachloride are the 216-Z Cribs and Trenches that received waste from PFP. Table 1-9 and Figure 3-1 highlight other possible carbon tetrachloride sources. As explained in Section 1.4.1, the plate map in Appendix A illustrates an estimated lateral extent of carbon tetrachloride at concentrations of 5 µg/L and 2,000 µg/L in the shallow portion of the unconfined aquifer. The isopleths in Appendix A represent carbon tetrachloride concentrations in the upper portion of the aquifer and are based on average annual concentrations. The bulleted items below include ongoing efforts to more completely define the lateral and vertical extent of the carbon tetrachloride plume, especially in the eastern portion of the plume near the Old Laundry Facility.

The three carbon tetrachloride plate maps presented in Appendix C are based on depth-discrete analytical data for the shallow (water table to 18.3 m [60 ft] below the water table), middle (18.3 m [60 ft] to 36.6 m [120 ft] below the water table), and deep (36.6 m [120 ft] below the water table to the aquifer base) portions of the unconfined aquifer underlying the 200-ZP-1 OU. The isopleths shown in Appendix C represent the estimated plume boundaries for the maximum carbon tetrachloride concentrations that were detected in depth-discrete data for each of the three selected depth intervals. The specific wells and maximum concentrations that were used to plot the isopleths are shown on each map. The maximum carbon tetrachloride concentration from the specified depth interval is noted next to each well. The inset vertical illustrations on the plate maps in Appendix C are also based on depth-discrete carbon tetrachloride analytical data.

Investigations of carbon tetrachloride in the vadose zone in LLWMA-4 are ongoing to evaluate its potential impact on groundwater. The highest carbon tetrachloride concentrations in groundwater are found near PFP and ranged up to 5,300 µg/L in individual FY05 samples. The highest FY05 average carbon tetrachloride concentrations of approximately 4,200 µg/L were found in extraction well 299-W15-34 (Figure 4-7) and monitoring well 299-W15-1 (Figure 4-8).

The carbon tetrachloride plume at the top of the unconfined aquifer includes the following significant features:

- Remediation is reducing the area where carbon tetrachloride concentrations exceed 4,000 µg/L near the 216-Z Cribs and Trenches.
- Carbon tetrachloride concentrations greater than 1,000 µg/L occur in the northern region of the 200-ZP-1 OU. Well 299-W11-10 (Figure 4-9), near the eastern boundary of the 200 West Area, consistently contains high carbon tetrachloride concentrations. The extent of the elevated carbon tetrachloride concentration is unknown because there are no wells for approximately 2 km (1.2 mi) in a downgradient direction. Well 299-W13-1 (Figure 4-10) is also near the eastern boundary of the 200 West Area (near the Old Laundry Facility) and shows carbon tetrachloride concentrations exceeding 2,000 µg/L. The extent of the carbon tetrachloride isopleth for the EPA's DWS (5 µg/L) is now known to be significantly east of the Old Laundry Facility. Field activities are in progress to better define the carbon tetrachloride plume near the Old Laundry Facility and T tank farm. The data acquisition plans are described in the *Sampling and Analysis Plan for Characterizing Groundwater in 200 West Area In Vicinity of Old Laundry Facility and T Plant* (DOE-RL 2006c), which was approved by the EPA.
- Carbon tetrachloride concentrations increased during the past several years in wells near the tank farms in WMA-S/SX, a regulated facility in the 200-UP-1 OU. Concentrations appear to have leveled-off or declined in this area, but additional time is needed to confirm the trends. Carbon tetrachloride concentrations continue to increase in wells on the east side of WMA-S/SX, indicating that the plume is moving downgradient.
- Carbon tetrachloride concentrations in some locations are higher at depth than at the top of the unconfined aquifer. Carbon tetrachloride may have moved deeper in the aquifer as DNAPL or under hydrodynamic gradients when dissolved. These issues are part of several of the ongoing investigations discussed in Section 3.1.1 and are further described in Section 4.4.

Information on the vertical distribution of carbon tetrachloride in wells with long-screened intervals has been reported in various documents (e.g., PNNL 1998, 1999, 2002; BHI 1996, 1997c, 1999b). These reports document areas where the maximum carbon tetrachloride concentration is lower at the water table than found at depth. Depth-discrete data are included on the three plate maps in Appendix C for carbon tetrachloride and its degradation compounds (i.e., chloroform, methylene chloride, and chloromethane) from the six referenced documents.

Carbon tetrachloride remediation was the subject of the 200-ZP-1 interim ROD (EPA et al. 1995). The ROD targeted remediation efforts on the portion of the carbon tetrachloride groundwater plume near the 216-Z Cribs and Trenches at PFP where carbon tetrachloride concentrations exceed 2,000 µg/L. The 200-ZP-1 pump-and-treat system was installed to remediate the carbon tetrachloride groundwater "hot spot." A portion of the high-concentration carbon tetrachloride plume extended north to WMA-TX/TY; however, it was beyond the capture zone of the 200-ZP-1 Phase III pump-and-treat system. The previously unaffected area of the plume is remediated by converting four monitoring wells to extraction wells: 299-W15-40, 299-W15-43, 299-W15-44, and 299-W15-765 (Figures 4-11 through 4-14). The four new extraction wells started pumping operations on July 27, 2005, as described in Section 3.3.

4.3.2 Trichloroethylene

TCE is detected in the 200-ZP-1 OU at levels above EPA's 5 µg/L DWS. The TCE concentrations are significantly lower and the TCE lateral extent is generally less than for carbon tetrachloride. The main TCE plume extends north and northeast from the 216-Z Cribs and Trenches. The maximum TCE concentration detected during FY05 routine monitoring was 36 µg/L in new well 299-W15-50 (Figure 4-15 and plate map in Appendix A), north of the 216-Z-9 Trench, at a screened depth interval of approximately 7.6 to 18.3 m (24.9 to 60 ft) below the water table. The maximum TCE concentration during FY04 was 15 µg/L in well 299-W15-44, south of WMA-TX/TY. The TCE concentration in well 299-W15-44 (Figure 4-16 and Appendix A plate map) increased to 16 µg/L in August 2005. As stated in the discussion of carbon tetrachloride contamination, TCE in well 299-W13-1 (Figure 4-17 and Appendix A plate map) reached a maximum concentration near the typical depth for the top of the Ringold Lower Mud Unit (bottom of the unconfined aquifer). Depth-discrete TCE concentrations for the RI/FS wells are included in the tables and vertical plots in Appendix L. Appendix M provides depth-discrete TCE data for other 200-ZP-1 wells. Well locations are shown on the 200 West Area map in Figure 4-36.

4.3.3 Nitrate

The nitrate contamination in groundwater is more widespread than tritium, iodine-129, or technetium-99. Nitrate continued to be present in groundwater beneath much of the 200-ZP-1 OU at concentrations in excess of the DWS (45 mg/L). The maximum concentration in this vicinity during FY05 was 3,540 mg/L in well 299-W10-4 (Figure 4-18 and Appendix A plate map), near the 216-T-36 Crib, south of WMA-T. The nitrate concentration increased rapidly in well 299-W10-4 during FY04 but was stabilizing in FY05. Well locations are shown on the 200 West Area map in Figure 4-36. There are likely multiple sources of nitrate in this area, including the 216-Z Crib and various trench disposal facilities.

Well 299-W18-16, which is an RI/FS well, was drilled east of the 216-Z-1A Crib during the first quarter of FY05. The average nitrate concentration was 819 mg/L in well 299-W18-16 in groundwater samples that were collected after well completion. Sharply increasing nitrate concentration in well 699-48-71 (Figure 4-19 and Appendix A plate map) indicates that the nitrate plume is migrating northeast from the 200 West Area. The average nitrate concentration in well 699-48-71 was 210 mg/L in FY05.

Elevated nitrate concentrations in the western portion of the Hanford Site are considered the result of offsite agricultural activities, primarily because the concentrations are persistent and present far upgradient of the waste disposal areas. Furthermore, the nitrate in the western portion of the Hanford Site is not associated with significant concentrations of other typical Hanford contaminants (e.g., tritium). The nitrate concentration was 49 mg/L during FY03 in well 699-36-93, located in the western portion of the Hanford Site. Most upgradient wells in the western portion of the Hanford Site were not scheduled for sampling during FY05.

4.3.4 Chromium

Chromium contamination is found in filtered samples in the immediate vicinity of WMA-T and WMA-TX/TY at levels above EPA's DWS (100 µg/L). The plume in the vicinity of WMA-T has changed little in size over the past decade, although the downgradient extent of the chromium plume is uncertain due to the lower density of monitoring wells. The highest levels of

chromium are found in well 299-W10-4 (Figure 4-20 and Appendix A plate map), located west (i.e., upgradient) and south of WMA-T. The maximum and average chromium concentrations in well 299-W10-4 were 722 µg/L and 666 µg/L, respectively, during FY05. The chromium concentration in well 299-W10-4 continued to decline after peaking in October 2004.

Chromium concentrations are also elevated east of WMA-TX/TY in well 299-W14-13 (Figure 4-21 and Appendix A plate map). The concentrations detected in filtered samples from this well in FY05 rose from 653 µg/L in October to 769 µg/L in August. The chromium contamination is associated with elevated nitrate, tritium, technetium-99, and iodine-129. Well locations are shown on the 200 West Area map in Figure 4-36.

4.3.5 Technetium-99

Technetium-99 within the 200-ZP-1 OU is found at levels above EPA's DWS of 900 pCi/L only on the east (i.e., downgradient) side of WMA-T and the east and south (i.e., downgradient) sides of WMA-TX/TY. Evidence points to multiple sources of technetium-99 within those areas.

The technetium-99 activity levels continued to increase during FY05 in wells on the eastern side (i.e., downgradient) of the tank farm near WMA-T. Well 299-W11-39 (Figure 4-22 and Appendix A plate map), near the northeastern corner of the WMA, had the highest activity level at the water table in the area with values ranging from 12,000 to 27,400 pCi/L. Technetium-99 activity levels in FY05 reached 182,000 pCi/L in well 299-W11-25B, which was drilled to 51 m (167.3 ft) below the water table.

Technetium-99 concentrations east of WMA-TX/TY in well 299-W14-13 (Figure 4-23 and Appendix A plate map) decreased slightly during the first three quarters of FY05 but increased during the last quarter. The average concentration in well 299-W14-13 decreased from 8,520 pCi/L in FY04 to 7,090 pCi/L in FY05. This contamination is associated with elevated levels of chromium, nitrate, tritium, and iodine-129. Well locations are shown on the plate map in Appendix A and on the 200 West Area map in Figure 4-36.

Section 4.4.2 of this RI report presents detailed discussion of the presence of maximum concentrations of technetium-99 at depths of 10 m (approximately 30 ft) below the water table. The DQO process is being used to establish a sampling design to assess the vertical and lateral extent of the technetium-99 contamination in the aquifer. Klein (2005) indicated that the DQO process should be used to establish a SAP to assess the technetium-99. The sampling and analysis design is currently under review. Data are not likely to be available until the FS is underway. Any data that are available during the writing of the FS will be attached as an appendix.

4.3.6 Uranium

Few analyses were performed for uranium on groundwater samples from the 200-ZP-1 OU during FY05 because most wells showed insignificant levels in previous monitoring. Some wells monitored near the SST farms and the LLBG are sampled for gross alpha measurements, which would show an increase if uranium contamination appeared. Uranium was detected above the EPA's DWS of 30 µg/L in well 299-W11-14 (Figure 4-24 and Appendix A plate map) until it went dry after the FY04 sampling event. The uranium concentration in well 299-W11-37 (Figure 4-25 and Appendix A plate map), located approximately 200 m (656 ft) northeast of well 299-W11-14 in the northeastern portion of the 200 West Area, was 183 µg/L in FY05.

Uranium declined below the EPA's DWS in well 299-W18-21 (Figure 4-26 and Appendix A plate map), near the southwestern corner (i.e., upgradient) of LLWMA-4. The concentration in well 299-W18-21 ranged from 25.7 to 27.3 μg/L in FY05. Well locations are shown on the 200 West Area map in Figure 4-36.

4.3.7 Iodine-129

An iodine-129 plume is found in the 200-ZP-1 OU, emanating from the vicinity of WMA-TX/TY and extending to the northeast. The EPA's DWS for iodine-129 is 1 pCi/L. The highest iodine-129 activity level detected in FY05 during routine groundwater monitoring was 26.1 pCi/L in well 299-W14-13 (Figure 4-27 and Appendix A plate map), where the FY05 average activity level was 18 pCi/L. Iodine-129 was also detected in well 299-W14-15 (Figure 4-28 and Appendix A plate map) at an activity level of 2.04 pCi/L in May 2005.

Well 299-W14-11 was drilled to 36 m (118 ft) below the water table in April 2005, approximately 4 m (13 ft) from well 299-W3-13, along the downgradient side of WMA-TX/TY. Groundwater samples were collected at 1.5-m (4.9-ft) intervals during drilling and analyzed for iodine-129, technetium-99, hexavalent chromium, tritium, and anions. The highest iodine-129 activity level measured on the Hanford Site during FY05 was 72 pCi/L in a depth-discrete groundwater sample that was collected in well 299-W14-11 at a depth of 0.7 m (2.3 ft) below the water table. Iodine-129 was undetectable in depth-discrete groundwater samples deeper than 25 m (82 ft) below the water table. No iodine-129 was detected in the August 2005 quarterly sample from well 299-W14-11.

Figure 4-36 shows well locations on the 200 West Area map. The extent of the iodine-129 groundwater plume is difficult to determine because the laboratory detection limits are sometimes equal to or higher than the EPA's DWS. The iodine-129 plume is approaching the northeast boundary of the 200 West Area and might extend beyond it (PNNL 2006).

4.3.8 Tritium

Tritium contamination at levels greater than the EPA's DWS of 20,000 pCi/L is restricted in the 200-ZP-1 OU to a plume extending northeast from waste disposal facilities in the vicinity of WMA-T and WMA-TX/TY. There are multiple potential sources of tritium in this vicinity. In addition, tritium from the permitted discharge at the SALDS is found in groundwater.

The highest tritium activity levels in wells screened at the water table are found in well 299-W14-13 (Figure 4-29 and Appendix A plate map), east of WMA-TX/TY, where the FY05 activity level ranged from 1.17 million pCi/L to 1.98 million pCi/L and averaged 1.54 million pCi/L. Tritium reached a maximum of 2.94 million pCi/L in well 299-W14-13 during FY00. Well 299-W14-13 replaced well 299-W14-12. The trend plots for the two wells (Figures 4-29 and 4-30) indicate that the high contamination levels at this location arrived in approximately 1999. High levels of chromium, nitrate, technetium-99, and iodine-129 are associated with the tritium contamination.

Tritium activity levels exceeded the EPA's DWS in three other wells during FY05. The average FY05 tritium activity level was 33,000 pCi/L in well 299-W14-15 (Figure 4-31 and Appendix A plate map), 49,000 pCi/L in well 299-W11-12 (Figure 4-32), and 55,000 pCi/L in well 299-W11-14 (Figure 4-33). Well 299-W11-12 is located southeast of WMA-T. Although WMA-T is not considered as a major source for tritium in well 299-W11-12, the tritium might be

the result of changing groundwater flow directions. Well locations are shown on the plate map in Appendix A and the 200 West Area map in Figure 4-36.

4.3.9 Chloroform

Groundwater samples that were collected in FY05 during routine sampling of 200-ZP-1 wells contain chloroform concentrations that are below the EPA's DWS of 80 µg/L (the standard is defined for total trihalomethane). Numerous depth-discrete samples collected during drilling operations contained chloroform concentrations above the DWS. The highest chloroform concentration of 1,100 µg/L was detected in a depth-discrete sample from well 299-W15-46, located near the 216-Z-9 Trench. A depth-discrete sample from well 299-W13-1 in FY04 also was above the chloroform DWS. Chloroform in well 299-W13-1 reached a maximum of 83 µg/L near the typical depth of the top of the Ringold Lower Mud Unit (i.e., bottom of the unconfined aquifer). Well locations are shown on the plate map in Appendix A and the 200 West Area map in Figure 4-36.

The 200-ZP-1 RI/FS work plan (DOE-RL 2004c) designates a preliminary target action level of 7.17 µg/L based on cleanup levels and risk calculations under the *Model Toxics Control Act* (MTCA) (WAC 173-340) cleanup regulations. Possible chloroform sources include biodegradation of carbon tetrachloride.

4.3.10 Fluoride

Fluoride contamination is seen in a restricted area around WMA-T at levels greater than the EPA's primary DWS (4 mg/L). The average fluoride concentrations in two wells north of WMA-T (299-W10-8 and 299-W10-23 [Figures 4-34 and 4-35, respectively]) exceed the EPA limit. Individual results also were above the EPA's DWS well 299-W10-4, where the fluoride concentration reached 10.1 mg/L in FY05. Well locations are shown on the plate map in Appendix A and the 200 West Area map in Figure 4-36.

4.4 THREE-DIMENSIONAL DISTRIBUTION OF CONTAMINANTS OF CONCERN IN GROUNDWATER

Data are being acquired to enhance the evaluation of the vertical extent of COCs in the saturated zone of the 200-ZP-1 OU. The 200-ZP-1 RI/FS work plan (DOE-RL 2004c) identified eight monitoring wells in Table A3-2 that were recently drilled to obtain depth-discrete data for COC concentrations and aquifer properties. Eight of the 200-ZP-1 RI/FS work plan wells and 11 other wells comprise the RI/FS wells. Depth-discrete groundwater data from the 19 RI/FS wells were collected while the wells were drilled. Other depth-discrete groundwater data were obtained from existing wells by VET. Section 4.4.1 describes the field screening and laboratory data for carbon tetrachloride and three of its degradation compounds (i.e., chloroform, methylene chloride, and chloromethane). Section 4.4.2 describes the depth-discrete groundwater data for technetium-99. Additional depth-discrete groundwater data and evaluations of the data are expected in calendar year 2006.

4.4.1 Carbon Tetrachloride and Associated Degradation Compounds

The three-dimensional distribution of COCs in groundwater within the unconfined aquifer is based on the analysis of depth-discrete groundwater samples collected during the drilling of new wells in the 200-ZP-1 and 200-UP-1 OUs (see Section 2.2). To illustrate the three-dimensional

distribution of carbon tetrachloride in groundwater, the three plate maps in Appendix C show vertical plots of the depth-discrete results for carbon tetrachloride and its potential degradation compounds (i.e., chloroform, methylene chloride, and chloromethane), as well as selected concentration contours for the carbon tetrachloride plume.

The data shown on the three plate maps in Appendix C include both field screening and laboratory analyses of depth-discrete groundwater samples collected during the drilling of wells from 1998 to 2005. The isopleths on the three plate maps are based on depth-discrete samples collected from 2002 through 2005. The data also include depth-discrete groundwater sampling results collected from 20 existing wells between November 2004 and January 2006 by VET as part of their carbon tetrachloride DNAPL investigation project (see Section 3.1.1). A straddle-packer system was used in the existing wells to isolate the well screen or perforated casing intervals (0.6-m [2-ft] intervals in 1.21–m [4-in.] and 1.83–m [6-in.] wells, and 0.91–m [3-ft] intervals in 2.44–m [8-in.] wells). Low-flow purging and sampling methods with a bladder pump were used to obtain each sample. Purge rates typically ranged from 160 to 400 mL/min until the field parameters of pH, specific conductivity, temperature, DO, and turbidity stabilized. Purge times ranged from 40 to 116 minutes per sample. The VET groundwater samples were analyzed for VOCs by EPA Method 8260 at an analytical laboratory.

The depth-discrete groundwater COC concentration data on the three plate maps in Appendix C were obtained from multiple sources. Consequently, analytical data may vary for individual samples from the same depth in a given well. Differences between two sample analyses are sometimes due to field screening analysis of one sample and laboratory analysis of another sample from the same depth (e.g., well 299-W15-42). Analytical differences also result when samples are not collected at the same time. For example, analytical data from the more recent VET sampling events may vary from older data due to natural groundwater plume movement and the influence of the 200-ZP-1 OU pump-and-treat system. Despite these issues, the data represent the most complete depth-discrete groundwater results for defining the three-dimensional distribution of the carbon tetrachloride plume and co-contaminants.

The vertical plot results for carbon tetrachloride are shown on two hydrogeologic cross-sections on the three plate maps in Appendix C and in Figures 4-37 and 4-38. A conceptual model of the carbon tetrachloride groundwater plume, summarized on these cross-sections and discussed in more detail below, is that the plume extends vertically from the top of the unconfined aquifer near the disposal source areas by PFP to the base of the unconfined aquifer at the top of the Ringold Lower Mud Unit (Unit 8). The plume extends through the Ringold Formation to the top of basalt where the Unit 8 confining layer is absent, as at well 299-W13-1. The cross-sections also show that, as the distance from the source area increases in a downgradient direction, the highest carbon tetrachloride concentrations occur deeper in the unconfined aquifer. Along the downgradient plume extent, recharge from natural infiltration and less-contaminated former wastewater discharges contribute to reduced carbon tetrachloride concentrations in the upper portion of the unconfined aquifer.

The observed increases in carbon tetrachloride concentration at depth in the unconfined aquifer, downgradient from the source area, may be associated with a vertical component to the groundwater gradient. Vertical gradient estimates will be developed from measurements in at least three sets of well pairs in the 200-ZP-1 OU: wells 299-W11-86 (deeper screen) and 299-W11-10 (shallow screen); wells 299-W15-17 (deeper screen) and 299-W15-30 (shallow-screened well that replaced well 299-W15-16); and wells 299-W18-21 (shallow screen) and

299-W18-22 (deep screen). Well 299-W11-86 was recently drilled to estimate vertical gradient and collect depth-discrete groundwater samples. The vertical gradient data will be evaluated and incorporated as needed in the FS.

The FS will consider a primary conceptual model and an alternative conceptual model for carbon tetrachloride. The primary model (i.e., the assumed current condition for which a remedy will be developed) will recognize that NAPL concentrations of carbon tetrachloride currently exist in the vadose zone but do not present a significant continuing source term to the groundwater. In the groundwater, the amount and spatial distribution of any NAPL sources are small relative to the magnitude of the dissolved phase present in the aquifer. In other words, the primary focus of the remedy in the FS will be to address the dissolved phase carbon tetrachloride in groundwater. The alternative model is that sources of NAPL carbon tetrachloride exist in the groundwater of sufficient mass and/or spatial distribution to require a supplementary and/or alternative remedial action and that these sources would be discovered either during implementation of the remedy or as part of performance monitoring resulting in the need for an adaptive contingency response for the groundwater. Such a response will be anticipated as part of the remedial strategy developed in the FS for the 200-ZP-1 OU. A key component of the remedy design will be to collect data aimed at testing the likelihood that the conditions presumed for the alternative conceptual model exist.

Although not shown in the vertical depth plots on the three plate maps in Appendix C, the approximate depth to groundwater in the wells shown ranges from about 67 to 76 m (220 to 250 ft) bgs, and the approximate depth to the Ringold Lower Mud Unit ranges from about 113 to 134 m bgs (370 to 440 ft) bgs. In general, the elevation of the water table decreases from west to east, and the elevation of the Lower Mud Unit increases from southwest to northeast.

The following discussion summarizes the general trends in the three-dimensional depth and concentration distribution of the carbon tetrachloride plume and co-contaminants on the three plate maps in Appendix C. The actual sample depths, concentrations, and sample dates for the wells are included in Appendix M.

Seven wells in the high-concentration portion of the carbon tetrachloride plume (listed from north to south, 299-W15-765, 299-W15-43, 299-W15-40, 299-W15-44, 299-W15-11, 299-W15-1, and 299-W15-7) showed the highest concentrations of carbon tetrachloride at depths of 6 to 21 m (20 to 70 ft) below the water table (Figure 4-15 and Appendix C plate maps). The highest carbon tetrachloride concentrations in these wells ranged from about 2,700 to 4,152 µg/L. Well 299-W15-43 showed the highest carbon tetrachloride concentration (3,300 µg/L) at 21 m (70 ft) below the water table and then lower concentrations below that depth when the well was drilled in 2002, clearly defining the vertical concentration profile of the plume in this area. The data from the other six wells in this area all show increasing carbon tetrachloride concentrations with depth, indicating that the full thickness of the plume was not penetrated by these wells. The data from well 299-W15-7 clearly indicate the effects of the nearby pump-and-treat extraction wells. When the well was initially drilled and sampled in 1996, the highest carbon tetrachloride concentrations ranged from 600 to 800 µg/L. The depth-discrete groundwater sampling conducted in 2005 showed that the highest carbon tetrachloride concentrations had increased to between 2,400 and 2,700 µg/L. A similar impact is seen in the data from well 299-W15-42, identified on the plate maps in Appendix C.

Three wells near the 216-Z-9 Trench (which is one of the primary carbon tetrachloride waste disposal sites near PFP) showed the highest concentration of carbon tetrachloride (2,000 to 3,700 μg/L) at depths of 18 to 33 m (60 to 110 ft) below the water table. Well 299-W15-46, which is located adjacent to the south side of the trench, showed two distinct carbon tetrachloride maxima with depth. The highest concentration of 3,700 μg/L was at 18 m (60 ft) below the water table, and a second but lower peak of about 1,200 μg/L was at 46 m (150 ft) below the water table. Depth-discrete groundwater sampling conducted in January 2006 in well 299-W15-46 showed that the highest carbon tetrachloride concentrations had increased to 5,000 μg/L at about 18 m (60 ft) below the water table.

Data from wells located downgradient (east) of the high-concentration portion of the carbon tetrachloride plume show how the depth of the plume maximum increases with downgradient distance. Wells 299-W14-11 and 299-W14-14 on the east side of the TX-TY Tank Farms penetrated the plume maximum (950 to 1,200 μg/L) at 33 to 40 m (110 to 130 ft) below the water table. Approximately 1,200 m (3,900 ft) further east, well 299-W13-1 penetrated the plume maximum (1,250 μg/L) at the base of the unconfined aquifer (about 46 m [150 ft] below the water table [Figure 4-15 and Appendix C plate maps]). As previously noted, because the Ringold Lower Mud Unit is not present at this well, the carbon tetrachloride plume extends into the lower aquifer, and the carbon tetrachloride concentration at the top of the basalt in this area is about 150 μg/L. Well 299-W14-9, located less than 300 m (980 ft) east of the 216-Z-9 Trench area, showed about 270 μg/L of carbon tetrachloride at the base of the unconfined aquifer just above the Lower Mud Unit.

Three wells near the 216-Z-1A, 216-Z-12, and 216-Z-18 waste sites (the other primary carbon tetrachloride waste disposal sites near PFP) show significantly lower carbon tetrachloride maxima than those seen near the 216-Z-9 Trench (as discussed above). The highest concentrations of carbon tetrachloride (250 to 850 μg/L) in wells 299-W15-152, 299-W18-1, and 299-W18-16 were found at depths 9 to 40 m (30 to 130 ft) below the water table. These wells are located about midway between the injection wells to the west and the extraction wells to the east of the pump-and-treat system, and are likely showing the impacts of that system (Figure 4-15 and Appendix C plate maps).

Four wells within the 200-UP-1 OU portion of the carbon tetrachloride plume illustrate the vertical distribution of carbon tetrachloride in the unconfined aquifer in this plume lobe. Wells 299-W15-37, 299-W19-49, and 299-W19-50 showed plume maximum concentrations (120 to 140 μg/L) at 6 to 30 m (20 to 100 ft) below the water table. To the east (i.e., downgradient) of these wells, well 699-38-70B penetrated the highest carbon tetrachloride concentration (480 μg/L) at the base of the unconfined aquifer (approximately 38 m [125 ft] below the water table).

Two wells near the T Tank Farm and one well near T Plant illustrate the vertical distribution of carbon tetrachloride in the unconfined aquifer in the northern plume area. Wells 299-W10-24 and 299-W11-25B showed plume maximum values (1,500 to 1,600 μg/L) at 21 to 24 m (70 to 80 ft) below the water table. About 450 m (1,500 ft) downgradient, well 299-W11-43 penetrated a high carbon tetrachloride concentration (1,000 μg/L) at about 20 m (65 ft) below the water table and then lower concentrations deeper in the aquifer. However, the last depth-discrete groundwater sample from this well at a depth of about 56 m (185 ft) below the water table near the base of the unconfined aquifer had a carbon tetrachloride concentration of 1,100 μg/L.

The vertical plots of the RI/FS wells in Appendix L include carbon tetrachloride and its potential degradation products (chloroform, methylene chloride, and chloromethane). A vertical plot is also included in Appendix L for the molar concentrations of carbon tetrachloride and chloroform in well 299-W15-46, based on laboratory analytical data (i.e., excluding field and VET data). The molar concentrations are calculated by converting units of "µg/L" to "g/L" and dividing the standard concentration of each COC by the molecular weight of that COC. The resulting vertical plot represents a comparison of the equivalent concentrations of carbon tetrachloride and chloroform. The vertical plot illustrates three peaks for carbon tetrachloride at depths of approximately 71 m, 81 m, and 112 m (234 ft, 267 ft, and 368 ft) and two peaks for chloroform at depths of approximately 97 m and 128 m (318 ft and 420 ft). The generally inverse relationship of the carbon tetrachloride and chloroform concentration trends between depths of approximately 76 m and 122 m (250 ft and 400 ft) suggests that the carbon tetrachloride in well 299-W15-46 is partially degrading to chloroform within a depth of approximately 15 m (50 ft) below the peak carbon tetrachloride concentrations.

Several wells (e.g., 299-W11-25B, 299-W15-1, 299-W15-7, 299-W15-31A, 299-W15-42, and 299-W15-46) show low levels of methylene chloride present within the aquifer, but only a few wells (e.g., 299-W15-11, 299-W15-46, and 299-W15-765) have detectable concentrations of chloromethane. The chloroform (trichloromethane), methylene chloride (dichloromethane), and chloromethane contaminants may be the result of carbon tetrachloride degradation. The association of carbon tetrachloride and its potential degradation products in the 200-ZP-1 unconfined aquifer will be examined in the FS as needed, especially for a monitored natural attenuation remedial alternative. Well locations and depth-discrete data are shown on the three plate maps in Appendix C.

4.4.2 Technetium-99

A technetium-99 plume has been identified northeast of WMA-T, which contains the T Tank Farm. A new well (299-W11-25B) was drilled and sampled in the northeast corner of WMA-T to assess the vertical extent of the technetium-99. Recent data from well 299-W11-25B indicate technetium-99 concentrations at 180,000 pCi/L at a depth of 10 m (30 ft) below the water table. The following information is from the FY05 annual groundwater report (PNNL 2006).

As noted in the FY05 annual groundwater report (PNNL 2006), depth-discrete data were collected by both air-lifted slurry and by pumping. The air-lifted slurry samples were collected from well 299-W11-25B every 1.5 m (4.9 ft) through the drilled portion of the aquifer. These samples were collected, the particulate was allowed to settle, and samples were then pumped through a filter and analyzed in the laboratory.

Pumped samples were collected every 6.1 m (20 ft) throughout the drilled portion of the aquifer. A pump was lowered into the borehole, and the borehole was purged for at least 1 hour before sampling.

The depth-discrete technetium-99, chromium, manganese, and nitrate data obtained during drilling of well 299-W11-25B are presented in Figures 4-39 through 4-41. Figure 4-40 includes chromium and manganese data from both air-lifted and pumped groundwater samples. As explained in the FY05 annual groundwater report (PNNL 2006 [Section 2.8.3.3, p. 2.8-16]), the air-lifted samples are generally considered invalid due to temporary reducing conditions caused by the drilling methods. The air-lifted samples shown in Figure 4-41 for technetium-99 are also considered invalid due to temporary reducing conditions caused by the drilling methods

(PNNL 2006 [Section 2.8.3.3, p. 2.8-16]). It should be noted that the maximum nitrate concentrations are at the same depth (10 m [30 ft]) below the water table as the maximum technetium-99 concentrations. Maximum chromium and manganese concentrations were at a depth slightly closer to the water table than the maximum technetium-99 and nitrate concentrations.

In order to assess the lateral extent of the technetium-99 plume in the deeper unconfined aquifer, well 299-W11-45 was drilled approximately 80 m (262.5 ft) downgradient (i.e., east) of well 299-W11-25B (Figure 4-15 and Appendix C plate maps). Well 299-W11-45 was sampled every 1.5 m (4.9 ft) throughout the top 56 m (183.7 ft) of the aquifer. The nitrate and technetium-99 concentrations are shown in Figure 4-42. Again, the depth distributions of both contaminants are similar to that of well 299-W11-25B; however, the maximum concentrations are lower. Additional wells are planned in the area during FY06 to assess the lateral and vertical extent of the technetium-99 plume.

Depth-discrete data for technetium-99 were collected for additional wells. Vertical technetium-99 data plots for the RI/FS wells and other 200-ZP-1 wells are shown in Appendices L and M, respectively. Wells 299-W10-24 and 299-W11-43 show increased technetium-99 concentrations at similar depths but significantly lower concentrations than well 299-W11-25B; both wells are located northeast of WMA-T (Figure 4-15 and Appendix C plate maps).

Wells east of the TX-TY Tank Farms area show mixed information with depths. Well 299-W15-43 shows generally low concentrations below 35 pCi/L, with the highest concentration 18.3 m (60 ft) below the water table. Well 299-W14-14 shows concentrations of 556 pCi/L at the water table and drops to 30 pCi/L at 11 m (36 ft) below the water table. Well 299-W14-19 shows a maximum of 399 pCi/L at 10.7 m (35 ft) below the water table. Well 299-W15-44, located southwest of the TX-TY Tank Farms, shows a maximum concentration of 89 pCi/L at a depth of 6.1 m (20 ft) below the water table (Figure 4-15 and Appendix C plate maps).

Well 299-W15-46, south of the 216-Z-9 Crib, has a maximum concentration of 850 pCi/L in an unfiltered sample at a depth of about 12 m (40 ft) below the water table. The same well showed maximum technetium-99 concentrations of 580 pCi/L from filtered samples collected at approximately 19.5 m (64 ft) below the water table. Three other wells near PFP (299-W15-50 [extraction well], 299-W18-16, and 299-W15-42) show technetium-99 concentrations well below 100 pCi/L at all sampling depths (Figure 4-15 and Appendix C plate maps).

Well 299-W15-49, on the northeast side of the 200-ZP-1 OU, shows a maximum technetium-99 concentration of 55 pCi/L at the water table. Generally, the higher technetium-99 concentrations found below the water table are to the northeast of WMA-T.

4.5 THREE-DIMENSIONAL DISTRIBUTION OF CONTAMINANTS OF CONCERN IN SEDIMENT

Sediment and soil gas data for selected COCs in the RI/FS wells are shown in the tables and vertical profiles provided in Appendix N. The 18 selected COCs include those that pose a significant human health or ecological risk, as discussed in Section 7.0 of this RI report. The human health risk drivers include the following: Group A COCs (i.e., carbon tetrachloride, total chromium, iodine-129, nitrate, technetium-99, TCE, tritium, and total and radioactive uranium), antimony, 1,2-dichloroethane, tetrachloroethylene, hexavalent chromium, iron, and chloroform.

The only ecological risk driver that is not also identified as a human health risk is cyanide. Other selected COCs are two additional degradation products of carbon tetrachloride (i.e., methylene chloride and chloromethane) and fluoride.

Appendix N includes vertical profiles and tables for the following five 200-ZP-1 wells where Group A COCs were detected in sediment samples: 299-W11-45, 299-W13-1, 299-W15-46, 299-W15-49, and 299-W17-1. Five of the eight Group A COCs (i.e., carbon tetrachloride, chromium, nitrate, technetium-99, and uranium) were detected in sediment samples from the five wells. Iodine-129, TCE, and tritium were not reported in available sediment or soil gas samples from the five wells. Appendix N also includes analytical results for sediment samples that are below the applicable laboratory detection limit.

Carbon tetrachloride was detected in sediment samples from one of the five wells (299-W15-46). The following carbon tetrachloride concentrations were reported for two sediment samples from well 299-W15-46: 380,000 µg/L from a depth of approximately 20 m (65 ft) bgs, and 4 µg/L at a depth of approximately 115.3 (378.25 ft) bgs.

Chromium was detected in six sediment samples from four of the five wells. The lowest (i.e., 4,180 µg/kg at a depth of approximately 90.1 m [295.5 ft] bgs) and highest (i.e., 162,000 µg/kg at a depth of approximately 36.9 m [121 ft] bgs) chromium concentrations were both detected in well 299-W15-46.

Nitrate was detected in five sediment samples from three of the five wells. The lowest detected nitrate concentration of 1,351 µg/kg occurred at a depth of 57.9 m (190 ft) bgs in well 299-W17-1. The highest detected nitrate concentration was found in well 299-W15-46 at a depth of 33.9 m (111.25 ft) bgs.

Technetium-99 was detected in three sediment samples in only one of the five wells (299-W15-46). The highest technetium-99 activity level of 18 pCi/g was obtained from a sediment sample at a depth of 15.5 m (50.75 ft) bgs in well 299-W15-46. Technetium-99 activity levels of 1 pCi/g were reported for sediment samples from depths of 15.5 and 90.1 m (50.75 and 295.5 ft) bgs in the same borehole.

Uranium was detected in four sediment samples from two of the five wells. The lowest detected uranium concentration of 210 µg/kg occurred in a sediment sample from a depth of 79.6 m (261 ft) bgs in well 299-W15-49. Uranium was reported in a second sediment sample from well 299-W15-49 at a concentration of 1,808 µg/kg from a depth of 133.4 m (437.5 ft) bgs. The highest uranium concentration of 2,040 µg/kg was found in a sediment sample from a depth of 19.8 m (65 ft) bgs in well 299-W15-46. Uranium was also detected at a concentration of 232 µg/kg in a sediment sample from a depth of 90.9 m (298.25 ft) bgs in well 299-W15-46.

Appendix N also includes vertical profiles and tables for carbon tetrachloride that was detected in soil gas measurements from three 200-ZP-1 wells: 299-W15-46, 299-W15-49, and 299-W18-16. The highest detected carbon tetrachloride concentration in soil gas (i.e., 9,700 ppmv) was found at a depth of 33.8 m (111 ft) bgs in well 299-W15-46. A carbon tetrachloride concentration of 1 ppmv was reported in soil gas from a depth of 43.3 m (142 ft) bgs in well 299-W15-46. Carbon tetrachloride was detected in the following soil gas samples: 5 ppmv at a depth of 51.2 m (167.9 ft) bgs and 1 ppmv at a depth of 39.6 m (130 ft) bgs in well 299-W15-49; and 87 ppmv at a depth of 37.2 m (122 ft) bgs and 3 ppmv at a depth of 43.9 m (144 ft) bgs in well 299-W18-16.

4.6 MODELING INPUT PARAMETERS FOR SEDIMENT

Data were collected for the modeling parameters identified in Table 2-1 during drilling, development, and aquifer testing of three recently installed wells in the 200-ZP-1 OU: 299-W15-49 (well "C"), 299-W11-43 (well "H"), and 299-W15-46 (see Appendix A plate map). The three wells were selected for multiple data needs because they are located near contamination sources and within several contaminant plumes. The plate map in Appendix A shows the approximate well locations.

Sediment samples were collected while drilling each of the three wells and were analyzed for the geotechnical, hydraulic, and geochemical parameters shown in Table 2-1. The analytical results are summarized in Tables 4-9, 4-10, and 4-11. As shown in Table 4-11, a total of 37 sediment samples were collected from well 299-W15-46 at intervals of approximately 0.6 to 8.2 m (2 to 27 ft) from the water table to the top of the Ringold Lower Mud Unit. The water table and Ringold Lower Mud Unit were found at depths of approximately 67.9 m (222.7 ft) and 127.2 m (417 ft) bgs, respectively. Additional sampling information for well 299-W15-46 is available in a borehole summary report (FH 2005c, Table 2-9).

As shown in Table 4-11, six sediment samples were obtained from well 299-W15-49 at depth intervals of approximately 9.4 m (30 ft). Only one sediment sample from well 299-W11-43 was submitted for analysis due to insufficient split-spoon sample recovery. Numerous attempts failed to retrieve adequate sediment for analysis in well 299-W11-43 when gravel repeatedly blocked the sampling tools. Sections 4.6.1.1, 4.6.2, and 4.6.3.1 provide detailed discussion of the results from this sampling.

Similar sets of geotechnical and geochemical data were obtained from three wells drilled in the 200-UP-1 OU during 2004: 299-W19-48 (well "K"), 699-30-66 (well "R"), and 699-36-70B (well "P") (see Appendix A plate map). PNNL analyzed 13 unconsolidated sediment core samples and 13 depth-discrete groundwater samples from the three 200-UP-1 wells. The 13 sediment cores were 10 cm (4 in.) in diameter and 15 cm (6 in.) long and were collected from the water table to approximately 55 m (180 ft) below the water table. Wells 699-30-66 and 699-36-70B were located near the mapped perimeter of an identified uranium groundwater plume. Well 299-W19-48 was located near the center of the mapped uranium groundwater plume. The analytical results for these sediment samples are considered applicable to the adjacent 200-ZP-1 OU.

The sediment cores from well 299-W19-48 were originally planned for detailed desorption studies of targeted COCs (e.g., uranium [VI], technetium-99, hexavalent chromium, iodine-129, selenium-79, neptunium-237, strontium-85, and cesium-137), but the COC content was too low. Therefore, alternative adsorption-desorption tests were performed. The depth, geologic formation, and condition of each sediment core are summarized in Table 4-12. The 200-UP-1 OU data are shown in Tables 4-12, 4-13, 4-14, 4-15, and 4-16 for parameters listed in Table 2-1. Sections 4.6.1.2, 4.6.2, and 4.6.3.2 provide a more detailed discussion of these results.

4.6.1 Geotechnical Parameters for Sediment Samples

The geotechnical parameters used as input for the sediment model are described in the following subsections for sediment samples from the installation of three 200-ZP-1 wells: 299-W15-49 (well "C"), 299-W11-43 (well "H"), and 299-W15-46. Similar data are also described from three 200-UP-1 wells: 299-W19-48, 699-36-70B, and 699-30-66.

4.6.1.1 Geotechnical Analyses of 200-ZP-1 Sediment Samples. Sediment samples from 200-ZP-1 OU wells 299-W15-49 (well "C"), 299-W11-43 (well "H"), and 299-W15-46 were analyzed for five of the six geotechnical (i.e., physical) parameters identified in Table 2-1: particle size, calcium carbonate, borehole geophysics, bulk density, and lithology. The number of geotechnical sediment samples from the 200-ZP-1 boreholes varied as follows: 20 samples from well 299-W15-46, 5 samples from well 299-W15-49, and one sample from well 299-W11-43. Mineralogy (i.e., x-ray diffraction) data are not yet available for the three 200-ZP-1 wells. Section 4.6.1.2 presents analogous data for the nearby 200-UP-1 OU wells.

The available particle-size data indicate that the 200-ZP-1 sediment samples are primarily sand and gravel with some silt. Sediment samples from depths of 127.2 to 132.7 m (417 to 435 ft) in wells 299-W15-46 and 299-W15-49 were primarily silt and/or clay. Calcium carbonate was identified in 8 of 17 analyzed sediment samples from wells 299-W15-46 and 299-W15-49. The highest measured calcium carbonate content was 12% in a sediment sample from a depth of 84.4 m (277 ft) in well 299-W15-46. Dry bulk density ranged from 1,290 to 2,416 kg/m^3 in sediment cores from the three sampled 200-ZP-1 OU wells. The lowest bulk density was measured in samples from depths of 127.9 and 132.6 m (419.5 and 435 ft) in wells 299-W15-46 and 299-W15-49, respectively. The bulk density, particle-size distribution, and calcium carbonate results are included in Tables 4-9 and 4-11. The analytical methods are summarized in Section 2.3.

4.6.1.1.1 Borehole Geophysical Surveys of 200-ZP-1 Sediment Samples. Geophysical surveys are generally conducted in boreholes drilled at Hanford after total depth is reached. Geophysical borehole survey data are currently available in borehole summary reports, CERCLA groundwater monitoring well summary reports, and various reports from the S. M. Stoller Corporation for 11 of the 19 RI/FS wells: 299-W11-25B, 299-W11-43, 299-W11-45, 299-W14-11, 299-W14-19, 299-W15-43, 299-W15-44, 299-W15-46, 299-W15-49, 299-W15-50, 299-W18-16, and 699-50-74. As shown in Table 4-3, six of the RI/FS wells were not logged. The geophysical borehole survey for well 299-W15-152 was not completed when this 200-ZP-1 RI report was prepared. Appendix O includes the available geophysical borehole survey logs for 12 of the RI/FS wells. The well locations are shown on the plate map in Appendix A.

The 200-ZP-1 RI/FS work plan (DOE-RL 2004c) required geophysical borehole surveys for wells 299-W11-43 (well "H"), 299-W15-46 (located on the south side of the 216-Z-9 Trench), and 299-W15-49 (well "C"). The spectral-gamma survey results are summarized below for wells 299-W11-43 (well "H"), 299-W15-46, and 299-W15-49 (well "C").

Well 299-W11-43 (well "H") was logged using total gamma. The spectra were generated but, due to the thickness of the Becker dual-walled pipe joints, accurate casing correction factors could not be calculated; thus, only total gamma is presented. The influence of the thick joints is apparent on the total gamma where reduced count rates are exhibited at approximately 3-m (10-ft)-depth intervals. A plot of the repeated log demonstrates reasonable repeatability of the total gamma log. The report indicates, "No anomalous activity was observed. This observation suggests no significant concentrations of man-made radionuclides..." (Stoller 2005).

The log for 299-W15-49 (well "C") is a standard log presenting gross gamma and to quantify cesium-137, as well as the natural gamma emitters of potassium-40, uranium-238, and thorium-232. The natural emitters are sometimes coupled with soil lithology and are not

indicative of contamination. One man-made radionuclide, cesium-137, was detected in well 299-W15-49 (well "C") at activity levels close to the MDL of approximately 0.2 pCi/g. The low-activity levels were observed at various depths, and were interpreted as "...probably the result of statistical fluctuations and are not considered valid..." (FH 2005b, p. 2-43). The geophysical survey logs are not included in the borehole summary report (FH 2005b).

The spectral-gamma logging system for well 299-W15-46 is an approach using extremely low-yield gamma rays from americium-241 and plutonium-239 to measure those nuclides, as well as using protactinium-233 to measure neptunium-237. The usefulness of this data is being further assessed for the following reasons:

- The americium-241 gamma used is at 662.4 keV, almost exactly the same as cesium-137 (661.6 keV). Therefore, it is difficult to distinguish between americium-241 and cesium-137 because the energies are so close. In addition, because of the respective gamma yield per decay, 1 pCi/g of cesium-37 appears as approximately 238,000 pCi/g of americium-241, so the potential for false positives needs to be further investigated.
- The 375 keV region used for plutonium-239 is a crowded area of the spectra with other nuclides (natural or process) emitting at the energies in the same spectral region. It may be difficult to resolve the low-yield plutonium-239 gamma from other higher yield gamma emitters in the waste, and the potential for false positives needs to be further investigated.

The geophysical survey report and other information are presented in FH (2005c).

4.6.1.1.2 Lithology of 200-ZP-1 Sediment Samples. The lithology for wells 299-W15-46 and 299-W15-49 was described in borehole summary reports (FH 2005c, 2005b, respectively). The lithologic descriptions for these two wells are summarized in Tables 4-1 and 4-2. The borehole summary report for well 299-W11-43 had not been issued at the time that this RI report was prepared. Table 4-3 lists references for lithologic descriptions of other 200-ZP-1 RI/FS wells.

4.6.1.2 Geotechnical Analyses of 200-UP-1 Sediment Samples. Because some of the 200-ZP-1 geotechnical sampling was not successful due to poor sample recovery, the following 200-UP-1 data have been provided to supplement 200-ZP-1 results.

A total of 13 sediment core samples were collected during the installation at 200-UP-1 wells 299-W19-48, 699-36-70B, and 699-30-66. Only 4 of the 13 sediment core samples from 200-UP-1 were considered intact; the other 9 sediment samples were reported as slough material. One of the 13 sediment samples was collected from the Ringold Lower Mud Unit (sample B19377 from well 299-W19-48) and was reported as intact fine-grained silt and clay. The other 12 sediment samples were described as pebbles and sand with some larger cobbles, retrieved from Ringold Unit E. The 200-UP-1 sediment cores are listed in Table 4-12.

Particle-size distributions in the 200-UP-1 samples were also measured using the dry sieve and hydrometer methods of ASTM Method D422-63 (ASTM 2002a). The Ringold Unit E sediment samples ranged from approximately 26% to 55% gravel, 27% to 68% sand, 4% to 13% silt, and less than 1% to 5% clay. The single Ringold Lower Mud sample was approximately 21% sand, 69% silt, and 10% clay. Table 4-13 includes the 200-UP-1 particle-size data.

The calcium carbonate content of the 200-UP-1 sediment cores was measured by ASTM Method D4373 (ASTM 2002b) and ranged from 0% to 1.860% in the four intact sediment cores. The results are listed in Table 4-14.

PNNL characterized the mineralogical composition of the 200-UP-1 sediment samples by x-ray diffraction (Um et al 2005). Sediment samples from both the Ringold Unit E and the Lower Mud Unit were predominately quartz with plagioclase and potassium feldspars, as well as minor inclusions of hornblende and clay minerals. The silt and sand-size grains were primarily quartz and feldspar with hornblende and biotite and muscovite flakes. The clay sediments were mostly composed of smectite, chlorite, and illite. Bulk density was not measured in the 200-UP-1 samples.

4.6.2 Hydraulic and Transport Parameters for Sediment Samples

Porosity is not reported in the available 200-ZP-1 sediment data. Bulk density is described along with the geotechnical data in Section 4.6.1.1. The K_h was reported as 2.5E-05 cm/s at a depth of approximately 111 m (364 ft) from well 299-W11-43. A total of 17 hydraulic conductivity values were reported for sediment samples from various depths in well 299-W15-46. The reported values ranged from 2.7E-08 cm/s at a depth interval of approximately 127.2 to 127.9 m (417 to 419.5 ft), to 1.0E-04 cm/s at a depth interval of approximately 89.8 to 90.6 m (294.5 to 297 ft). Three hydraulic conductivity values were reported for well 299-W15-49 for sediment samples from two depth intervals. Hydraulic conductivity values of 1.2E-04 and 5.9E-05 were reported for two samples from the depth interval of approximately 79.3 to 79.9 m (260 to 262 ft). A hydraulic conductivity of 3.6E-07 was reported for the depth interval of 122.3 to 123.8 m (401 to 406 ft). The K_h data for the 200-ZP-1 sediment samples are shown in Table 4-10. Porosity and bulk density were not measured in the 200-UP-1 sediment samples.

4.6.3 Geochemical Parameters for Sediment Samples

The following subsections describe the geochemical parameters for sediment samples that were collected from three 200-ZP-1 wells while they were drilled: 299-W15-49 (well "C"), 299-W11-43 (well "H"), and 299-W15-46. Similar data are also described for samples from three 200-UP-1 wells: 299-W19-48 (well "K"), 699-36-70B (well "P"), and 699-30-66 (well "R").

4.6.3.1 Geochemical Analyses of 200-ZP-1 Sediment Samples. The number of sediment samples from each of the 200-ZP-1 boreholes that were analyzed for geochemical parameters varied as follows: 37 samples from well 299-W15-46, 6 samples from well 299-W15-49, and one sample from well 299-W11-43. The six geochemical parameters identified in Table 2-1 were obtained from the 200-ZP-1 sediment samples (i.e., major cations, CEC, TOC, TIC, pH, and K_d). The analytical methods are summarized in Section 2.4. Table 4-11 provides the analytical results for the major cations (i.e., sodium and calcium), CEC, TOC, TIC, and pH, and other geochemical parameters that were not required in the 200-ZP-1 RI/FS work plan (DOE-RL 2004c).

As shown in Table 4-11, sodium and calcium cation data are available for 30 of the 37 sediment samples from well 299-W15-46, all 6 of the sediment samples from well 299-W15-49, and the single sediment sample from well 299-W11-43. The lowest and highest sodium and calcium cation concentrations were identified in sediment samples from approximately the same depths in the 299-W15-46 borehole. Sodium cation concentrations in well 299-W15-46 ranged from 2.97E+04 µg/kg at a depth of approximately 90.6 m (297 ft) to 2.66E+06 µg/kg at a depth of approximately 37.2 m (122 ft). Calcium cation concentrations in well 299-W15-46 ranged from

1.16E+06 μg/kg at a depth of approximately 91.3 m (299.5 ft) to 3.29E+07 μg/kg at a depth of approximately 36.4 m (119.5 ft).

The CEC data are available from 27 of the 37 sediment samples from well 299-W15-46, all 6 of the sediment samples from well 299-W15-49, and the single sediment sample from well 299-W11-43. The lowest and highest CEC values were identified in sediment samples from the 299-W15-46 borehole. The CEC values in well 299-W15-46 ranged from 2.8 mEQ/100 g at a depth of approximately 28.2 m (92.5 ft) to 97.7 mEQ/100 g at a depth of approximately 79.1 m (259.5 ft).

The TOC and TIC data are available from 29 of the 37 sediment samples from well 299-W15-46, all 6 of the sediment samples from well 299-W15-49, and the single sediment sample from well 299-W11-43. The lowest and highest TOC and TIC concentrations were identified in sediment samples from the 299-W15-46 borehole. The TOC concentrations in well 299-W15-46 ranged from 3.64E+04 μg/kg at a depth of approximately 90.6 m (297 ft) to 2.60E+06 μg/kg at a depth of approximately 37.2 m (122 ft). The TIC concentrations in well 299-W15-46 ranged from 4.70E+03 μg/kg at depths of approximately 69.1 m (226.5 ft) and 73 m (239.5 ft) to 5.44E+06 μg/kg at a depth of approximately 37.2 m (122 ft).

Table 4-11 shows that pH data are available from 31 of the 37 sediment samples from well 299-W15-46, each of the 6 of the sediment samples from well 299-W15-49, and the single sediment sample from well 299-W11-43. The lowest and highest pH values were identified in sediment samples from the 299-W15-46 borehole. The pH values in well 299-W15-46 ranged from a pH of 3.86 at a depth of approximately 20.1 m (66 ft) to a pH of 9.7 at a depth of approximately 147 m (482 ft).

Table 4-11 also includes available data for manganese, nitrate, iron, and sulfate concentrations in sediment samples from the same three wells. The K_d data for well 299-W15-46 were developed in Riley et al. (2005), as described in Section 3.1.4. The K_d for carbon tetrachloride ranged from 0.106 to 0.367 L/kg. The K_d for chloroform ranged from 0.084 to 0.432 L/kg. While attempts were made to collect soil samples from wells 200-W15-49 and 299-W11-43 for K_d analysis, poor sample recovery did not allow these analyses to be performed. Additional samples for K_d analysis are planned for FY06 from 200-ZP-1 wells to be installed between the Old Laundry Facility and T Plant.

4.6.3.2 Geochemical Analyses of 200-UP-1 Sediment Samples. Because some of the 200-ZP-1 geochemical sampling was unsuccessful due to poor sample recovery, the following 200-UP-1 data are provided as a supplement. A total of 13 sediment core samples were collected during the installation of 200-UP-1 wells 299-W19-48, 699-36-70B, and 699-30-66. PNNL measured properties in the 200-UP-1 sediment cores that were specified in Table A2-2 of the 200-ZP-1 RI/FS work plan for 200-ZP-1 sediment samples (Um et al. 2005): TOC, TIC, pH, K_d, and CEC. The TOC and TIC were measured according to ASTM Method E1915-01 (ASTM 2005). The total carbon in the four 200-UP-1 intact sediment cores ranged from 0.015% to 0.239%; TIC ranged from 0% to 0.223%. The corresponding pH values ranged from 7.48 to 7.59. The 200-UP-1 TOC, TIC, and pH data are included in Table 4-14.

Three sediment properties were measured that were not specified in Table A2-2 of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c): moisture content, alkalinity, and electrical conductivity. Analyses of the four intact 200-UP-1 sediment cores showed the following results: moisture content ranged from 5.88% to 32.5%; alkalinity ranged from 170.2 to 743.4 mg/L; electrical

conductivity ranged from 0.40 to 1.812 mS/cm. The additional data are shown in Table 4-14. The calcium carbonate values in Table 4-14 were previously discussed in Section 4.6.1.2.

PNNL measured the CEC of five 200-UP-1 sediment cores by a radiotracer procedure (Routson et al. 1973). As shown in Table 4-15, the CECs ranged from 1.66 to 44.91 meq/100 g and increased as the proportion of clay minerals and hydrous iron oxides increased. The clay minerals of the Ringold Lower Mud Unit resulted in a high CEC. The higher-than-expected CEC for the bulk sample with gravel (i.e., combination of HEIS samples B19136 and B19137 from well 699-36-70B) was described as the result of silt and clay coatings on gravel surfaces (Um et al. 2005).

PNNL estimated K_d values in short-term adsorption tests on 200-UP-1 sediment cores that represented three lithologic units: Ringold Unit E, Ringold gravel, and Ringold Lower Mud Unit. The K_d values were estimated for the following eight contaminants: technetium-99, uranium (VI), strontium-90, cesium-137, neptunium (V), hexavalent chromium, selenium (VI), and iodine-129 (Um et al. 2005). PNNL noted that the short-term adsorption tests might under-estimate actual desorption K_d values for sediments that are contaminated for decades, and that the adsorption-based K_d values could then over-estimate contaminant quantities that are released to water through soil flushing or pump-and-treat remediation technologies (Um et al. 2005 [Section 5.0, pp. 5-3 through 5-4]).

The recommended K_d values for use in risk transport modeling are shown in Table 4-16 for each of the three tested lithologic units. For remediation modeling, PNNL recommended applying the higher uranium desorption K_d values at the bottom of Table 4-16 to compensate for the difference in desorption and adsorption K_d values that are noted above. PNNL did not perform detailed desorption studies on the seven evaluated contaminants other than uranium. As a precaution, PNNL recommended using K_d values twice as high as those shown in Table 4-16 for technetium-99, strontium-90, neptunium, hexavalent chromium, selenium, and iodine-129.

4.7 MODELING INPUT PARAMETERS FOR GROUNDWATER

Groundwater data for the hydraulic and geochemical modeling parameters in Table 2-1 were collected during drilling, development, and aquifer testing of three recently installed wells in the 200-ZP-1 OU: 299-W11-43 (well "H"), 299-W15-46, and 299-W15-49 (well "C"). The three wells were selected for multiple data needs because they are located near contamination sources and within several contaminant plumes. The K_h measurements were also obtained during drilling of wells 299-W11-43 (well "H"), 299-W15-50 (well "E"), and 299-W18-16 (well "D"). Additional hydraulic data are presented that were obtained during the development of the RI/FS wells. The approximate well locations are shown on the plate map in Appendix A.

Groundwater samples were collected for geochemical analyses from various depths while drilling three 200-ZP-1 wells and were reported as follows: 5 depth intervals in well 299-W11-43 ranging from approximately 90.9 to 136.9 m (298 to 449 ft); 31 depth intervals in well 299-W15-46 ranging from approximately 69.5 to 161.5 m (228 to 529.5 ft); and 9 depth intervals in well 299-W15-49 ranging from approximately 82.4 to 134.2 m (270 to 440 ft). These samples were analyzed for the parameters identified in Table 2-1. The hydraulic and geochemical analytical results are summarized in Tables 4-17, 4-18, and 4-19.

4.7.1 Hydraulic and Transport Parameters for Groundwater Samples

The 200-ZP-1 RI/FS work plan (DOE-RL 2004c) and Table 2-1 identify six hydraulic and transport parameters as required modeling inputs: hydraulic gradient, aquifer slug test data (e.g., K_h), groundwater production rates, water-level drawdown, groundwater pumping performance, and dispersivity. The 200-ZP-1 area hydraulic gradient is discussed in Section 4.1.3.2; the other five hydraulic parameters are discussed in the following subsections.

4.7.1.1 Slug Test and Hydraulic Conductivity. PNNL reported the results of unconfined aquifer tests in the 200-ZP-1 OU (PNNL 2005b). A series of seven slug tests were conducted in FY05 during the drilling of wells 299-W11-43 (well "H"), 299-W15-50 (well "E"), and 299-W18-16 (well "D") to estimate horizontal K_h at three depth intervals in the Ringold Formation (Unit 5): the upper zone, 71 to 98 m (232.9 to 321.5 ft) bgs; the middle zone, 83 to 137 m (272.3 to 449.5 ft) bgs; and the lower zone, 99 to 137 m (324.8 to 449.5 ft) bgs. Table 4-17 provides a summary of the slug test results, including the intervals tested and methods used. The calculated K_h values ranged from 2.58 to 3.07 m/day (8.46 to 10.07 ft/day) for the upper zone, 2.93 to 25.5 m/day (9.61 to 83.66 ft/day) for the middle zone, and 8.06 to 17.7 m/day (26.44 to 58.07 ft/day) for the lower zone. The highest K_h values were obtained from well 299-W11-43, which is the northernmost of the three tested boreholes. Limited data were collected from the borehole for well 299-W18-16 due to borehole instability and deadline requirements. PNNL reported that the limited K_h vertical data did not indicate a consistent depth-related pattern, but that testing of well 299-W11-25 in the WMA-T area (east to northeast of the three tested 200-ZP-1 wells) exhibited "slightly increasing permeability with depth pattern" (PNNL 2005b, p. 18).

Slug tests have been conducted within the upper 10 m (32.8 ft) of the Ringold Formation on 30 other wells in the 200 West Area since FY99 (Spane et al. 2001a, 2001b, 2002, 2003; Spane and Newcomer 2004). The calculated K_h for the 30 wells ranged from 0.07 to 28.1 m/day (0.23 to 92.19 ft/day), with a geometric mean of 3.08 m/day (10.1 ft/day). The only comparable slug test for the three wells tested in FY05 was conducted on the upper zone in well 299-W15-50, and the resulting K_h value was 3.07 m/day (10.07 ft/day).

4.7.1.2 Well Development Data. Groundwater production rates, water-level drawdown, and groundwater pumping performance are included in Table 4-18 for 10 of the RI/FS wells with available well development data. The borehole summary reports for six RI/FS wells were either unavailable or did not include well development data. The borehole summary report for wells 299-W11-43, 299-W15-152, and 699-50-74 (FH 2006a [in publication]) had not yet been issued when this 200-ZP-1 RI report was prepared. The available borehole summary reports for the RI/FS wells are listed in Table 4-3. Well development data for other 200-ZP-1 wells may be obtained from the applicable borehole summary reports. Similar data for well 299-W11-43 were not available when this RI report was prepared. The data were obtained during development of multiple intervals in each well. Well development pumping data are provided in borehole summary reports. Drawdown, turbidity, electrical conductivity, temperature, pH, and other data for each developed depth interval are shown in Table 4-18.

4.7.1.3 Dispersivity. Dispersivity is a coefficient used in groundwater fate and transport modeling to describe the movement of a solute (i.e., dissolved contaminant) relative to average groundwater velocity. On a small scale, dispersivity describes solute movement due to differential velocities caused by pore space geometry. On a larger scale, dispersivity may

describe solute movement due to differential velocities caused by heterogeneities in the aquifer. The solute dispersion due to a dispersivity coefficient results in spreading of the contaminant plume with gradual concentration profiles at the plume edges.

PNNL evaluated dispersivity as one of five stochastic modeling parameters by Monte Carlo methods in lieu of field tracer measurements that were shown in Table 2-1. The study was reported in *Assessment of Carbon Tetrachloride Groundwater Transport in Support of the Hanford Carbon Tetrachloride Innovative Technology Demonstration Program* (Truex et al. 2001). The other four parameters were the carbon tetrachloride K_d, K_a, porosity, and the "stream-tube" cross-sectional area. The study is summarized in Section 3.1.5. A triangular probability distribution was used for longitudinal dispersivity, with a minimum value of 10 m (32.8 ft), a maximum value of 100 m (328.1 ft), and a most probable value of 30 m (98.4 ft).

4.7.2 Geochemical Parameters for Groundwater Samples

Depth-discrete groundwater samples were collected from three 200-ZP-1 wells (i.e., 299-W11-43, 299-W15-46, and 299-W15-49) and analyzed for geochemical properties and COC concentrations. The following nine geochemical parameters identified in Table 2-1 were analyzed in groundwater samples from the three 200-ZP-1 wells: major cations (i.e., sodium and calcium), specific conductance, TOC, TIC, pH, temperature, alkalinity, DO, and turbidity. The tenth geochemical parameter identified in Table 2-1, CEC, was measured in soil samples from the boreholes for the three wells, but because there is no appropriate analytical method for this parameter in water, it was not measured in the groundwater samples. The following geochemical parameters are not required in the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) but are included in Table 4-19: sulfate, nitrate, manganese, and iron. The depth-discrete groundwater data are summarized in Table 4-19.

As shown in Table 4-19, sodium and/or calcium cation data are available for 10 of the 37 groundwater samples from well 299-W15-46, 9 of the 12 groundwater samples from well 299-W15-49, and all 6 of the groundwater samples from well 299-W11-43. The lowest sodium and calcium cation concentrations (200 and 33.8 µg/L, respectively) were identified in well 299-W15-49. The highest sodium and calcium cation concentrations (50,900 and 209,000 µg/L, respectively) were found in well 299-W15-46 at depths of approximately 70.3 m (230.5 ft) for sodium and at approximately 90.6 m (297 ft) for calcium.

Specific conductance data are available for 16 of the 37 groundwater samples from well 299-W15-46, 8 of the 12 groundwater samples from well 299-W15-49, and 5 of the 6 groundwater samples from well 299-W11-43. The lowest specific conductance value of 312 µS/cm was identified in well 299-W15-49 at a depth of approximately 93 m (305 ft). The highest specific conductance value of 1,283 µS/cm was identified in well 299-W15-46 at a depth of approximately 89.4 m (293 ft).

Data for TOC and/or TIC are available from 14 of the 37 groundwater samples from well 299-W15-46, 7 of the 12 groundwater samples from well 299-W15-49, and 5 of the 6 groundwater samples from well 299-W11-43. The lowest TOC and TIC concentrations were identified in well 299-W15-49. The TOC in well 299-W15-49 ranged from 500 µg/L in two groundwater samples at depths of approximately 82.4 m and 134.2 m (270 ft and 440 ft) to 17,000 µg/L at a depth of approximately 93 m (305 ft). The TIC in well 299-W15-49 ranged from 3,600 µg/L at an unspecified depth to 32,600 µg/L at a depth of approximately 93 m (305 ft). The TOC concentration of 17,000 µg/L in well 299-W15-49 was also the highest TOC

of the three 200-ZP-1 wells. The highest TIC concentration of 51,500 µg/L was found in well 299-W11-43 at a depth of approximately 136.9 m (449 ft).

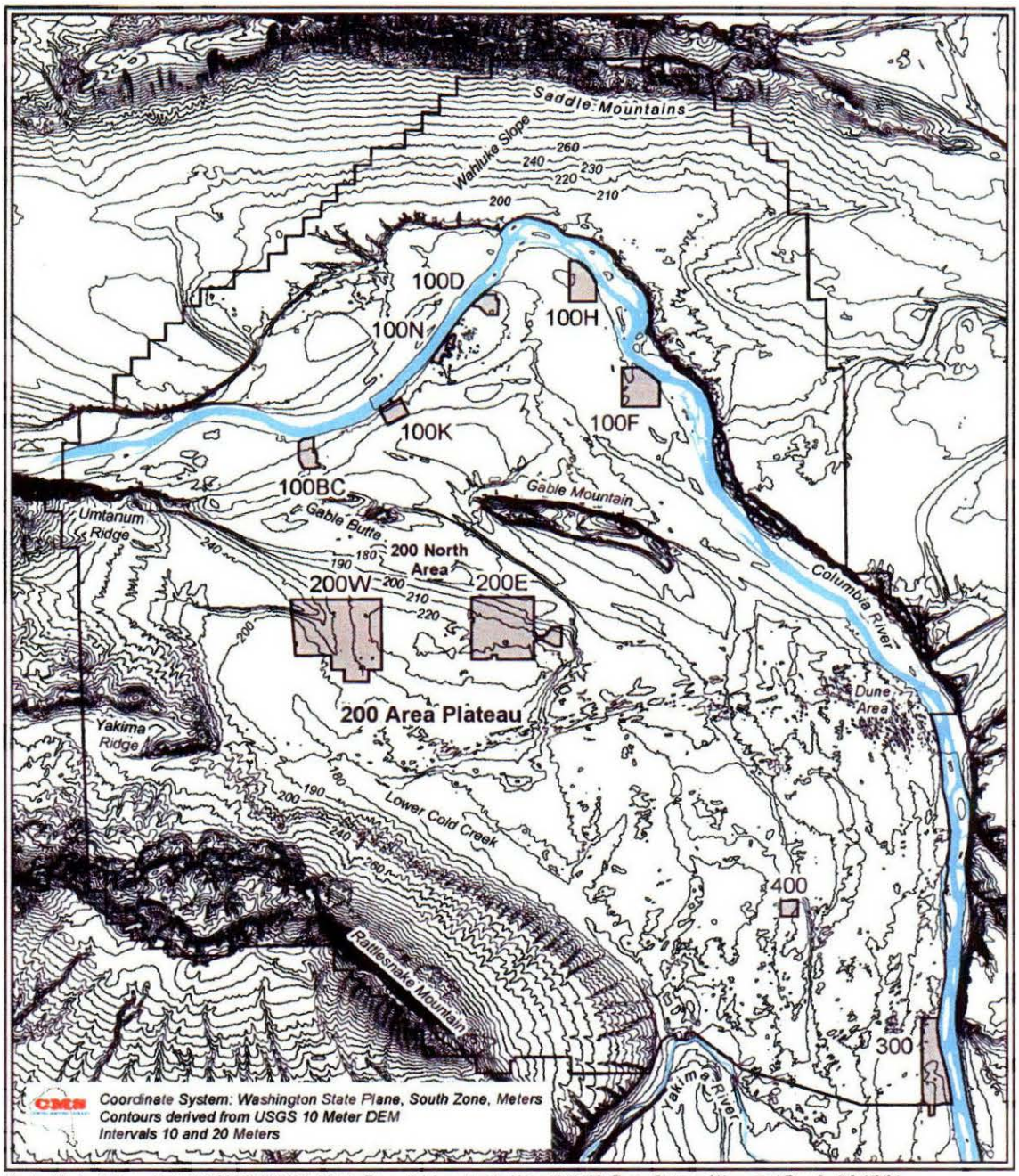
Table 4-19 shows that pH and/or temperature data are available from 19 of the 37 groundwater samples from well 299-W15-46, 11 of the 12 groundwater samples from well 299-W15-49, and all 6 of the groundwater samples from well 299-W11-43. The lowest and highest pH values were measured in well 299-W15-46. The pH in well 299-W15-46 ranged from 4.654 at a depth of approximately 90.7 m (297.5 ft) to 8.791 at a depth of approximately 122 m (400 ft). The lowest temperature of 13.7°C (56.7°F) was measured in well 299-W15-46 a depth of approximately 122 m (400 ft) in the same groundwater sample with the highest pH value. The highest temperature of 24.2°C (75.6°F) was measured in well 299-W11-43 at a depth of approximately 111.1 m (364 ft).

Alkalinity data are available for none of the 37 groundwater samples from well 299-W15-46, 7 of the 12 groundwater samples from well 299-W15-49, and 5 of the 6 groundwater samples from well 299-W11-43. The lowest alkalinity value of 2,000 µg/L was measured in well 299-W15-49 at an unspecified depth. The highest alkalinity value of 129,000 µg/L was measured in well 299-W11-43 at a depth of approximately 136.9 m (449 ft).

The DO data are available from 11 of the 37 groundwater samples from well 299-W15-46, 4 of the 12 groundwater samples from well 299-W15-49, and 5 of the 6 groundwater samples from well 299-W11-43. The lowest DO concentration of 160 µg/L was measured in well 299-W15-46 at a depth of approximately 147 m (482 ft). The highest DO concentration of 8,800 µg/L was measured in well 299-W11-43 at a depth of approximately 100 m (328 ft).

Turbidity data are available from 15 of the 37 groundwater samples from well 299-W15-46, 7 of the 12 groundwater samples from well 299-W15-49, and 5 of the 6 groundwater samples from well 299-W11-43. The lowest turbidity value of 0.21 nephelometric turbidity units (NTU) was measured in well 299-W15-46 at a depth of approximately 72.3 m (237 ft). The highest turbidity value of 1,000 NTU was measured in wells 299-W15-46 and 299-W15-49 at various depths.

Figure 4-1. Topographic Map of the Hanford Site.



System\Projects\OperableUnits\200CS1\031203_Webb_Remedial_Investigation\Maps\040106_Topo_Plateau_2N_ap.mxd Rev. 0 dhf 1/6/04

Figure 4-2. Generalized Stratigraphic Column for the 200-ZP-1 Operable Unit.

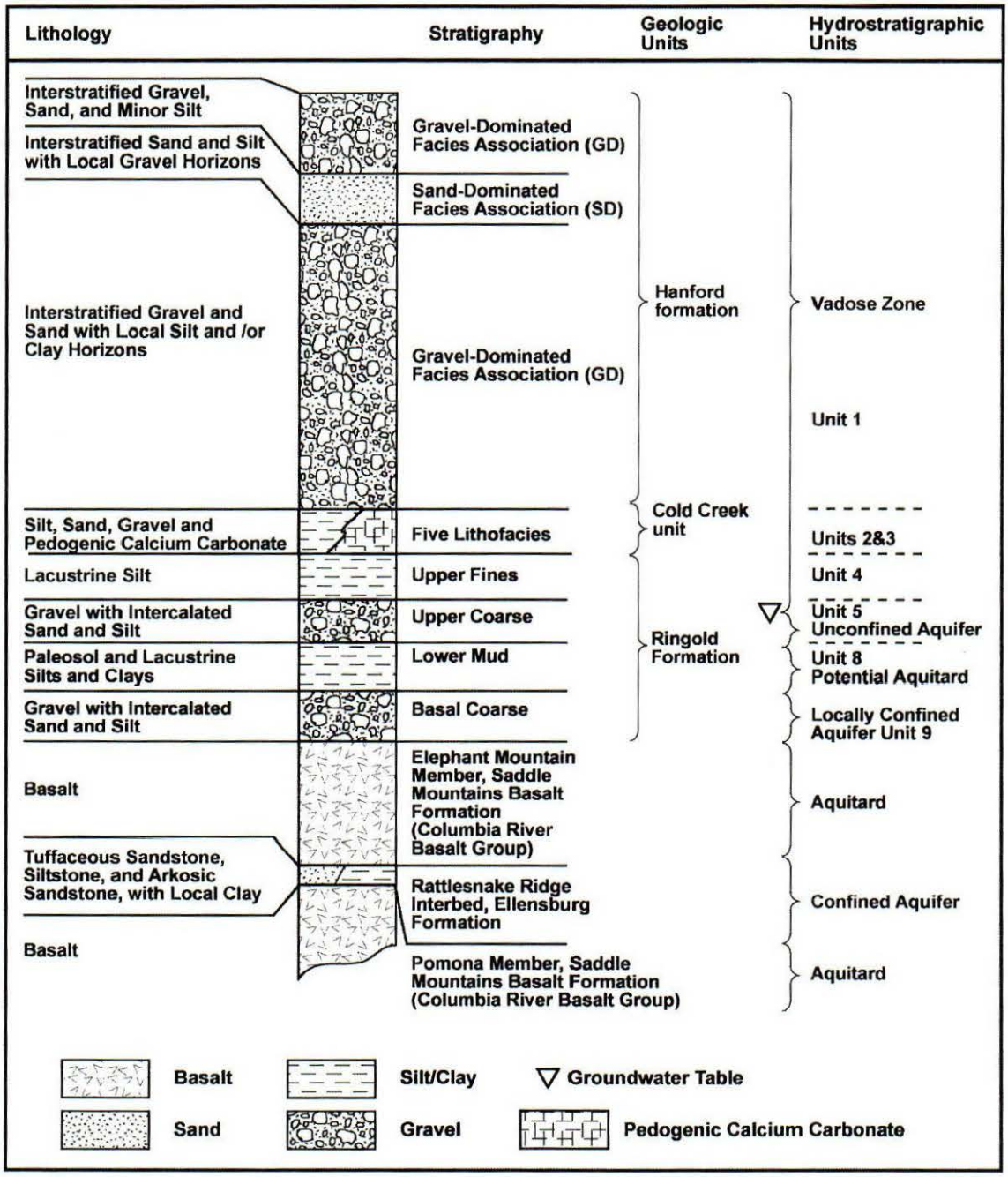


Figure 4-3. Hydrogeologic Cross-Section Locations in the 200 West Study Area (from Williams et al. 2002).

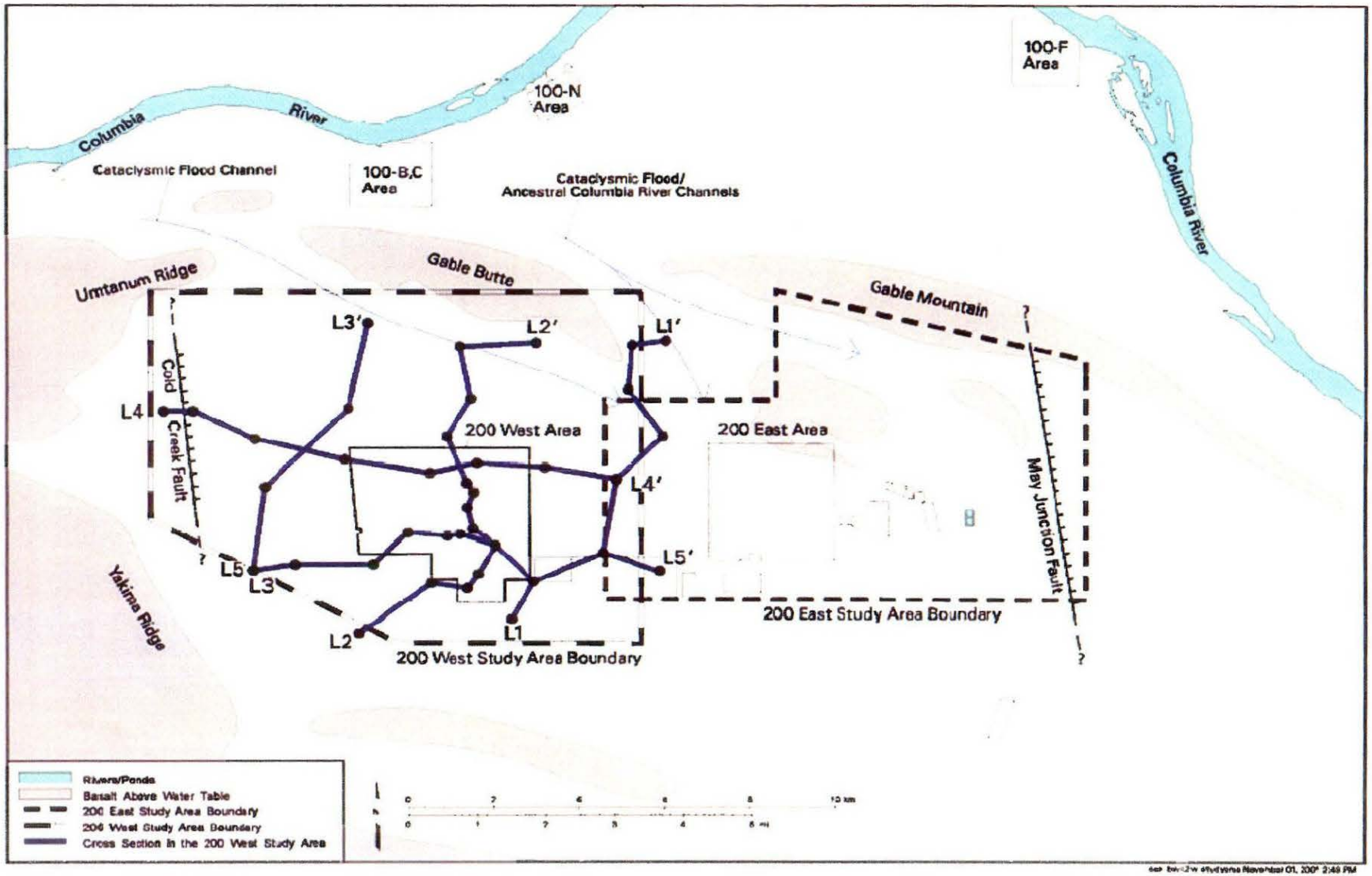


Figure 4-4. Schematic Hydrogeologic Cross Section of Line 2-2' (from Williams et al. 2002).

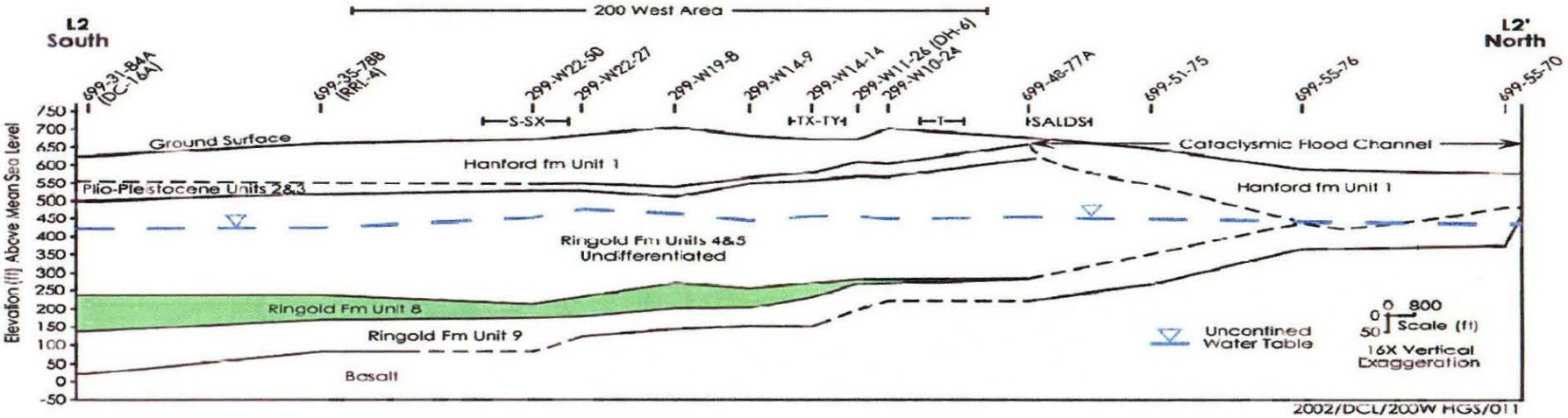


Figure 4-5. Schematic Hydrogeologic Cross Section of Line 4-4' (from Williams et al. 2002).

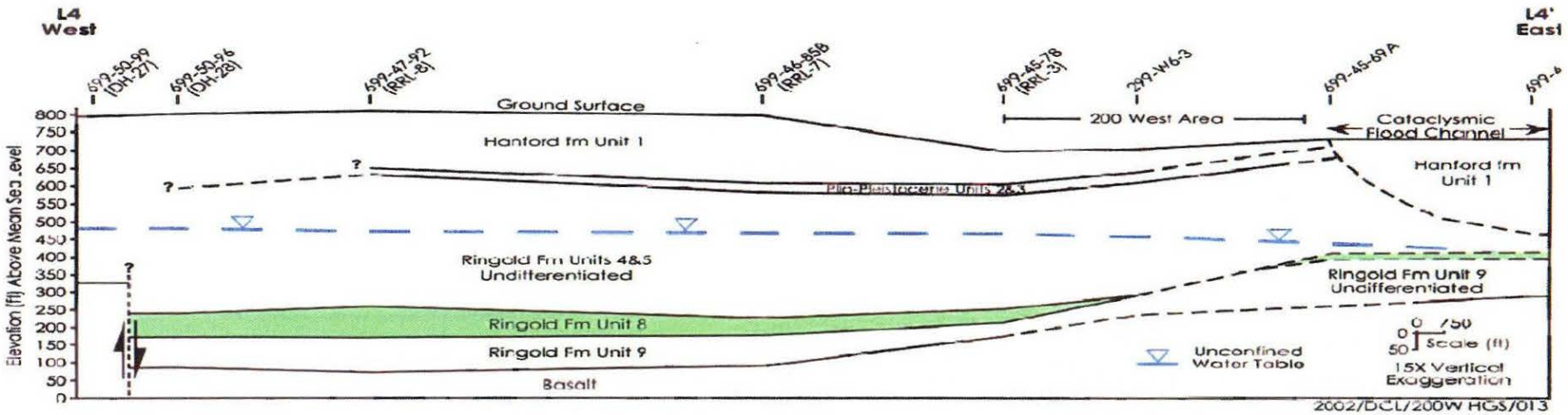


Figure 4-6. Hanford Site Water Table Map, March 2004 (from PNNL 2005a).

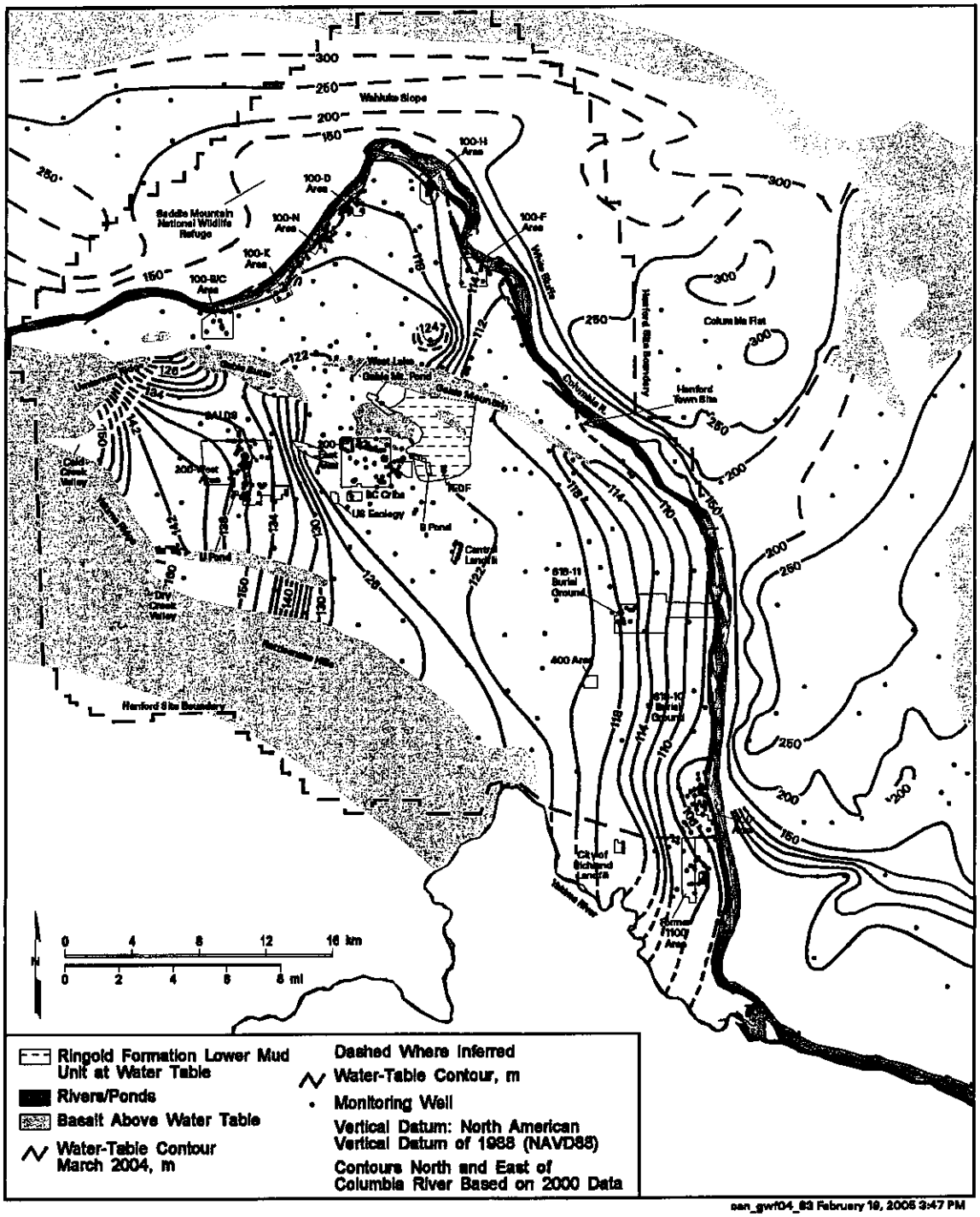


Figure 4-7. 299-W15-34 Carbon Tetrachloride Trend Plot.

Well:299-W15-34 **Category:** ORGANIC **Constituent:** Carbon tetrachloride
Class: VOA **Preliminary Target Action Limit:** 3 ug/L

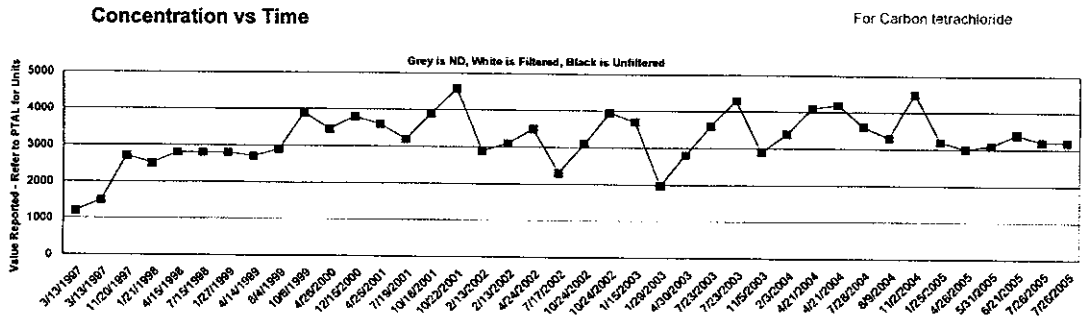


Figure 4-8. 299-W15-1 Carbon Tetrachloride Trend Plot.

Well:299-W15-1 **Category:** ORGANIC **Constituent:** Carbon tetrachloride
Class: VOA **Preliminary Target Action Limit:** 3 ug/L

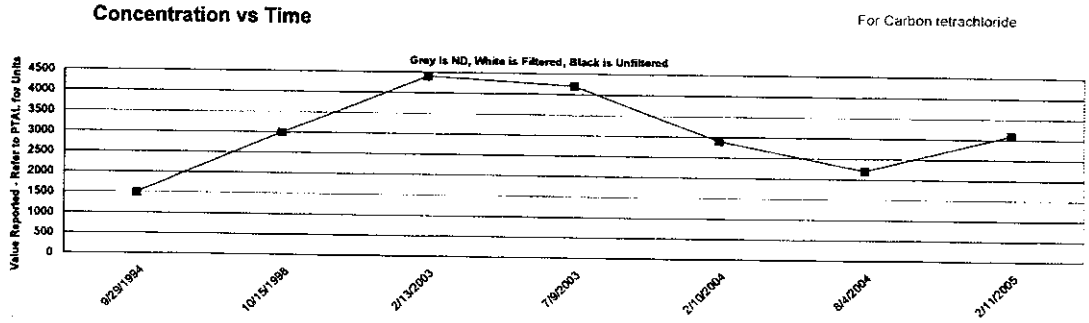


Figure 4-9. 299-W11-10 Carbon Tetrachloride Trend Plot.

Well:299-W11-10 **Category:** ORGANIC **Constituent:** Carbon tetrachloride
Class: VOA **Preliminary Target Action Limit:** 3 ug/L

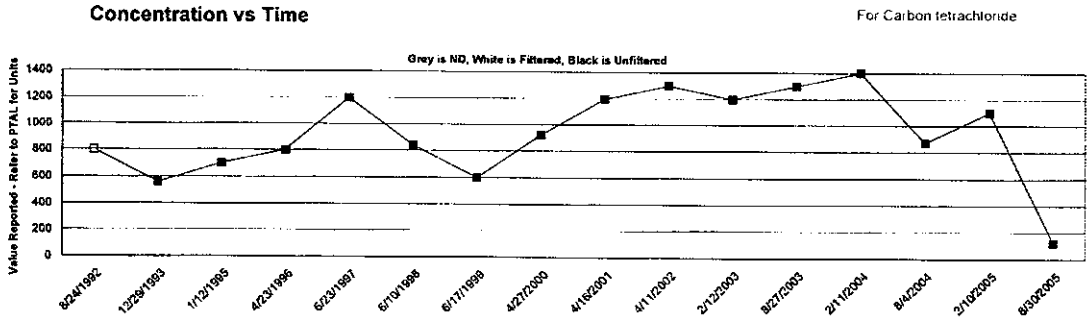


Figure 4-10. 299-W13-1 Carbon Tetrachloride Trend Plot.

Well:299-W13-1 **Category:** ORGANIC **Constituent:** Carbon tetrachloride
Class: VOA **Preliminary Target Action Limit:** 3 ug/L

Concentration vs Time For Carbon tetrachloride

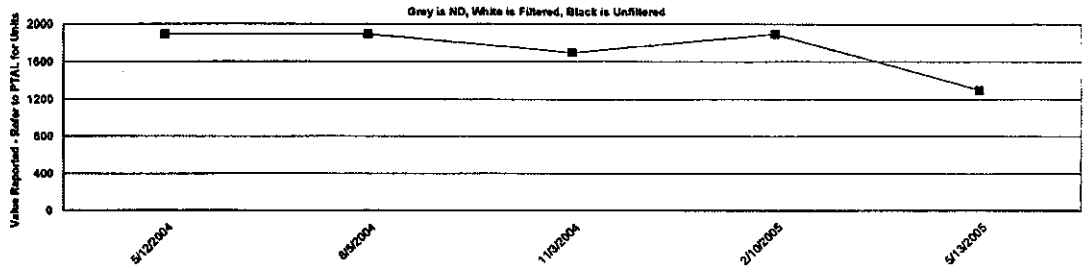


Figure 4-11. 299-W15-40 Carbon Tetrachloride Trend Plot.

Well:299-W15-40 **Category:** ORGANIC **Constituent:** Carbon tetrachloride
Class: VOA **Preliminary Target Action Limit:** 3 ug/L

Concentration vs Time For Carbon tetrachloride

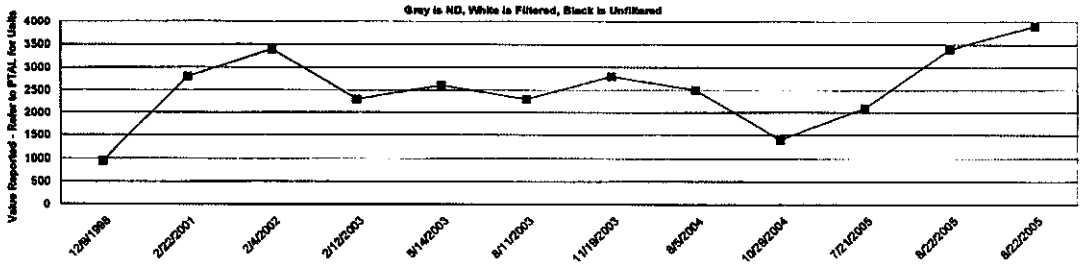


Figure 4-12. 299-W15-43 Carbon Tetrachloride Trend Plot.

Well:299-W15-43 **Category:** ORGANIC **Constituent:** Carbon tetrachloride
Class: VOA **Preliminary Target Action Limit:** 3 ug/L

Concentration vs Time For Carbon tetrachloride

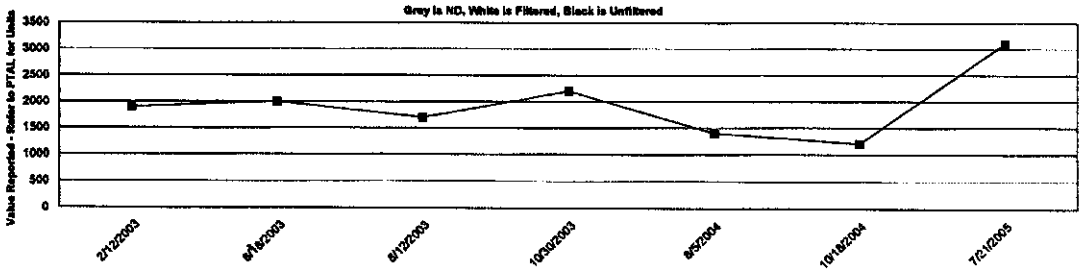


Figure 4-13. 299-W15-44 Carbon Tetrachloride Trend Plot.

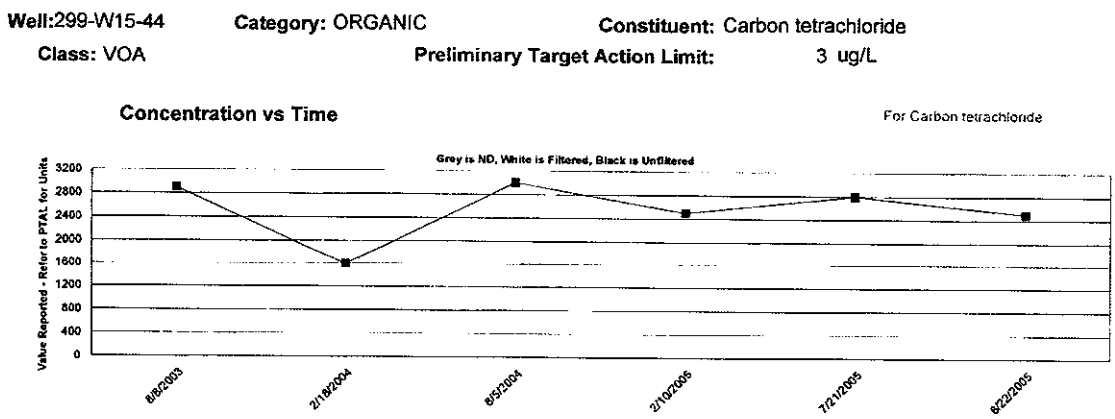


Figure 4-14. 299-W15-765 Carbon Tetrachloride Trend Plot.

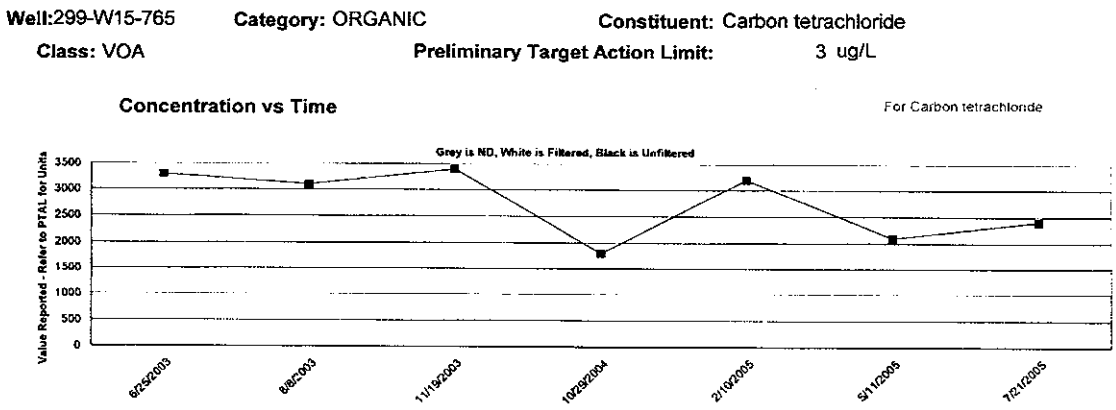


Figure 4-15. 299-W15-50 Trichloroethylene Trend Plot.

Well:299-W15-50 **Category:** ORGANIC **Constituent:** Trichloroethylene
Class: VOA **Preliminary Target Action Limit:** 5 ug/L

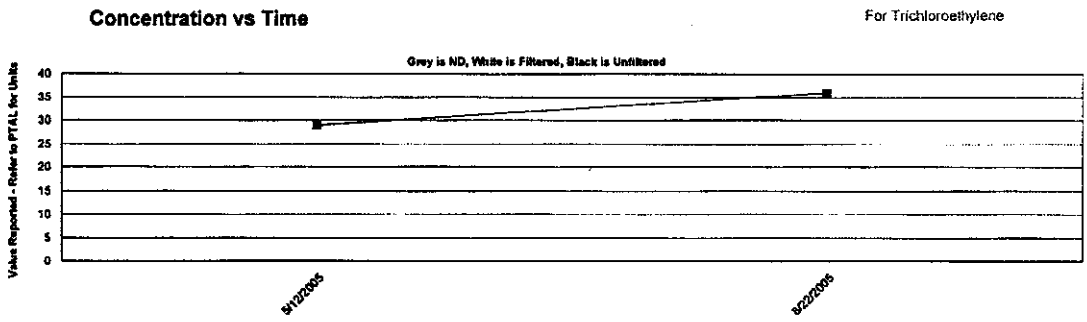


Figure 4-16. 299-W15-44 Trichloroethylene Trend Plot.

Well:299-W15-44 **Category:** ORGANIC **Constituent:** Trichloroethylene
Class: VOA **Preliminary Target Action Limit:** 5 ug/L

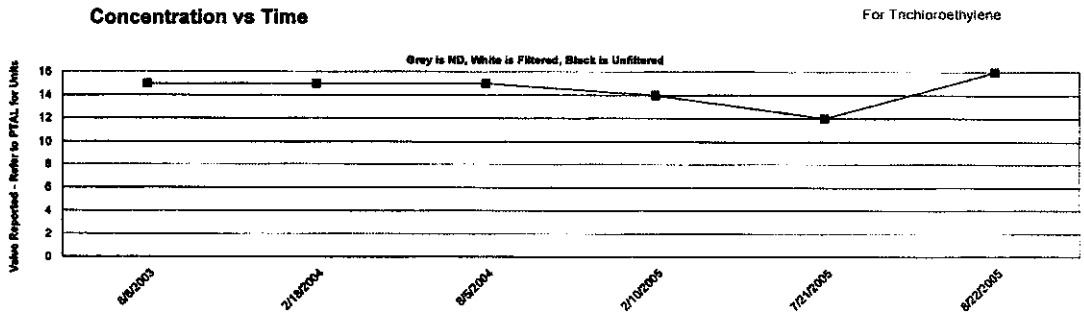


Figure 4-17. 299-W13-1 Trichloroethylene Trend Plot.

Well:299-W13-1 **Category:** ORGANIC **Constituent:** Trichloroethylene
Class: VOA **Preliminary Target Action Limit:** 5 ug/L

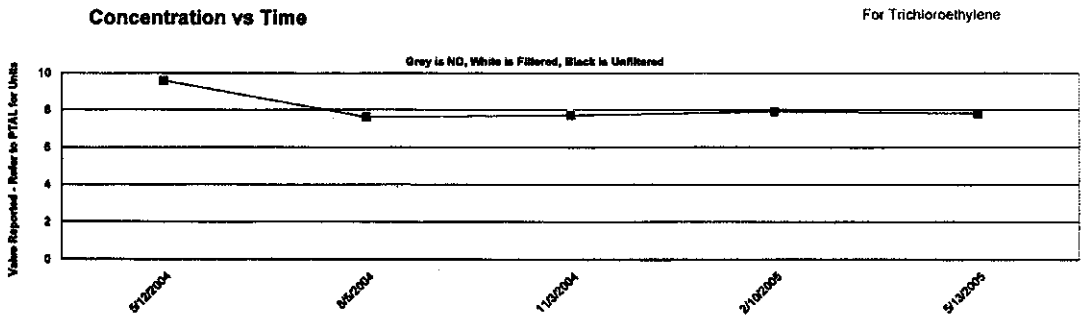
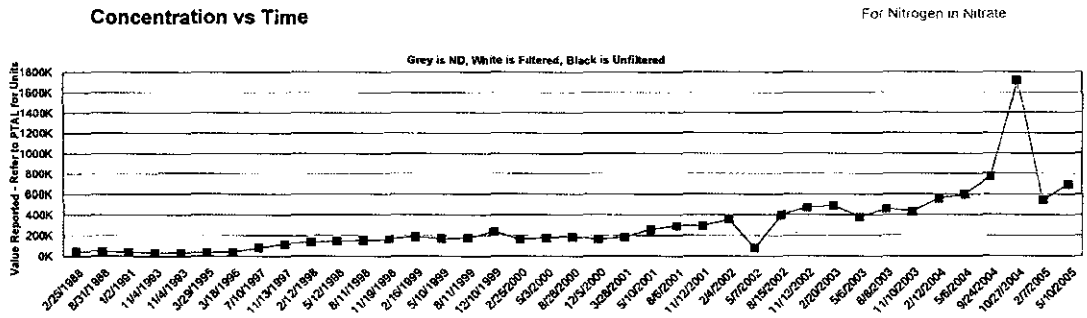


Figure 4-18. 299-W10-4 Nitrate Trend Plot.

Well:299-W10-4 **Category:** INORGANIC **Constituent:** Nitrogen in Nitrate
Class: WETCHEM **Preliminary Target Action Limit:** 10,000 ug/L



Well:699-48-71 **Category:** INORGANIC **Constituent:** Nitrogen in Nitrate
Class: WETCHEM **Preliminary Target Action Limit:** 10,000 ug/L

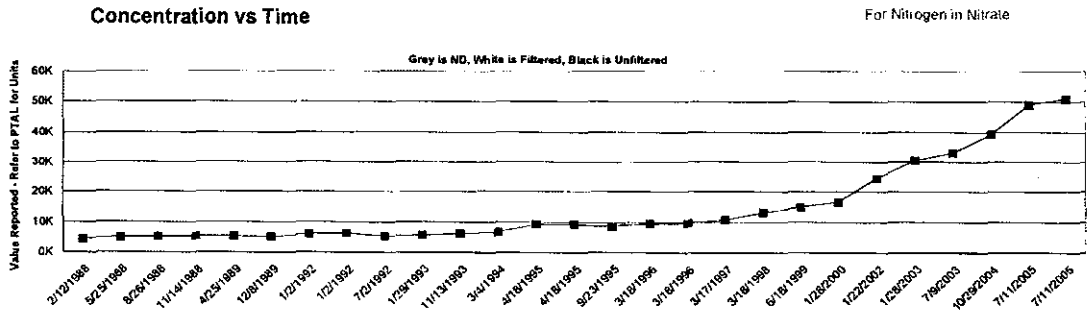


Figure 4-19. 699-48-71 Nitrate Trend Plot.

Figure 4-20. 299-W10-4 Chromium Trend Plot.

Well:299-W10-4 **Category:** INORGANIC **Constituent:** Chromium
Class: METALS **Preliminary Target Action Limit:** 100 ug/L

Concentration vs Time For Chromium

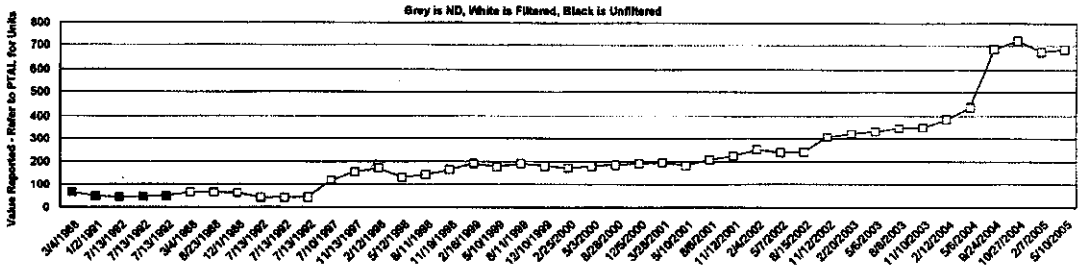


Figure 4-21. 299-W14-13 Chromium Trend Plot.

Well:299-W14-13 **Category:** INORGANIC **Constituent:** Chromium
Class: METALS **Preliminary Target Action Limit:** 100 ug/L

Concentration vs Time For Chromium

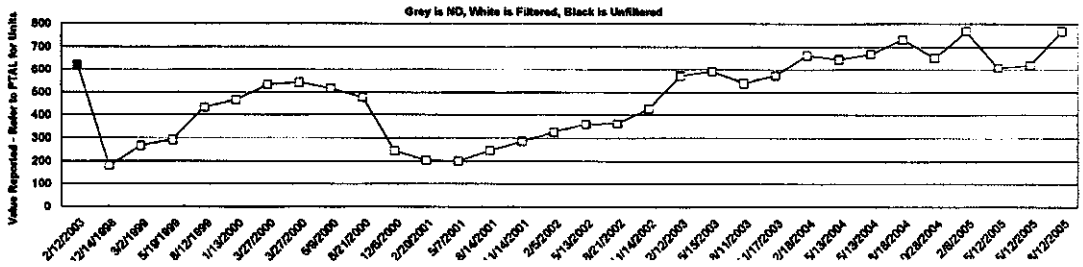


Figure 4-22. 299-W11-39 Technetium-99 Trend Plot.

Well:299-W11-39 **Category:** RAD **Constituent:** Technetium-99
Class: RAD **Preliminary Target Action Limit:** 900 pCi/L

Concentration vs Time For Technetium-99

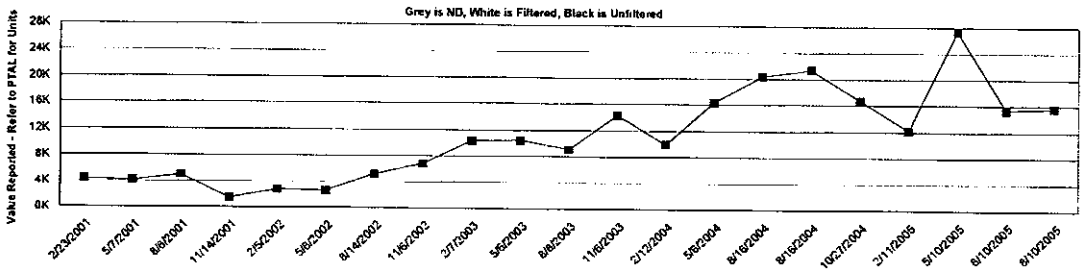


Figure 4-23. 299-W14-13 Technetium-99 Trend Plot.

Well:299-W14-13 **Category:** RAD **Constituent:** Technetium-99
Class: RAD **Preliminary Target Action Limit:** 900 pCi/L

Concentration vs Time For Technetium-99

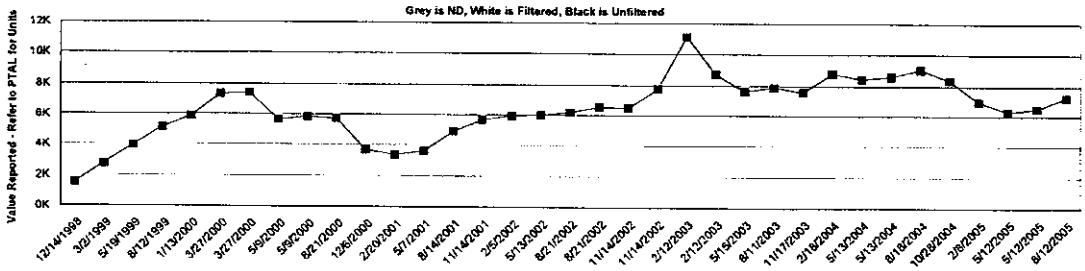


Figure 4-24. 299-W11-14 Uranium Trend Plot.

Well:299-W11-14 **Category:** INORGANIC **Constituent:** Total Uranium
Class: METALS **Preliminary Target Action Limit:** 30 ug/L

Concentration vs Time For Total Uranium

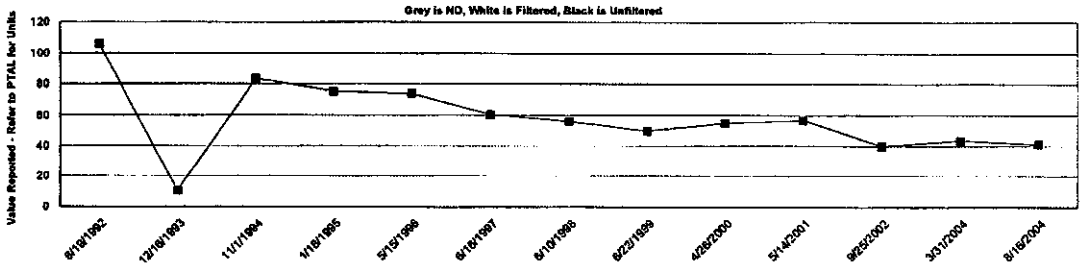


Figure 4-25. 299-W11-37 Uranium Trend Plot.

Well:299-W11-37 **Category:** INORGANIC **Constituent:** Total Uranium
Class: METALS **Preliminary Target Action Limit:** 30 ug/L

Concentration vs Time For Total Uranium

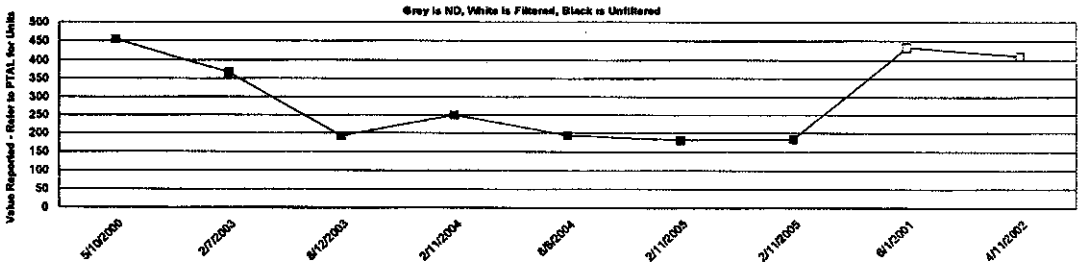


Figure 4-26. 299-W18-21 Uranium Trend Plot.

Well:299-W18-21 **Category:** INORGANIC **Constituent:** Total Uranium
Class: METALS **Preliminary Target Action Limit:** 30 ug/L

Concentration vs Time For Total Uranium

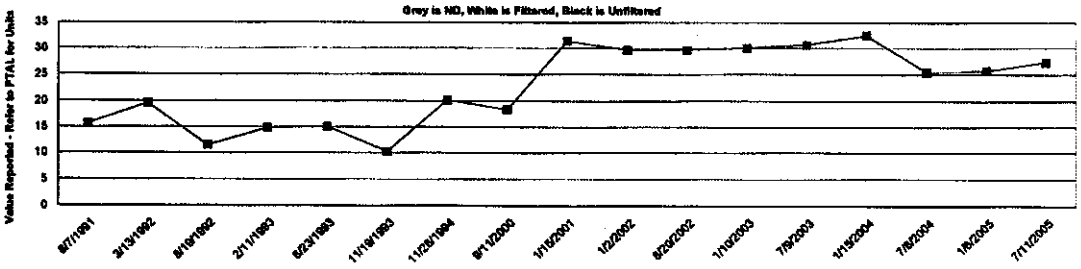


Figure 4-27. 299-W14-13 Iodine-129 Trend Plot.

Well:299-W14-13 **Category:** RAD **Constituent:** Iodine-129
Class: RAD **Preliminary Target Action Limit:** 1 pCi/L

Concentration vs Time For Iodine-129

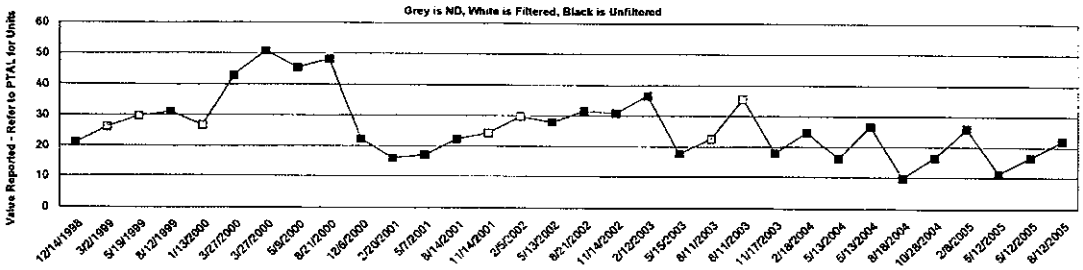


Figure 4-28. 299-W14-15 Iodine-129 Trend Plot.

Well:299-W14-15 **Category:** RAD **Constituent:** Iodine-129
Class: RAD **Preliminary Target Action Limit:** 1 pCi/L

Concentration vs Time For Iodine-129

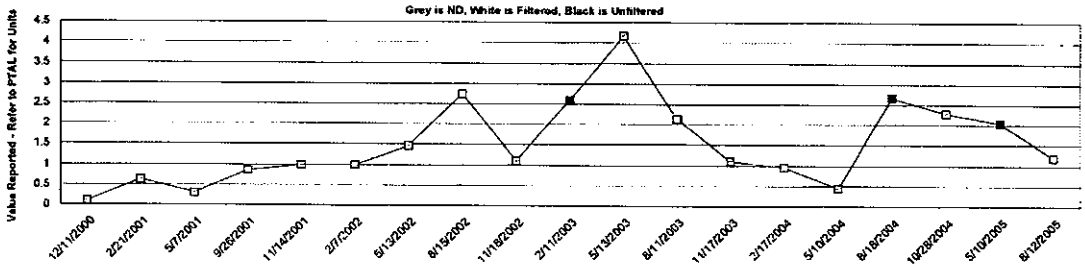


Figure 4-29. 299-W14-13 Tritium Trend Plot.

Well:299-W14-13 **Category:** RAD **Constituent:** Tritium
Class: RAD **Preliminary Target Action Limit:** 20,000 pCi/L

Concentration vs Time For Tritium

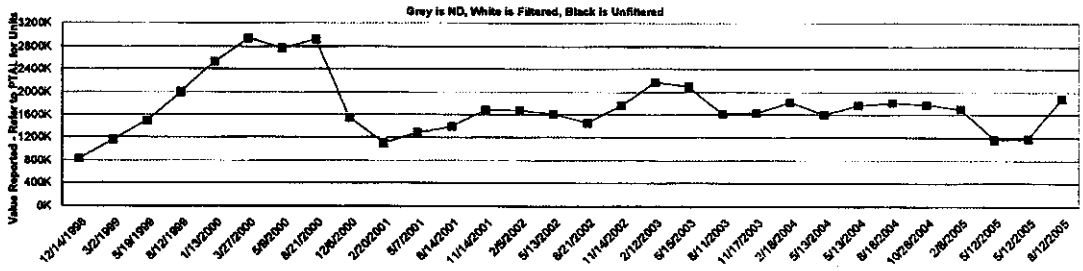


Figure 4-30. 299-W14-12 Tritium Trend Plot.

Well:299-W14-12 **Category:** RAD **Constituent:** Tritium
Class: RAD **Preliminary Target Action Limit:** 20,000 pCi/L

Concentration vs Time For Tritium

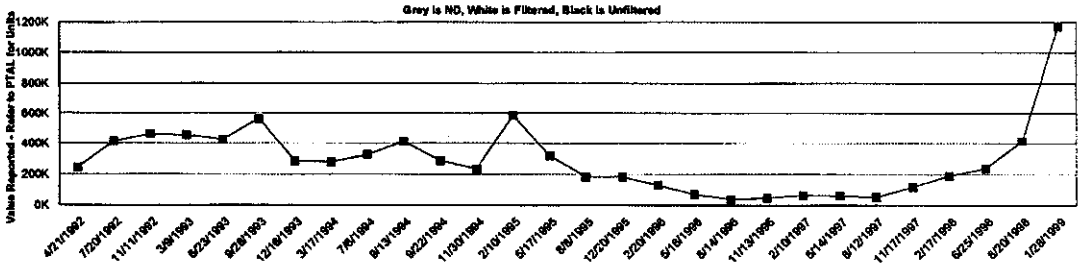


Figure 4-31. 299-W14-15 Tritium Trend Plot.

Well:299-W14-15 **Category:** RAD **Constituent:** Tritium
Class: RAD **Preliminary Target Action Limit:** 20,000 pCi/L

Concentration vs Time For Tritium

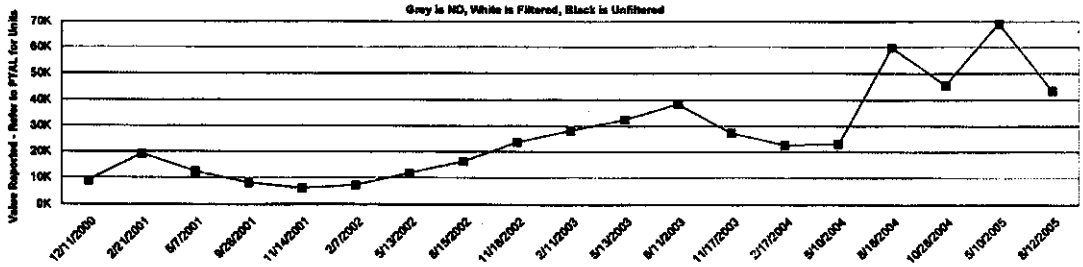


Figure 4-32. 299-W11-12 Tritium Trend Plot.

Well:299-W11-12 **Category:** RAD **Constituent:** Tritium
Class: RAD **Preliminary Target Action Limit:** 20,000 pCi/L

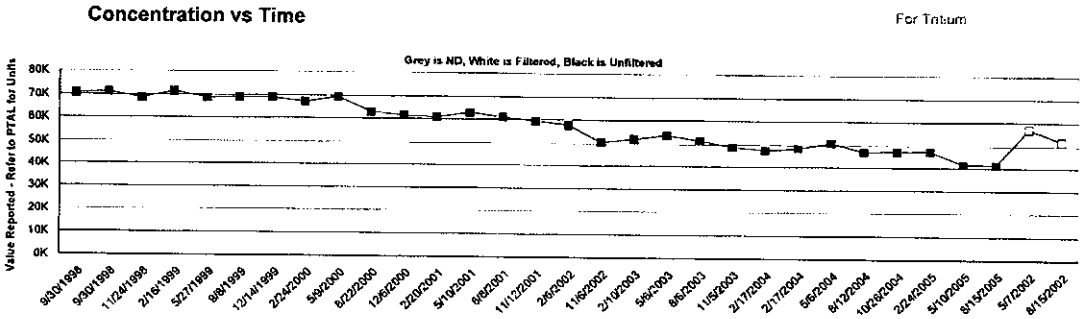


Figure 4-33. 299-W11-14 Tritium Trend Plot.

Well:299-W11-14 **Category:** RAD **Constituent:** Tritium
Class: RAD **Preliminary Target Action Limit:** 20,000 pCi/L

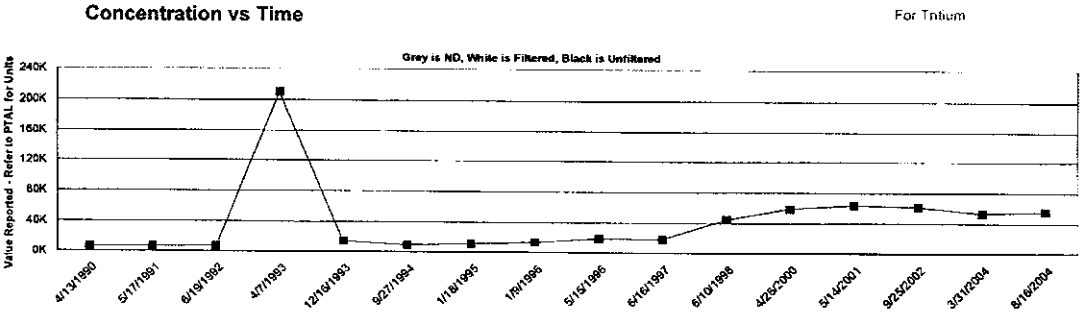


Figure 4-34. 299-W10-8 Fluoride Trend Plot.

Well:299-W10-8 **Category:** INORGANIC **Constituent:** Fluoride
Class: WETCHEM **Preliminary Target Action Limit:** 960 ug/L

Concentration vs Time For Fluoride

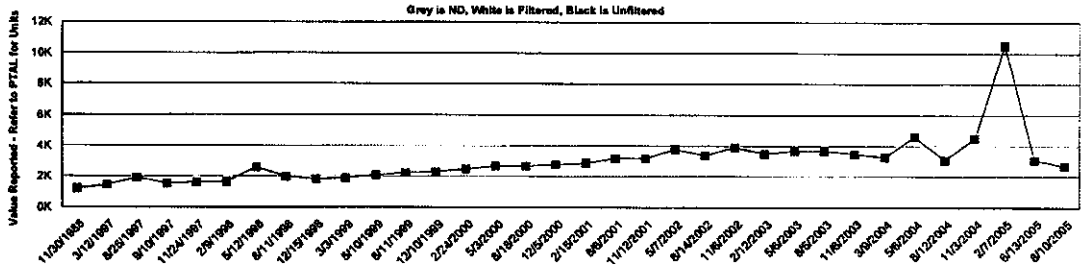


Figure 4-35. 299-W10-23 Fluoride Trend Plot.

Well:299-W10-23 **Category:** INORGANIC **Constituent:** Fluoride
Class: WETCHEM **Preliminary Target Action Limit:** 960 ug/L

Concentration vs Time For Fluoride

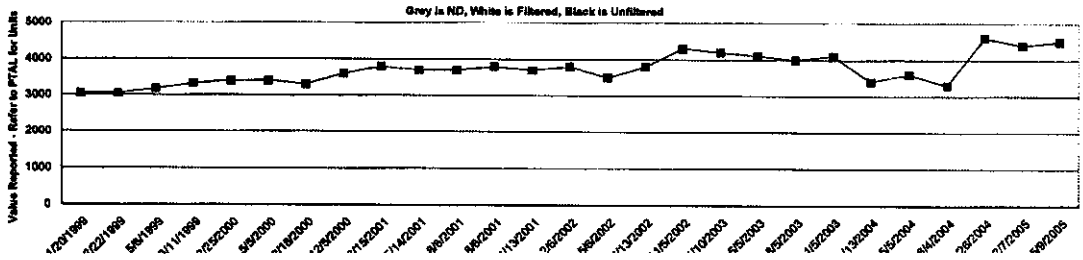


Figure 4-36. 200 West Area.

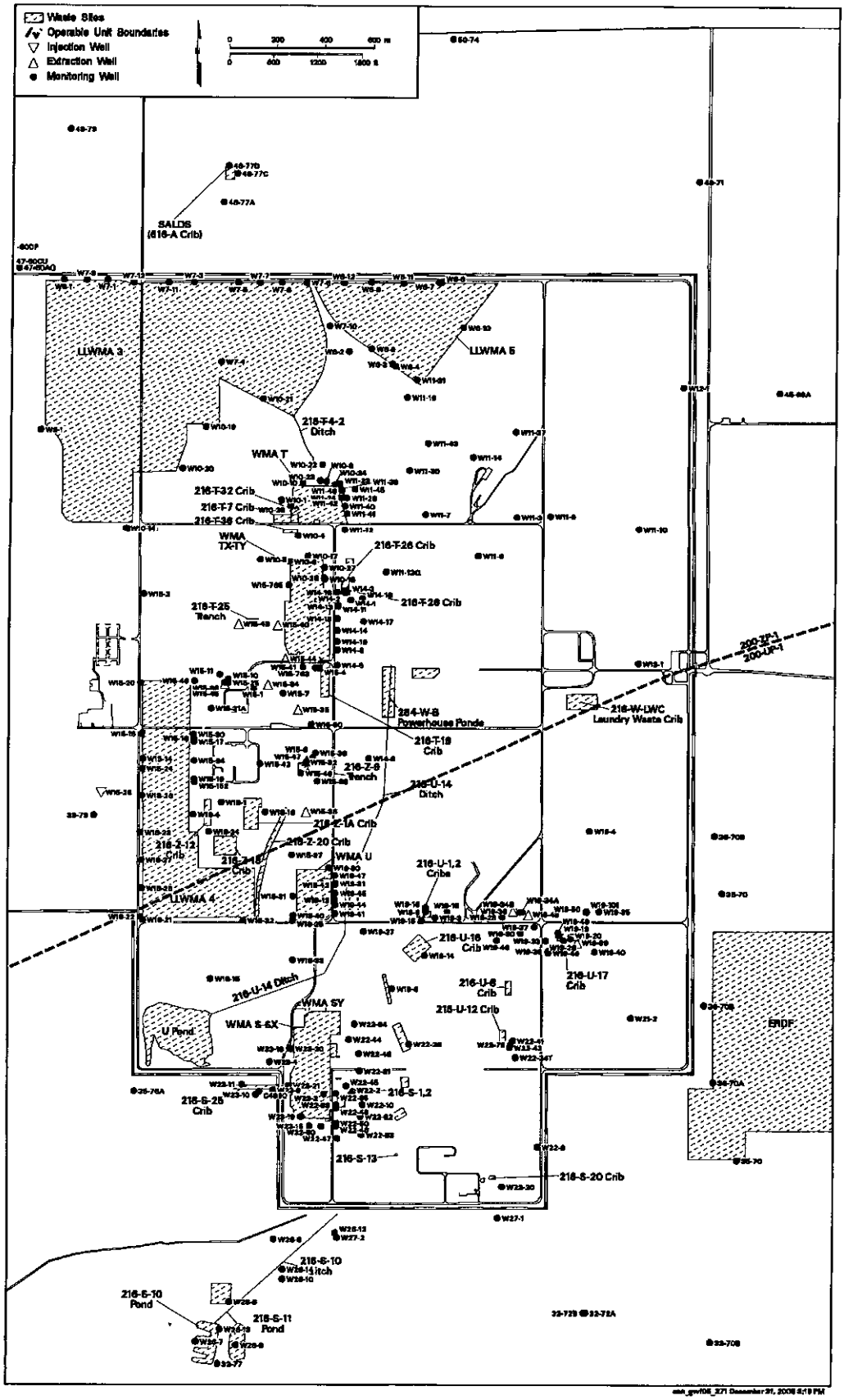


Figure 4-37. Hydrogeologic Cross-Section for Wells with Depth-Discrete Carbon Tetrachloride Concentration Data, Northwest to Southeast.

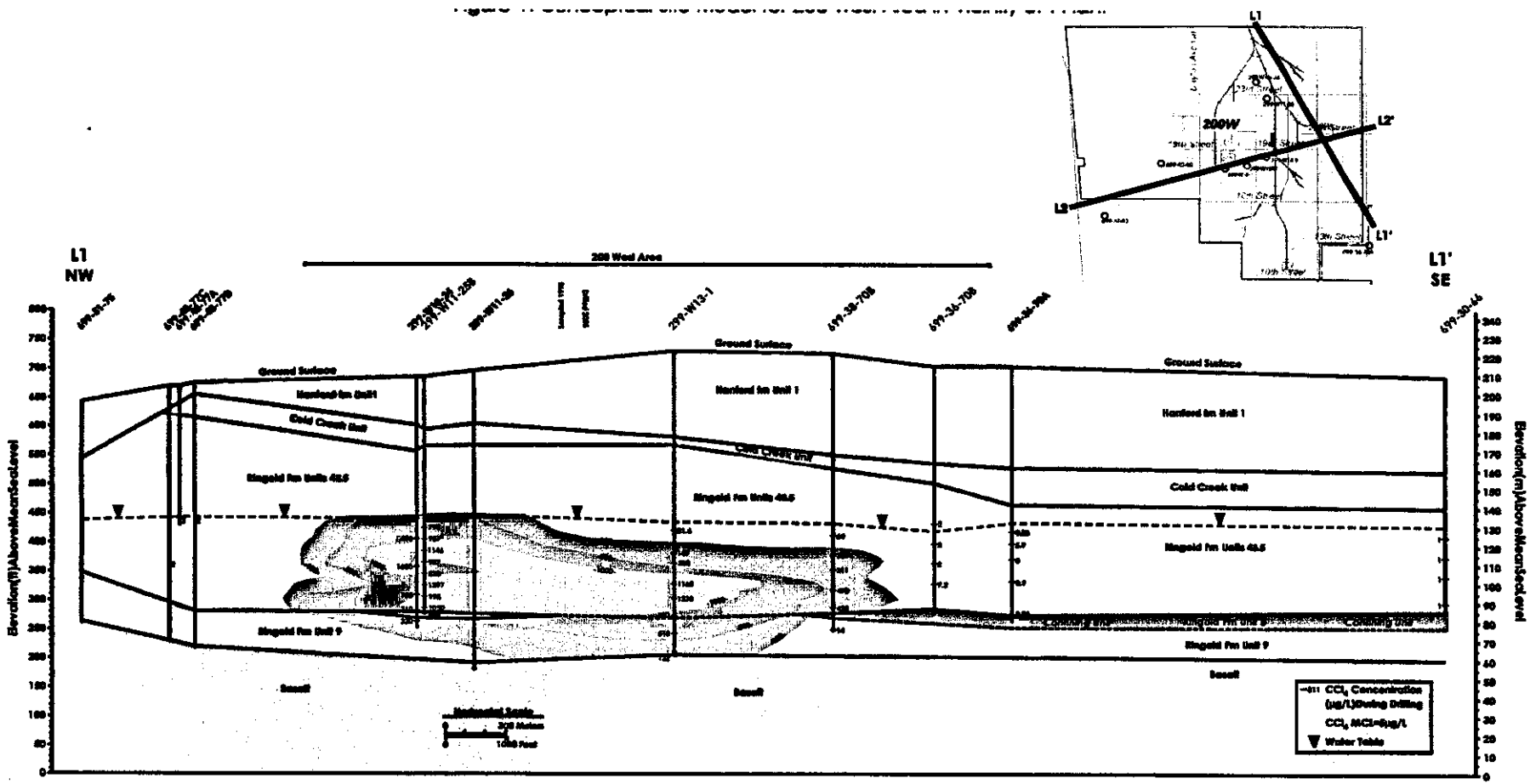


Figure 4-38. Hydrogeologic Cross-Section for Wells with Depth-Discrete Carbon Tetrachloride Concentration Data, Northeast to Southwest.

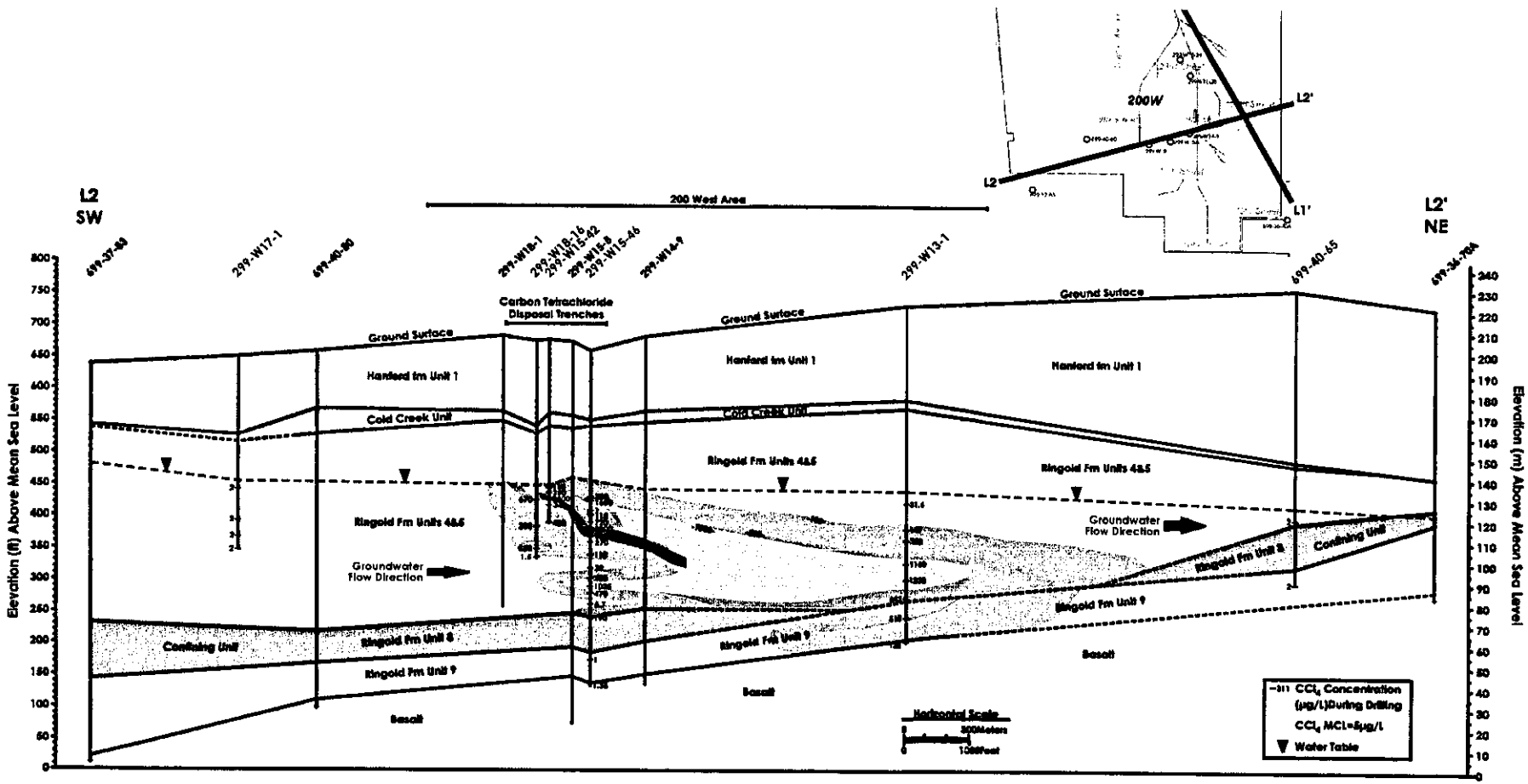


Figure 4-39. Technetium-99 Concentrations at Well 299-W11-25B.

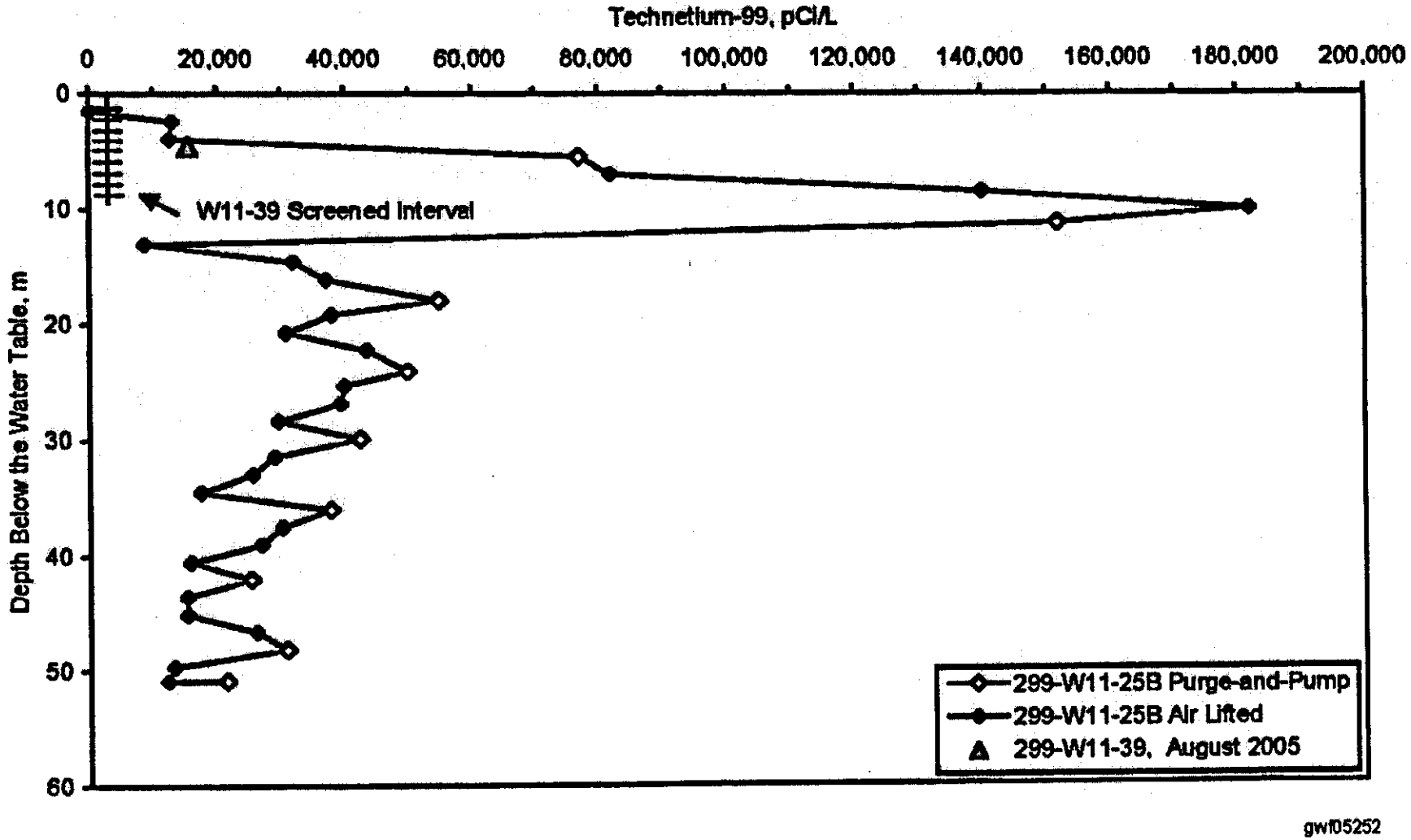


Figure 4-40. Depth Distribution of Chromium and Manganese in Well 299-W11-25B, Waste Management Area T.

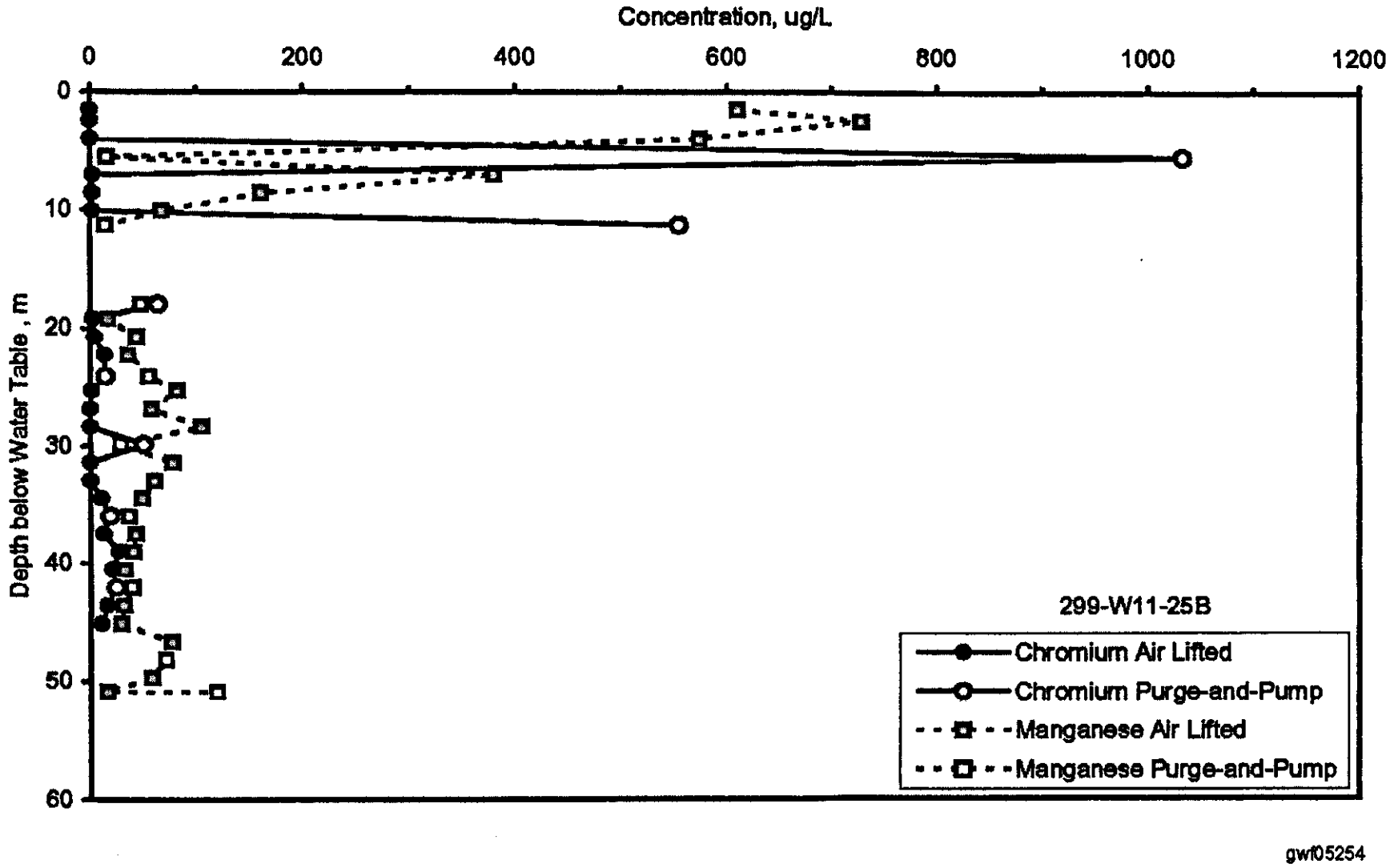


Figure 4-41. Depth Distribution of Technetium-99 and Nitrate at Well 299-W11-25B.

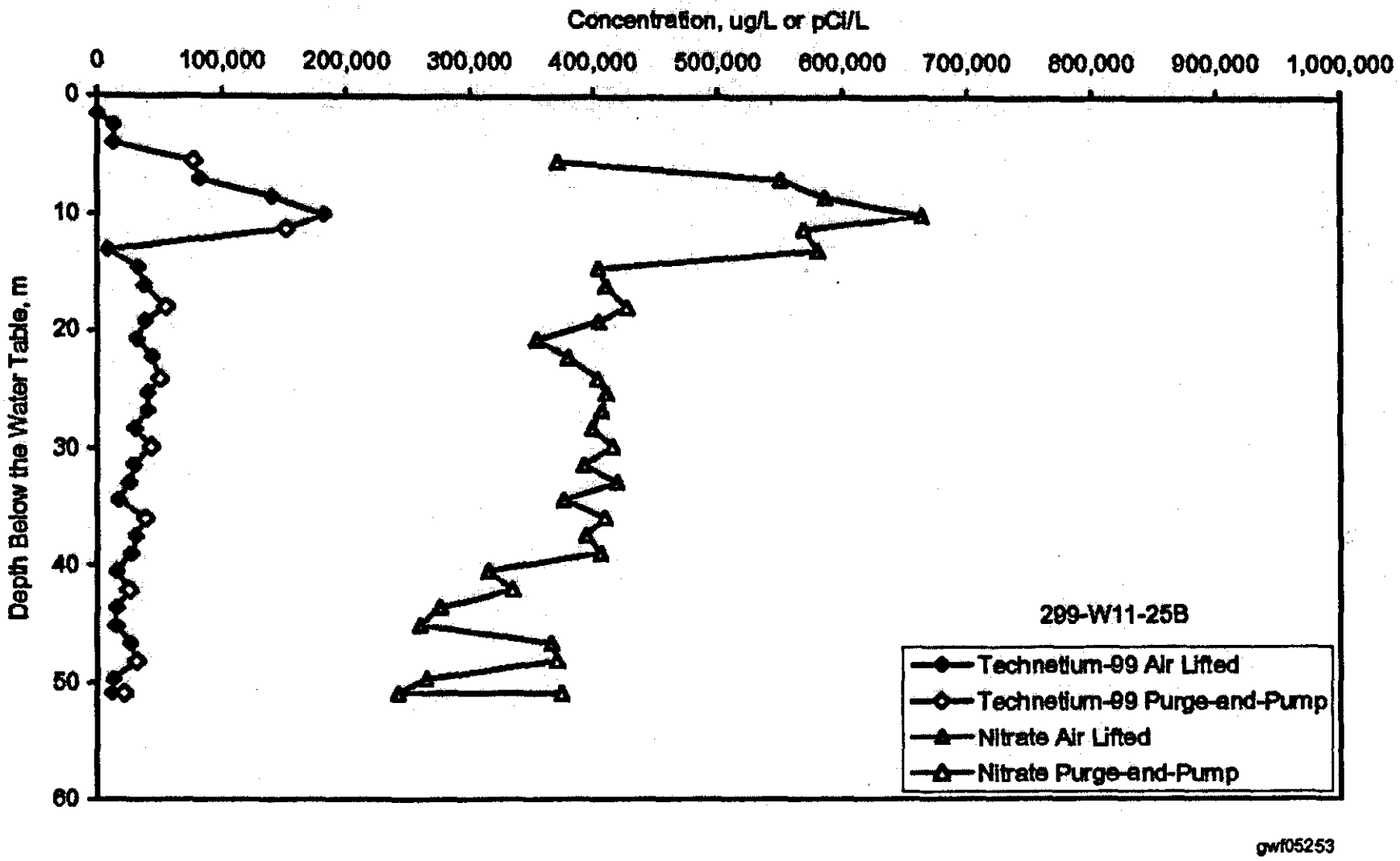


Figure 4-42. Technetium-99 and Nitrate Concentrations Encountered During Drilling of Well 299-W11-45.

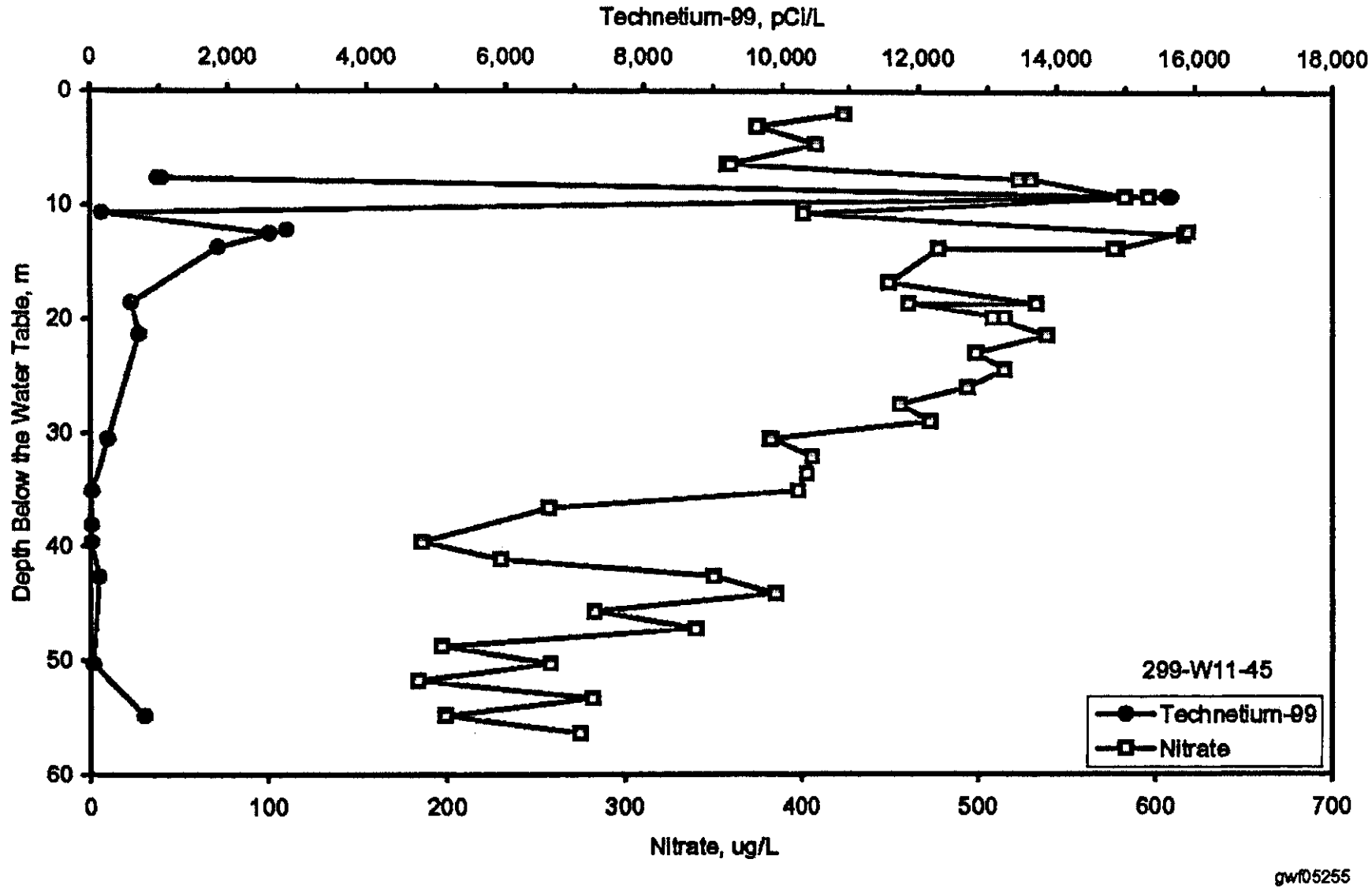


Table 4-1. Well 299-W15-46 Lithology.

Depth Interval (bgs)	Name	Description
4 to 65 ft	Hanford formation	Fine to coarse sand, and gravelly sand
65 to 67 ft	Hanford formation	Dense, well-compacted silt
67 to 108.5 ft	Hanford formation	Thin interbedded silty sand and sand
108.5 to 116.5 ft	Cold Creek unit	Well-compacted silt and fine sand
116.5 to 118 ft	Cold Creek unit	Silty, strongly cemented caliche (calcic paleosol)
118 to 128 ft	Upper Ringold Unit	Sandy gravel and varying silt
128 to 131 ft	Ringold Unit E	Sandy gravel and large, rounded basalt cobbles
131 to 147 ft	Ringold Unit E	Fine to medium sand, local gravelly interbeds
147 to 290.5 ft	Ringold Unit E	Sandy gravel and local thin interbedded sand; basalt cobbles and metamorphic volcanic clasts; alteration to clay, carbonate stringers, gypsum, and iron oxides
290.5 to 303 ft	Ringold Unit E	Interbedded sand and sandy gravels
303 to 360 ft	Ringold Unit E	Sandy gravel with clay alteration as above
360 to 380 ft	Ringold Unit E	Sandy gravel, intense clay alteration
380 to 417 ft	Ringold Unit E	Sandy gravel with clay alteration as above
417 to 473 ft	Ringold Lower Mud Unit	Well-compacted, dense silt and silty clay with interbedded very fine sand
473 to 512 ft	Ringold Unit A	Gravelly sand with varying silt
512 to 521.5 ft	Ringold Unit A	Sandy gravel
521.5 to 525 ft	Elephant Mountain Member, Saddle Mountains Basalt	Vesicular basalt

bgs = below ground surface

Table 4-2. Well 299-W15-49 Lithology.

Depth Interval (bgs)	Name	Description
1 to 128 ft	Hanford formation	Sandy gravel to gravelly sand
128 to 130.5 ft	Cold Creek unit	Silty sand
130.5 to 132.5 ft	Cold Creek unit	Caliche
132.5 to 437.5 ft	Ringold Formation	Gravely silty sand to silty sandy gravel

bgs = below ground surface

Table 4-3. Remedial Investigation/Feasibility Study Wells in the 200-ZP-1 Operable Unit.

Well	Other Well Designation	Borehole Summary Report	Geophysical Borehole Survey Logs[a]
299-W10-24	d	NA	Not logged
299-W11-25(B)	T1	FH 2005d	DOE-EM/GJ837-2005
299-W11-43	H	FH 2006a[b]	DOE-EM/GJ936-2005
299-W11-45	T2	NA	DOE-EM/GJ1129-2006
299-W13-01	G	FH 2004	Not logged
299-W14-11	d	FH 2005d	DOE-EM/GJ904-2005
299-W14-13	d	NA	Not logged
299-W14-14	d	NA	Not logged
299-W14-19	d	FH 2003e	Log exists on Stoller web site[c]
299-W15-152	F	FH 2006a[b]	Log not completed
299-W15-42	A	BHI 2002b	Not logged
299-W15-43	d	FH 2003e	Log exists on Stoller web site[c]
299-W15-44	d	FH 2003e	Log exists on Stoller web site[c]
299-W15-46	Z-9	FH 2005c	DOE-EM/GJ832-2005
299-W15-49	C	FH 2005b	DOE-EM/GJ773-2004
299-W15-50	E	FH 2005b	DOE-EM/GJ847-2005
299-W17-01	I	FH 2004	Not logged
299-W18-16	D	FH 2005b	DOE-EM/GJ860-2005
699-50-74	T	FH 2006a[b]	DOE-EM/GJ968-2005

[a] Spectral-gamma log references provided by S. M. Stoller Corporation, Hanford Office, Richland, Washington.
[b] Not issued as of April 4, 2006.
[c] The S. M. Stoller web site can be found on the Internet at www.gj.em.doe.gov/hanf/.
[d] No other well designation applies.
NA = not available

Table 4-4. Summary Results of Group A Analytes that Exceed Two Times the Preliminary Remediation Goal.

Analyte	Number of Wells with Data >2X PRG	Number of Samples >2X PRG	PRG
Carbon tetrachloride	56	2,326	3 µg/L
Chromium (total[a])	12	254	100 µg/L
I-129	7	219	1 pCi/L
Nitrate[b]	61	2,963	12,400 µg/L
Tc-99	7	347	900 pCi/L
Trichloroethylene	11	255	5 µg/L
Tritium	12	657	20,000 pCi/L
Uranium (total)	2	103	30 µg/L
Uranium (radioactive)	1	8	20 pCi/L

[a] Table 1-3 includes hexavalent chromium (48 µg/L).
[b] Table 1-3 also includes nitrate as nitrogen (10,000 µg/L), NO_2 (3,268 µg/L), and NO_2 as nitrogen (1,000 µg/L).
PRG = preliminary remediation goal

Table 4-5. Summary Statistics for the Question B-3, No (Analytes with <10% of the Detects Greater Than the Preliminary Remediation Goal).

Analyte	N	Num. Detect	Freq. of Detect	Min. ND	Max. ND	Min. Detect	Median	Mean	Max. Detect	Standard Deviation
Inorganic Metal (µg/L)										
Antimony	2,195	63	0.029	1.1	212	2.4	40.9	60.52	77	58.38
Arsenic	846	414	0.489	0.4	73	0.6	5	5.275	101	8.629
Cadmium	2,217	81	0.037	0.078	14.5	0.0424	2.6	3.465	328	7.785
Lead	1,314	260	0.198	0.01	37	0.0486	1.5	3.659	340	11.67
Manganese	2,210	1,528	0.691	0.072	10	0.193	4.5	19.81	2,320	92.5
Nickel	2,195	665	0.303	0.1	74	1	14.2	24.55	1,400	45.94
Selenium	851	215	0.253	0.3	163	0.312	5	7.203	22.2	17.75
Silver	2,195	83	0.038	0.1	33.5	0.91	4.5	6.72	171	6.854
Vanadium	2,211	1,952	0.883	0.2	72.5	2.2	29.1	30.97	1,140	27.29
Detected Organic Compounds (µg/L)										
1,1,1-trichloroethane	1,475	29	0.020	0.028	500	0.06	0.23	3.954	62	19.37
1,2-dichloroethane	1,457	10	0.007	0.018	500	0.089	0.2	4.186	100	20.61
4-methyl-2-pentanone	1,236	3	0.002	0.1	20,00	0.35	0.9	24.75	8.8	117.1
Benzene	1,515	26	0.017	0.013	500	0.062	0.23	3.927	7	20.19
cis-1,2-dichloroethylene	993	12	0.012	0.025	100	0.06	0.127	1.212	1.38	7.101
Tetrachloroethylene	1,652	354	0.214	0.031	500	0.039	0.57	6.466	37	26.38
Trans-1,2-dichloroethylene	1,111	5	0.005	0.031	100	0.24	0.17	1.847	0.48	6.951
General Inorganic Compounds (µg/L)										
Cyanide	384	49	0.128	0.94	400	1	10	14.85	33.6	35.17
Nitrogen in nitrite	1,763	89	0.050	1	304.5	7.4	7.4	53.24	11,000	458.3

ND = nondetect

Table 4-6. Comparisons of 95% Bootstrapped Upper Contamination Level to the Preliminary Remediation Goal for Question B-3, No (Analytes with <10% of the Detects Greater than Preliminary Remediation Goal).

Analyte	Shapiro-Wilk p-Value	Bootstrap UCL	PRG	95% Boot UCL > PRG?
Inorganic Metal (µg/L)				
Antimony	7.44E-50	62.55	10	Yes
Arsenic	1.34E-49	5.789	10	No
Cadmium	3.39E-71	3.756	5	No
Lead	4.60E-60	4.273	15	No
Manganese	1.34E-71	23.25	50	No
Nickel	8.55E-68	26.24	320	No
Selenium	3.24E-50	8.187	50	No
Silver	6.13E-58	6.96	80	No
Vanadium	3.37E-68	32.06	112	No
Detected Organic Compounds (µg/L)				
1,1,1-trichloroethane	1.22E-62	4.787	200	No
1,2-dichloroethane	2.90E-62	5.135	5	Yes
4-methyl-2-pentanone	2.36E-58	30.49	640	No
Benzene	2.52E-63	4.849	5	No
cis-1,2-dichloroethylene	6.13E-55	1.614	70	No
Tetrachloroethylene	1.34E-63	7.57	5	Yes
trans-1,2-dichloroethylene	5.29E-55	2.18	100	No
General Inorganic Compounds (µg/L)				
Cyanide	1.82E-37	18.18	200	No
Nitrogen in nitrite	2.03E-68	72.78	1,000	No

PRG = preliminary remediation goal
UCL = upper confidence limit

Table 4-7. Summary Statistics for the Question B-3, Yes (Analytes with Greater Than 10% of the Detects Greater Than Preliminary Remediation Goal).

Analyte	N	Num. Detect	Freq. of Detect	Min. ND	Max. ND	Min. Detect	Median	Mean	Max. Detect	Standard Deviation
Inorganic Metal (µg/L)										
Hexavalent chromium	29	27	0.931	3	3	3	10.9	74.99	730	151.9
Iron	2,228	1,628	0.731	5.55	384	5.1	46	517.8	328,000	7,263
Detected Organic Compounds (µg/L)										
Chloroform	1,692	1,175	0.694	0.028	500	0.047	5	13.74	1,100	44.94
General Inorganic Compounds (µg/L)										
Fluoride	2,221	2,121	0.955	18	500	94	500	842.5	10,500	956.2

ND = nondetect

Table 4-8. Comparisons of 95% Bootstrapped Upper Contamination Level to the Preliminary Remediation Goal for Question B-3, Yes (Analytes with Greater Than 10% of the Detects Greater Than Preliminary Remediation Goal).

Analyte	Shapiro-Wilk p-value	Bootstrap UCL	PRG	95% Boot UCL > PRG?
Inorganic Metal (µg/L)				
Hexavalent chromium	1.56E-08	122.5	48	Yes
Iron	1.18E-74	800.9	300	Yes
Detected Organic Compounds (µg/L)				
Chloroform	8.59E-64	15.74	7	Yes
General Inorganic Compounds (µg/L)				
Fluoride	1.15E-56	876.7	960	No

PRG = preliminary remediation goal
UCL = upper confidence limit

Table 4-9. Geotechnical Depth-Discrete Sediment Data for 200-ZP-1 OU Wells 299-W11-43, 299-W15-46, and 299-W15-49. (2 sheets)

Depth (ft)		Bulk Density		Moisture		Percent Passing Sieve											
Top	Bottom	Dry (kg/m^3)	Wet (kg/m^3)	Dry Sample (%)	Wet Sample (%)	3 in. (%)	1.5 in. (%)	3/4 in. (%)	3/8 in. (%)	No.4 (%)	No.10 (%)	No.20 (%)	No.40 (%)	No.60 (%)	No.100 (%)	No.140 (%)	No.200 (%)
Well 299-W11-43																	
NA	364	1,796	2,129			100	83.8	69.9	65.5	63.4	62.7	62.3	53.6	32	10.8	7.1	5.4
Well 299-W15-46																	
90	92.5	1,676	1,759	4.4	4.2	100	100	100	100	100	99.5	91.7	69.8	49.4	36	28.1	18.9
119	121.5	1,430	1,608	6.2	5.8	100	100	100	91.1	82.9	68.3	56.5	51.1	48.5	46.2	44.9	42.4
119.5	122	1,898	2,015	5.5	5.2	100	100	94	87.4	79.6	69.7	57.9	49.5	43.9	39	36	32.7
184	186.5	2,102	2,150	2.9	2.8	100	100	81.8	50.8	36.8	30.7	27.4	25.2	23.4	20.7	16.6	12
224	226.5	1,752	1,857			100	100	85.7	65	44.9	38.4	33.6	29	22.4	17.3	15	13.1
237	239.5	2,416	2,550	8.6	8	100	84.1	70.6	53.6	43.6	35.6	30.2	25.5	21.8	16.1	13.7	12
247	249.5	2,017	2,251	9.3	8.5	100	100	96.8	94.6	87.5	64.3	51.9	46.4	37.8	20	13.6	9.8
257	259.5	2,185	2,352	13.5	11.9	100	100	83.6	57.5	47.7	39	34.5	31	25.6	20.6	17.9	15.2
277	279.5	2,166	2,353	12	10.7	100	93	84.7	66.2	58.7	50	44.9	39.3	31	24.9	21.9	19.4
294.5	297	1,873	2,193	21.8	17.9	100	100	85.5	82.6	79.1	75.6	73.2	64	26.4	14.4	10.2	6.9
297	299.5	1,760	2,071	23.7	19.2	100	100	83.8	78.4	74.7	72.9	72.2	66.1	19	8.4	6.5	5.1
317	319.5	1,882	2,150	12.3	10.9	100	94.7	86.7	72.8	65.7	59.6	56.7	41.5	12.7	7.3	5.9	4.9
337	339.5	2,233	2,459	17.1	14.6	100	77.7	68.6	53.7	46.2	41.5	36.8	33.5	29.8	23.1	18.8	15.4
367	369.5	1,676	1,965	18.2	15.4	100	100	77.4	64.2	61.4	59.7	57.3	33	18.8	13.3	11.3	9.7
377	379.5	1,841	2,070	8.3	7.7	100	100	81.8	61.2	49.7	42.3	39.3	36.2	25.6	17.7	14.9	12.7
398	400.5	2,254	2,502	12.6	11.2	100	100	83	55.3	44.3	40.5	37.6	29.8	16	12	10.5	9
417	419.5	1,490	1,935	30.3	23.3	100	100	95.5	84.5	80.2	78.8	78.6	78.3	77.4	77.1	77	76.8
419.5	421	1,290	1,751	27.7	21.7	100	100	93.7	81.5	78.8	77.6	77.3	75.9	73.3	71.6	70.6	69.1

Table 4-9. Geotechnical Depth-Discrete Sediment Data for 200-ZP-1 OU Wells 299-W11-43, 299-W15-46, and 299-W15-49. (2 sheets)

Depth (ft)		Bulk Density		Moisture		Percent Passing Sieve											
Top	Bottom	Dry (kg/m^3)	Wet (kg/m^3)	Dry Sample (%)	Wet Sample (%)	3 in. (%)	1.5 in. (%)	3/4 in. (%)	3/8 in. (%)	No.4 (%)	No.10 (%)	No.20 (%)	No.40 (%)	No.60 (%)	No.100 (%)	No.140 (%)	No.200 (%)
482	484.5	1,637	2,042	25.5	20.3	100	100	100	100	100	100	99.9	81.4	41.5	17.3	13.1	10.4
520	522.5	1,626	2,060	41.4	29.3	100	84.4	70.4	61.8	53.4	39.6	30.2	24.8	20.9	17.3	15.8	13.9
Well 299-W15-49																	
260	262	2,070	2,290			100	100	91.9	81	74.9	65.9	55.8	47.1	32	20.9	17.1	14.5
260	262	2,134	2,281			100	80.7	74.4	60.1	48.1	29	17.4	13	9.2	6.4	5.5	4.6
330	335	2,210	2,414			100	92.9	72.7	55.2	46	39.9	33.8	28.9	20	14.7	13	11.4
401	406	2,239	2,475			100	100	79	59.5	50.9	43.3	36.8	29.3	20	14.7	12.7	10.8
435	440	1,320	1,833			100	100	100	100	100	100	98.7	94.2	87.9	84.3	83.4	82

NA = not available when this remedial investigation report was prepared
Shaded cells indicate data that were not needed at all depth intervals. The contractor determined which depth intervals to collect the data basis on sampling requirements, the volume of material recovered, and modeling needs.

Table 4-10. Hydraulic Depth-Discrete Sediment Data for 200-ZP-1 Wells 299-W11-43, 299-W15-46, and 299-W15-49.

Depth (ft)		Hydraulic Conductivity (cm/s)	Specific Gravity (Unit-less)		Percent Solids (%)
Top	Bottom		Result	Method	
Well 299-W11-43					
NA	364	2.5E-05	2.5929	C127	***NA***
			2.6881	D854	
Well 299-W15-46					
90	92.5	***NA***	2.7201	D854	95.8
119	121.5	***NA***	2.7705	D854	94.2
119.5	122	***NA***	2.8383	D854	94.8
184	186.5	8.1E-07	2.7326	D854	97.2
224	226.5	2.9E-05	2.7576	D854	NA
237	239.5	3.2E-05	2.6652	D854	92
247	249.5	1.3E-05	2.6161	C127	91.5
247	249.5		2.7025	D854	
257	259.5	5.1E-06	2.5806	C127	88.1
257	259.5		2.7045	D854	
277	279.5	2.6E-07	2.719	D854	89.3
294.5	297	1.0E-04	2.6877	D854	82.1
297	299.5	1.4E-04	2.6794	D854	80.8
317	319.5	4.2E-05	2.5774	C127	89.1
317	319.5		2.7061	D854	
337	339.5	3.3E-05	2.5797	C127	85.4
337	339.5		2.7735	D854	
367	369.5	1.6E-06	2.5133	C127	84.6
367	369.5		2.7399	D854	
377	379.5	4.5E-05	2.4912	C127	92.3
377	379.5		2.7308	D854	
398	400.5	4.3E-06	2.5623	C127	88.8
398	400.5		2.7323	D854	
417	419.5	2.7E-08	2.6312	C127	76.7
417	419.5		2.7168	D854	
419.5	421	6.5E-06	2.6145	C127	78.3
419.5	421		2.7636	D854	
482	484.5	2.1E-05	2.6836	D854	79.7
520	522.5	2.5E-07	2.2928	C127	70.7
520	522.5		2.9094	D854	
Well 299-W15-49					
260	262	5.9E-05	2.7171	D854	NA
260	262	1.2E-04	2.721	D854	
330	335	1.6E-06	2.7334	D854	NA
401	406	3.6E-07	2.5399	C127	NA
401	406		2.7248	D854	
435	440	3.9E-07	2.7638	D854	NA

NOTE: Cells that do not contain data and where "NA" is indicated in bold/italic indicate data that were not needed at all depth intervals. The contractor determined which depth intervals to collect the databases on sampling requirements, the volume of material recovered, and modeling needs.

NA = not available when this remedial investigation report was prepared.

Table 4-11. Geochemical Depth-Discrete Sediment Data for 200-ZP-1 Wells 299-W11-43, 299-W15-46, and 299-W15-49. (2 sheets)

Depth (ft)		Mn (µg/kg)	NO_3 (µg/kg)	Fe (µg/kg)	SO_4 (µg/kg)	TOC (µg/kg)	TIC (µg/kg)	Ca (µg/kg)	Na (µg/kg)	$CaCO_3$ (%)	CEC (mEQ/100g)	pH
Top	Bottom											
299-W11-43												
NA	364	1.60E+05	5.84E+04	1.50E+07	1.14E+04	5.93E+05	1.81E+05	1.84E+06	4.86E+05		23.4	7.63
299-W15-46												
NA	NA	1.81E+05	5.58E+06	1.49E+07	1.20E+03			2.96E+06	9.98E+05			
49.5	51.5	1.57E+05	3.88E+05		1.70E+05	3.41E+05	2.38E+04					6.5
63.5	66	1.90E+05	1.63E+06		4.56E+05	2.43E+06	2.60E+05					3.86
90	92.5	3.53E+05	1.55E+06	1.53E+07	8.10E+03	1.43E+05	1.98E+06	7.94E+06	6.48E+05	1	2.8	8.4
110	112.5	3.10E+05	2.62E+07		2.87E+05							5.97
117	119.5	4.08E+05	1.53E+05	4.94E+07	1.13E+04			3.29E+07	1.77E+06			7.41
119	121.5	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	6	N/S	N/S
119.5	122	4.10E+05	2.28E+06	3.41E+07	3.97E+04	2.60E+06	5.44E+06	3.06E+07	2.55E+06	5	11.2	8.316
119.5	122	3.73E+05	1.43E+05	3.70E+07	3.42E+04	NA	NA	2.90E+07	2.66E+06			
174	176.5	2.07E+05	8.37E+04	1.26E+07	1.75E+04	7.65E+04	6.03E+04	2.57E+06	5.61E+05		7.4	9.377
184	186.5	2.24E+06	9.56E+04	1.39E+07	1.02E+04	3.95E+04	1.75E+05	2.31E+06	6.61E+05	0	18.4	9.379
224	226.5	3.18E+05	2.89E+04	1.65E+07	1.12E+04	9.79E+04	4.70E+03	3.28E+06	3.25E+05	0	13.2	8.454
226.5	229	5.15E+05	5.44E+04	1.70E+07	5.00E+03	2.80E+05	2.29E+04	3.21E+06	1.45E+05		25.6	8.059
228	230.5	1.66E+05	4.10E+04	1.20E+07	9.93E+03	2.27E+05	5.95E+04	2.49E+06	1.97E+05		20	8.2
228	230.5	2.69E+05	4.11E+04	1.48E+07	5.00E+03	9.03E+04	4.60E+04	3.04E+06	2.00E+05		24.4	8.128
230.5	232	2.09E+06	3.30E+04	1.63E+07	5.00E+03	N/S	N/S	3.13E+06	2.38E+05		N/S	8.332
232	234.5	N/S	N/S	N/S	N/S	1.00E+05	2.15E+05	N/S	N/S	N/S	9.8	N/S
237	239.5	2.63E+05	2.43E+04	1.74E+07	5.70E+03	4.16E+04	4.70E+03	3.75E+06	2.30E+05	0	10.9	7.999
247	249.5	8.82E+05	1.48E+04	1.06E+07	1.01E+04	7.74E+04	7.12E+04	1.65E+06	1.27E+05	0	25.7	8.546
257	259.5	2.51E+05	7.61E+03	1.84E+07	5.65E+03	1.21E+05	1.24E+05	3.30E+06	2.39E+05	0	26.9	8.888
257	259.5	9.16E+05	1.24E+04	1.50E+07	5.22E+03	2.53E+05	4.75E+04	3.13E+06	3.44E+05		97.7	8.725
277	279.5	6.16E+05	8.72E+04	1.60E+07	1.18E+04	7.98E+05	6.25E+05	1.32E+07	1.86E+05	12	19	8.795
294.5	297	1.64E+05	2.16E+05	1.26E+07	1.24E+04	3.64E+04	1.27E+05	2.65E+06	6.52E+04	1	6.4	7.69
294.5	297	1.12E+05	1.96E+05	8.95E+06	4.90E+03	2.49E+05	3.43E+05	1.30E+06	2.97E+04		16.4	8.2
297	299.5	1.06E+05	1.33E+05	8.83E+06	5.00E+03	5.16E+04	2.52E+05	1.16E+06	3.38E+04	0	27.4	7.08
317	319.5	2.37E+05	3.67E+04	2.32E+07	5.37E+03	1.68E+05	1.18E+05	3.22E+06	1.16E+05	0	19.3	8.046

Table 4-11. Geochemical Depth-Discrete Sediment Data for 200-ZP-1 Wells 299-W11-43, 299-W15-46, and 299-W15-49. (2 sheets)

Depth (ft)		Mn (µg/kg)	NO_3 (µg/kg)	Fe (µg/kg)	SO_4 (µg/kg)	TOC (µg/kg)	TIC (µg/kg)	Ca (µg/kg)	Na (µg/kg)	$CaCO_3$ (%)	CEC (mEQ/100g)	pH
Top	Bottom											
337	339.5	2.38E+05	3.17E+04	1.77E+07	5.00E+03	9.40E+04	3.30E+05	4.46E+06	2.75E+05	1	23.1	8.78
367	369.5	1.47E+05	2.66E+04	1.75E+07	6.70E+03	1.42E+05	1.15E+05	2.28E+06	6.88E+04	0	15.6	7.78
367	369.5	1.20E+05	1.98E+04	1.50E+07	5.00E+03	5.38E+05	5.79E+05	1.99E+06	1.02E+05		21.9	8.2
377	379.5	3.05E+05	2.49E+04	2.89E+07	4.90E+03	4.90E+04	2.58E+06	7.94E+06	7.18E+05	3	18.4	8.27
398	400.5	2.14E+05	6.55E+03	1.96E+07	4.90E+03	1.02E+05	2.07E+06	1.12E+07	2.71E+05	0	31.3	8.61
417	419.5	1.63E+05	8.46E+03	1.76E+07	5.00E+03	1.02E+06	1.39E+06	3.97E+06	7.98E+04	0	35.4	7.72
419.5	421	3.40E+05	9.96E+03	1.66E+07	6.93E+03	5.56E+05	9.62E+05	3.37E+06	8.23E+04	0	28	7.92
482	484.5	1.00E+05	2.88E+03	8.19E+06	5.00E+03	5.16E+04	1.62E+05	1.46E+06	7.12E+04	0	9.3	9.7
520	522					5.31E+05	1.65E+06			N/S	26.3	
520	522.5	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	1	N/S	N/S
570	572.5	4.45E+05	6.29E+03	2.22E+07	1.11E+04			7.24E+06	3.70E+05			9.15
299-W15-49												
260	262	5.10E+05	1.02E+04	2.01E+07	9.02E+03	7.20E+04	3.13E+04	3.39E+06	1.39E+05	0	7	8.26
260	262	1.38E+05	9.21E+03	9.37E+06	6.42E+03	9.59E+04	5.40E+04	1.62E+06	1.38E+05	0	10.2	8.64
330	335	7.91E+05	7.61E+03	1.54E+07	1.27E+05	4.23E+04	1.21E+05	3.45E+06	1.93E+05	0	12.1	8.49
401	406	1.78E+05	1.01E+04	1.62E+07	1.06E+04	3.88E+04	6.00E+04	2.81E+06	2.31E+05	0	13.7	8.71
435	440	1.14E+05	9.69E+03	2.32E+07	5.00E+03	1.99E+05	6.29E+04	4.71E+06	6.81E+04	0	14	7.99
435	440	1.34E+05	7.84E+03	2.04E+07	7.87E+03	4.44E+05	6.81E+04	4.53E+06	8.85E+04		31.6	8.6

NOTE: Shaded cells where data are not included indicate data that were not needed at all depth intervals. The contractor determined which depth intervals to collect the databases on sampling requirements, the volume of material recovered, and modeling needs.

CEC = cation exchange capacity
TIC = total inorganic carbon
TOC = total organic carbon
NA = not available when this remedial investigation report was prepared
N/S = not sampled

Table 4-12. Description of Core Liners for 200-UP-1 Sediments.

Borehole	HEIS #	Liner #[a]	Depth Interval	Formation	Intact Core?	Sediment Wet Weight (g)
C4298 Well "R" (699-30-66) depth to water table =254.45 ft bgs						
C4298	B192K1	1	279-279.5	Ringold Unit E	No - slough	2,013.30
C4298	B192K2	1	314-314.5	Ringold Unit E	No - slough	1,544.35
C4298	B192K3	1	347-347.5	Ringold Unit E	No - slough	1,646.60
C4298	B192K4	1	386.5-387	Ringold Unit E	No - slough	1,329.21
C4299 Well "P" (699-36-70B) depth to water table = 264.84 ft bgs						
C4299	B19136	1	271.5-272	Ringold Unit E	Yes	2,032.09
C4299	B19137	2	308.5-309	Ringold Unit E	Yes	2,024.12
C4299	B19138	1	344-344.5	Ringold Unit E	No - slough	1,777.87
C4299	B19139	2	373.5-374	Ringold Unit E	No - slough	1,683.90
C4299	B19140	1	419-419.5	Ringold Unit E	Yes	1,674.00
C4300 Well "K" (299-W19-48) depth to water table = 258.20 ft bgs						
C4300	B19373	1	289-289.5	Ringold Unit E	No - slough	1,532.17
C4300	B19374	1	341-341.5	Ringold Unit E	No - slough	1,322.90
C4300	B19375	1	406-406.5	Ringold Unit E	No - slough	1,688.87
C4300	B19377	2	427.5-428	Ringold Lower Mud	Yes	1,263.07

[a] Liner # indicates the split-spoon sampling, which consisted of four sleeves, each 6 in. long in each push; #1 is closest to the shoe (deepest), and #4 is the shallowest. Usually liners #1 and #2 represent "virgin" sediment not impacted by slough falling back in the hole.

bgs = below ground surface

HEIS = Hanford Environmental Information System

Table 4-13. Summary of Particle-Size Distributions for Bulk Samples as Determined by Dry Sieve/Hydrometer Method for 200-UP-1 Sediments.

Sediment Sample	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
B192K1, with gravel	25.9	68.5	4.90	0.60
B19136 and B19137, with gravel	42.0	52.2	4.34	1.46
B19140, with gravel	55.0	26.7	13.2	5.10
B19377, with gravel	0.0	20.8	69.3	9.83

Table 4-14. Moisture and Carbon Content of Sediments and pH, Alkalinity, and Electrical Conductivity of 1:1 Water Extracts[a] from 200-UP-1 Sediments.

HEIS #	Well	Moisture Content (%)	Total Carbon (%)	Inorganic Carbon (%)	$CaCO_3$	Alkalinity (mg/L)	pH	EC (mS/cm)
B192K1	699-30-66	9.74	0.026	0.001	0.010	*445.5* (127.4)	*7.64* (7.69)	*0.867* (0.255)
B192K2	699-30-66	17.7	0.049	0.000	0.000	*261.3* (90.0)	*7.47* (7.39)	*0.578* (0.215)
B192K3	699-30-66	9.64	0.017	0.000	0.000	*404.3* (86.4)	*7.17* (7.56)	*0.771* (0.184)
B192K4	699-30-66	25.4	0.025	0.000	0.000	*215.9* (90.0)	*7.60* (7.52)	*0.534* (0.229)
B19136	699-36-70B	5.88	0.026	0.000	0.000	*743.4* (108.3)	*7.59* (7.81)	*1.812* (0.318)
B19137	699-36-70B	11.7	0.239	0.223	1.860	*577.9* (60.0)	*7.58* (7.45)	*0.961* (0.214)
B19138	699-36-70B	23.6	0.015	0.000	0.000	*201.4* (112.7)	*7.57* (7.54)	*0.453* (0.268)
B19139	699-36-70B	26.0	0.021	0.000	0.000	*180.1* (91.5)	*7.61* (7.42)	*0.443* (0.222)
B19140	699-36-70B	18.4	0.039	0.000	0.000	*170.2* (ND)	*7.48* (ND)	*0.573* (ND)
B19373	299-W19-48	18.5	0.019	0.000	0.000	*253.2* (130.3)	*7.63* (7.62)	*0.686* (0.391)
B19374	299-W19-48	15.1	0.033	0.003	0.026	*286.6* (96.6)	*7.20* (7.65)	*0.777* (0.264)
B19375	299-W19-48	13.4	0.056	0.009	0.071	*378.9* (125.6)	*7.44* (7.50)	*0.840* (0.297)
B19377	299-W19-48	32.5	0.015	0.000	0.000	*178.7* (99.6)	*7.59* (7.67)	*0.400* (0.237)

[a] The moisture content and total carbon (inorganic carbon) were measured using core sediments. The alkalinity, pH, and electrical conductivity measured in 1:1 water extracts are shown in italics. The alkalinity and EC were already dilution-corrected. The measured values in the extracted porewater are shown in parentheses.

EC = electrical conductivity
HEIS = Hanford Environmental Information System
ND = nondetect

Table 4-15. Cation Exchange Capacity for 200-UP-1 Sediments.

Sample	Well 699-30-66 (<2 mm)	Well 699-36-70B (Bulk with Gravel)	Well 699-36-70B (<2 mm)	Well 299-W19-48 (Ringold Lower Mud Unit)	Well 699-36-70B (<2 mm)
Cation exchange capacity (meq/100 g)	1.66 (±0.34)	3.28 (±3.29)	3.39 (±0.21)	17.12 (±2.45)	44.91 (±9.25)

Table 4-16. Recommended K_d Values to Use in 200-UP-1 Risk Transport Predictions.

K_d Values	Ringold Unit E (mL/g)	Ferric Oxide/Clay-Rich Coated Gravel (Ringold) (mL/g)	Ringold Lower Mud Unit (mL/g)
Tc (VII)	0 (±0.1)	0 (±0.1)	0.08 (±0.03)
U (VI)	0.5 (±0.2)	5.0 (±1.3)	1.8 (±0.1)
Sr-90	8 (±3)	15 (±10)	25 (±5)
Cs-137	500 (±100)	500 (±100)	1,000 (±200)
Np (V)	2.5 (±0.5)	9.0 (±2.0)	3.6 (±0.2)
Cr (VI)	0 (±0.05)	0 (±0.05)	0.1 (±0.1)
Se (VI)	0 (±0.5)	0.05 (±0.02)	0.05 (±0.02)
I-129	0 (±0.05)	0 (±0.02)	0 (±0.05)
Recommended Desorption K_d Values for Uranium to Use in Remediation Effectiveness Predictions			
U (VI)	2.5 (±1)	8.0 (±3)	5 (±2)

K_d = partition (or distribution) coefficient

Table 4-17. Slug Test Characteristics for Selected Test/Depth Intervals and Slug Test Analysis Results at 200-ZP-1 Operable Unit Test Wells 299-W11-43, 299-W15-50, and 299-W18-16.

Test Well	Test Zone	Hydro-geological Unit Tested[a]	Depth/Test Interval (m bgs)	Depth to Water (m bgs)	Slug Tests #	Bower and Rice Method	Type Curve Method	
						Horizontal Hydraulic Conductivity, K_h[b,c] (m/day)	Horizontal Hydraulic Conductivity, K_h[b,c] (m/day)	Specific Storage, S_s (m^{-1})
299-W11-43	1	Ringold Formation (Unit 5)	87.78 to 90.83 (3.05)	81.56	4	N/A	N/A	N/A
	2	Ringold Formation (Unit 5)	106.28 to 109.33 (3.05)	81.53	3	N/A	24.1 - 25.5 (24.8)	N/A
	3	Ringold Formation (Unit 5)	133.50 to 136.55 (3.05)	81.53	4	N/A	14.3 to 17.7 (16.0)	N/A
299-W15-50	1	Ringold Formation (Unit 5)	71.02 to 74.04 (3.02)	67.02	5	2.58	3.07	1.0E-5
	2	Ringold Formation (Unit 5)	83.45 to 86.50 (3.05)	66.67	6	2.93	3.20	5.0E-5
	3	Ringold Formation (Unit 5)	99.97 to 102.93 (2.96)	66.30	6	8.07 - 9.63 (8.77)	8.06 to 9.50 (8.66)	1.0E-6
299-W18-16	1	Ringold Formation (Unit 5)	95.70 to 97.99 (2.29)	~71.69	2	N/A	N/A	N/A

NOTE: For all test wells, $r_c = 0.051$ m; r_w ranged between 0.111 and 0.149 m. The "~" symbol used in combination with depth-to-water measurements indicates that the value is not considered to reflect static conditions at the time of testing.

[a] Unit number in parenthesis indicates the relevant groundwater-flow model layer.

[b] Number in parenthesis is the average value for all tests.

[c] Assumed to be uniform within the well-screen test section. For tests exhibiting a heterogeneous formation response, only outer zone analysis results are considered representative of in situ formation conditions.

bgs = below ground surface

K_h = hydraulic conductivity

N/A = method either not applicable or not applied

Table 4-18. Well Development Data for Remedial Investigation/Feasibility Study Wells. (3 sheets)

Well	Static Water Level (ft) (bgs)	Development Date	Development Pumping Duration (minutes)	Final Turbidity (NTU)	Final Conductivity (µS/cm)	Final Temp (°C)	Final Flow Rate (gpm)	Final Drawdown (ft)	Total Gallons Pumped
299-W10-24	234.78	10/23/98	U 14 L 192	U 4.19 L 4.5	Not measured	Not measured	~10	U 11.62 L 11.62	~2,100
299-W11-25B[a,b]	241.9	02/02/05 to 07/26/05	Not applicable, replaced by 299-W11-46						
299-W11-43	269.24	07/21/05	68	4.5	1,171	23.0	30	20.74	1,800
299-W11-45[c]	253.7	03/08/06 and 03/09/06	429	4.33	1,582	15.8	17.6 6.6	23.89 7.59	6,366
299-W11-46[c]	243.5	08/05/05	U 87 L 110	3.88	1,288	23.3	U 43 L 41	U 15.2 L 15.2	2,400
299-W13-1[d]	289.09	02/09/04 02/10/04	U 64 L 80	2.07 4.13	532 533	16.8 18.0	19 19	4.55 4.436	1,216 1,558
299-W14-11[e]	227.17	05/10/05	U 110 L 87	U 4.78 L 6.0	U 787 L 795	U 20.2 L 20.8	U 33 L 33	U 10.25 L 10.25	6,000
299-W14-13	216.6	09/17/98 to 09/21/98	L 90 U 20	L 4.07 U 2.08	L 823 U 925	L 23.4 U 21.0	L 8 U 7	L 7.5 U 7.25	~860
299-W14-14	217.42	11/13/98	U 55 L 185	U 5.69 L 4.55	U 467 L 440	U 19.8 L 20.1	6	Not measured	1,700
299-W14-19[a]	223.55	11/08/02	U 226.8 U 73.2 L 81	U 9.83 U 0.97 L 1.41	U -- U 648 L 663	U -- U 16.9 L 17.5	U 15 U 7 L 6	U -- U 4.907 L 3.542	U 3,405 U 511 L 190
299-W15-152	237.3	09/26/05	U 35 U 5 L 52	U 3.17 L 4.97	U 546 L 537	U 21.5 L 21.7	U 30 U 30 L 32	U 3.280 L 3.618	U 1,600 L 1,800

Table 4-18. Well Development Data for Remedial Investigation/Feasibility Study Wells. (3 sheets)

Well	Static Water Level (ft) (bgs)	Development Date	Development Pumping Duration (minutes)	Final Turbidity (NTU)	Final Conductivity (µS/cm)	Final Temp (°C)	Final Flow Rate (gpm)	Final Drawdown (ft)	Total Gallons Pumped
299-W15-42[f]	226.6	01/28/02 to 02/06/02	U 98 L 80	U 3.82 L 4.83	U 712 L 703	U 18.7 L 18.8	U 15 L 14	U --[g] L 2.5	1,470 1,120
299-W15-43[e]	227.42	11/13/02 11/18/02	U 55.8 U 31.8 L 99	U 1.62 U 2.28 L 0.63	U 523 U 519 L 521	U 16.9 U 17.9 L 16.8	U 23 U 6 L 15	U 3.76 U 0.38 L 2.106	U 1,288 U 192 L 1,485
299-W15-44[e]	220.24	11/22/02 11/25/02	U 93.6 L 66.6	U 4.81 L 3.81	U 542 L 547	U 18.9 L 18.4	U 7 L 8.5	U 2.609 L 2.679	U 658 L 570
299-W15-46[h]	222.69	04/28/05	103	4.18	869	20.7	23.7	2.155	2,441
		04/29/05	57	4.58	816	18.8	25.0	2.31$\dot{3}$	1,425
		04/29/05	30	4.08	832	20.7	23.3	Not measured	699
299-W15-49[i]	234.5	12/27/04	U 32 L 89	U 4.76 L 4.49	U 443 L 441	U 17.9 L 17.4	U 20 L 20	U 8.16 L 8.5	2,420
299-W15-50[i]	218.5	02/24/05 to 02/25/05	U 110 M 54 L 183	U 1.81 M 3.86 L 4.45	U 508 M 512 L 522	U 21.7 M 19.2 L 15.0	U 11 M 15 L 26	U 6.36 M 16.72 L 29.44	6,700
299-W17-1[d]	195.95	12/15/03 to 12/16/03	U 92 L 65 L 97 L 110	4.45 63.3 10.2 4.69	389 526 391 391	17.1 17.1 16.6 17.1	18 30 26 30	13.85 17.02 16.18 15.71	1,656 1,950 2,522 3,300

Table 4-18. Well Development Data for Remedial Investigation/Feasibility Study Wells. (3 sheets)

Well	Static Water Level (ft) (bgs)	Development Date	Development Pumping Duration (minutes)	Final Turbidity (NTU)	Final Conductivity (µS/cm)	Final Temp (°C)	Final Flow Rate (gpm)	Final Drawdown (ft)	Total Gallons Pumped
299-W18-16[d]	233.6	12/28/04 to 12/29/04	U 212 L 297	U 4.38 L 5.14	U 1806 L 1854	U 18.3 L 18.9	U 13 L 13.5	U 3.02 L 3	7,000
699-50-74	220.8	08/23/05 to 08/24/05	U 30 M 75 L 215	U 2.82 M 4.77 L 4.80	U 284 M 287 L 291	U 20.0 M 19.0 L 18.4	L 35 M 35 U 27	U 10.8 M 13.8 L 12.5	11,500

[a] Source: *Borehole Summary Report for the Drilling and Construction of Four New Wells 299-W22-47, (C4667); 299-W11-25B, (C4669); 299-W14-11, (C4668), and 299-W11-46 (C4950) Drilled in the 200 West Area* (FH 2005d).
[b] During well-completion activities at well C4669 (299-W11-25B), the 4-in. stainless-steel well casing was constricted over a 3-ft section, preventing access to the screened interval at the bottom of the well. A decision was made to decommission this well and drill a substitute well, 299-W11-46 (C4950) (FH 2005d).
[c] Data not shown in relevant borehole summary reports but were provided by Fluor Hanford, Inc. in e-mail correspondence.
[d] Source: Table 2-8, *Fiscal Year 2004 CERCLA Groundwater Monitoring Well Summary Report for the 100-HR-3, 200-ZP-1, 200-UP-1 Operable Units* (FH 2004).
[e] Source: Table 5, *Calendar Year 2002 RCRA and CERCLA Groundwater Monitoring Well Summary Report* (FH 2003e).
[f] Source: page 11, *Borehole Summary Report for Well 299-W15-42 (C3803) and Borehole 299-W15-764 (C3494), 200-ZP-1 Operable Unit* (BHI 2002b).
[g] Information for upper drawdown not provided in *Borehole Summary Report for Well 299-W15-42 (C3803) and Borehole 299-W15-764 (C3494), 200-ZP-1 Operable Unit* (BHI 2002b).
[h] Source: Table 2-4, *Borehole Summary Report for Well 299-W15-46 (C3426) Drilled at the 216-Z-9 Trench* (FH 2005c).
[i] Source: Table 2-15, *Borehole Summary Report for Six CERCLA Wells Drilled in the 200-UP-1 and 200-ZP-1 Operable Units, and Six RCRA Wells Drilled in the A-AX, B-BX, and U WMA; CY 2004-2005* (FH 2005b).

bgs = below ground surface
gpm = gallons per minute
L = lower
M = middle
NTU = nephelometric turbidity unit
U = upper

Table 4-19. Geochemical Depth-Discrete Groundwater Data for Wells 299-W11-43, 299-W15-46, and 299-W15-49.[a] (3 sheets)

Depth (ft)		Mn (µg/L)	NO_3 (µg/L)	Fe (µg/L)	SO_4 (µg/L)	TOC (µg/L)	TIC (µg/L)	Ca (µg/L)	Na (µg/L)	pH	Alkalinity (µg/L)	DO (µg/L)	Specific Cond. (µS/cm)	Temp. (°C)	Turbidity (NTU)
Top	Bottom														
299-W11-43															
N/A	298	24	282,000	39.4	59,900			109,000	16,900	7.589[a]		8,300[a]	823[a]	21.7[a]	3.25[a]
N/A	328	15.4	284,000	116	60,100	890	28,400	106,000	17,100	7.555[a]	106,000	8,800[a]	918[a]	20.0[a]	1.15[a]
		15.6	276,000	128	57,600	950	28,500	104,000	16,600	7.68	107,000				
N/A	364	30.4	266,000	56.2	54,600	800	35,300	107,000	19,300	7.58[a]	128,000	7,200[a]	901[a]	24.2[a]	3.83[a]
N/A	418	43.7	317,000	41.5	57,600	950	35,400	116,000	21,300	7.54[a]	122,000	7,200[a]	964[a]	22.1[a]	11.1[a]
N/A	449	66.1	296,000	37.9	56,000	1,070	51,500	108,000	20,200	7.529[a]	129,000	6,400[a]	981[a]	21.5[a]	9.07[a]
299-W15-46															
N/A	N/A	3.2	270,000	16.1	25,400			94,700	32,400	8.21			874	19.7	
N/A	N/A	1.3	315,000	31.1	33,300			99,800	28,800	7.77			885	20.1	0.73
228	230.5	1,210	406,000	25,100	41,300			124,000	50,900	b		b	b	b	b
N/A	234.5	81.4	397,000	21	42,200			116,000	46,600	7.782					
N/A	237									7.565		210	112.4	22.3	0.21
N/A	251					5,800	23,300								
N/A	257					920									
N/A	267					950	28,400								
						650	26,900								
						540									
N/A	268									8.029		350	163.5	22.4	1,000
N/A	278									8.33		300	422	19.2	1,000
N/A	293									6.984		340	1,283	19.6	1,000
294.5	297	1,960	1,040,000	27.9	17,300			197,000	30,400						
		2,030	956,000	21	15,300			209,000	28,400						
N/A	297.5									4.654		310	1,242	19.8	1,000
297	299.5					1,400	11,200								

Table 4-19. Geochemical Depth-Discrete Groundwater Data for Wells 299-W11-43, 299-W15-46, and 299-W15-49.[a] (3 sheets)

Depth (ft)		Mn (µg/L)	NO_3 (µg/L)	Fe (µg/L)	SO_4 (µg/L)	TOC (µg/L)	TIC (µg/L)	Ca (µg/L)	Na (µg/L)	pH	Alkalinity (µg/L)	DO (µg/L)	Specific Cond. (µS/cm)	Temp. (°C)	Turbidity (NTU)
Top	Bottom														
N/A	317									7.028			1,034	19.4	1,000
317	319.5					1,900	11,300								
N/A	339									7.823		8,160	375	18.9	53.5
337	339.5					3,100	15,900								
N/A	357					3,700	33,200			8.481		b	537	16.7	1,000
	365									8.135		b	533	14.9	1,000
367	369.5	482	161,000	114	18,400			53,400	14,800						
		468	156,000	21	16,400			56,800	15,400						
N/A	379									8.245		6,340	783	13.8	1,000
377	379.5					1,940	26,400								
N/A	397					14,200	50,300								
N/A	397.5									8.4		5,130	620	17.1	1,000
N/A	400									8.791		5,290	1,221	13.7	1,000
419.5	421					1,800	32,900								
N/A	482									8.351		160	323	18.7	1,000
482	484.5					5,570	34,300								
N/A	520									8.337		240	347	19.7	1,000
527	529.5	121	37,700	227	17,300			30,400	20,700	8.38					
527	529.5	121	37,600	230	17,300			30,700	21,100	8.34					
299-W15-49															
N/A	N/A	0.84	74,400	20.2	26,200	10,400	3,600	51,400	16,900	7.87	2,000		438	19	4.26
N/A	N/A	0.193	78,400	21	28,400			33.8	200	7.84			435	20	2.22
N/A	N/A		62,000	21	23,500				200	7.72			420	20.4	4.52
N/A	N/A		62,400		23,000					7.91			419	19	1.13
N/A	N/A		974		1,500					6					
N/A	N/A		97.4		150										
N/A	270	78	65,500	21	24,500	500	26,400	44,000	17,200	7.82	102,000				

Table 4-19. Geochemical Depth-Discrete Groundwater Data for Wells 299-W11-43, 299-W15-46, and 299-W15-49.[a] (3 sheets)

Depth (ft)		Mn (µg/L)	NO_3 (µg/L)	Fe (µg/L)	SO_4 (µg/L)	TOC (µg/L)	TIC (µg/L)	Ca (µg/L)	Na (µg/L)	pH	Alkalinity (µg/L)	DO (µg/L)	Specific Cond. (µS/cm)	Temp. (°C)	Turbidity (NTU)
Top	Bottom														
N/A	305	157	17,000	21	17,900	17,000	32,600	34,500	10,300	8.073[a]	101,000	6,000[a]	312[a]	15.0[a]	63.8[a]
N/A	330	284	47,800	21	22,500	590	26,100	41,300	13,200	7.789	98,800	5,600[a]	376[a]	17.3[a]	285.0[a]
N/A	401	0.556	39,600	35.3	24,400	630	29,900	40,800	14,800	8.048[a]	119,000	5,400[a]	398[a]	--[a]	--[a]
N/A	440	248	28,200	38	22,200	500	30,500	38,700	15,100	7.462[a]	120,000	5,300[a]	375[a]	15.5[a]	1,000[a]
		258	27,500	21	21,900	850	15,200	38,400	15,300	7.84	128,000				

NOTE: Blank shaded cells indicate data that were not needed at all depth intervals. The contractor determined which depth intervals to collect the data based on sampling requirements, the volume of material recovered, and modeling needs.

[a] Data provided in emails from Fluor Hanford, Inc.

[b] No field readings taken.

DO = dissolved oxygen
N/A = not available
NTU = nephelometric turbidity unit
TOC = total organic carbon
TIC = total inorganic carbon

5.0 HUMAN AND ECOLOGICAL RISK EVALUATION

5.1 HUMAN HEALTH RISK EVALUATION

The discussion of human health risk in this RI report will limited to the following two risk areas:

- Discussion of estimates of existing risks based on current interpretations of contaminant plumes that originate within the 200-ZP-1 OU and exceed DWSs. The plume interpretations are developed in the annual groundwater monitoring report for FY05 (PNNL 2006). This discussion only focuses on a few indicator COCs that include carbon tetrachloride, technetium-99, iodine-129, and uranium.
- Discussion of preliminary risks associated with the carbon tetrachloride plume based on information developed in a previous modeling study of carbon tetrachloride (Bergeron and Cole 2005).

Because the groundwater model that will eventually be used to perform the baseline risk assessment and FS analysis is an updated version of the older groundwater model (Bergeron and Cole 2005), specific information of the groundwater contaminant fate and transport is limited to what has been included in Section 6.1.2. The reader is referred to the report by Bergeron and Cole (2005) for more detailed descriptions of groundwater flow and transport resulting from this past modeling effort.

5.2 ECOLOGICAL RISK EVALUATION

This section includes the ecological risk screening of contaminants in the 200-ZP-1 OU versus the aquatic screening concentrations for nonradionuclides from various sources, as documented in *100-B/C Pilot Project Risk Assessment* (DOE-RL 2005a) and *Data Quality Objectives Summary Report for the 100 Area and 300 Area Component of the River Corridor Baseline Risk Assessment* (BHI 2005). Radionuclides in water were screened against values in *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2002), which was prepared for DOE by the Biota Dose Assessment Committee (BDAC) and presents screening levels (i.e., biota concentration guides [BCGs]) for radionuclides, as well as a methodology for conducting ecological risk assessments for radionuclides. DOE-RL (2005a) contains additional details on the BDAC document.

5.2.1 Ecological Risk Screening

Steps 1 and 2 of the ecological risk assessment guidelines process (EPA 1997) consist of risk screening that compares concentrations of contaminants of potential environmental concern (COPECs) in water at the site to ecotoxicity-based water concentrations. The water concentrations considered include the following:

- Maximum analyte-specific levels in groundwater from the 200-ZP-1 OU
- Maximum analyte-specific levels in groundwater from the 200-ZP-1 OU diluted by 50% (0.5 dilution factor) to represent the Columbia River hyporheic mixing zone
- Maximum analyte-specific levels in groundwater from the 200-ZP-1 OU diluted 100-fold (0.01 dilution factor) to represent OU groundwater mixed with Columbia River water.

For risk screening of the exposure scenarios at the 200-ZP-1 OU, pre-established screening levels for water were used for comparison to concentrations of nonradionuclides from multiple sources. Concentrations of radionuclides in water were compared to the dose-based screening levels developed in the DOE's BCGs for protection of aquatic systems (DOE 2002). The basis of these screening levels and the underlying assumptions are discussed in the following subsections.

5.2.2 Aquatic Receptors Exposure

Methods for screening nonradionuclides in water are based on exposure pathways to aquatic organisms. The screening approach assumes that aquatic organisms are generally exposed to the greatest fraction of contamination by means of direct media contact (i.e., continuous bodily contact with water). Ecological screening for waterborne COPCs pertains to receptors associated with benthic surfaces and the free water column. These screening values are broadly protective of aquatic plant and animal species. For example, EPA has developed methods intended to protect a large fraction (roughly 95%, unless otherwise stated) of species found in aquatic environs (EPA 1995). By using the EPA's national ambient water quality criteria (EPA 2002b), it is assumed that any particular species selected to be representative of feeding guilds in the aquatic realms of the Hanford Reach will be protected.

General guidance from the International Council for Radiological Protection (ICRP 1991), the International Atomic Energy Agency (IAEA 1992), and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR 1996) concludes that radiological doses to aquatic animals (vertebrates and invertebrates) and terrestrial plants and terrestrial animals (invertebrates and vertebrates) should not exceed 1 and 0.1 rad/day, respectively. Provided that radiation exposure does not exceed these levels, the consensus opinion of the international radiological organizations is that ecological populations will be protected. The DOE has adopted these thresholds and integrated them into DOE (2002). The BCGs presented in DOE (2002) represent radionuclide concentrations in soil, water, or sediment that would produce a dose equal to the 1 or 0.1 rad/day threshold (depending on the type of biota).

5.2.3 Ecological Screening Values

In the effects characterization, potential adverse effects associated with varying levels of exposure to contaminants are documented. Effects data may consist of literature-derived, single-chemical toxicity data and of results from site-specific biological field surveys and toxicity tests of ambient media. For this screening assessment, only literature-derived, single-chemical toxicity data were used to evaluate risks to ecological receptors exposed to groundwater from the 200-ZP-1 OU. Screening benchmarks based on no-effect concentrations in media were assembled from multiple sources. Applicable or relevant and appropriate requirements (ARARs) from the State of Washington and the Federal regulatory agencies were used whenever available. If there are two or more ARARs available for an analyte-receptor combination, the lowest of the values was used in conducting this screening assessment. Available ARARs are as follows:

- "Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A)
- *National Recommended Water Quality Criteria: 2002* (EPA 2002b).

When an ARAR for an analyte was not available, the lowest value among other sources was used, including the following:

- Oak Ridge National Laboratory's toxicity benchmark values for plants, soil invertebrates, and aquatic biota (Suter and Tsao 1996)
- Los Alamos National Laboratory's risk-reduction toxicity reference values (LANL 2005).

Radionuclides were evaluated using an adaptation of the graded approach outlined in DOE (2002). The graded approach is a step-wise process for evaluating exposure and risks from radionuclides to ecological receptors. The process starts using a series of conservative exposure assumptions to determine if radionuclide exposure for the most highly exposed individuals may exceed internationally accepted dose limits. If the conservative exposure estimate exceeds those dose limits, the evaluation proceeds to the next level and incorporates more site-specific data and biologically more realistic exposure assumptions to better clarify likely exposure levels.

At this initial screening level, maximum measured radionuclide concentrations are compared to radionuclide-specific BCGs. The BCGs represent the limiting radionuclide concentration that would result in accepted dose limits not being exceeded. More radionuclides were measured in water from 200-ZP-1 OU than were represented by BCGs presented in DOE (2002). An additional BCG, carbon-14, was derived using the same approach employed in Table 5-16 of DOE-RL (2005a).

5.2.4 Screening-Level Risk Calculations

Using the representative water concentrations described above, the HQ approach was used to compare to the screening-level effects, where:

$$HQ = \text{exposure concentration/effects concentration.}$$

If the HQ is <1, it can reasonably be concluded that adverse effects are unlikely. For a given exposure scenario, the contaminants for which HQ <1 were obtained were considered not to present a significant ecological risk and were not retained for further evaluation in this risk assessment.

Similarly, for radionuclides, the ratios of maximum measured concentrations versus the BCG are summed over all radionuclides. If the sum is <1, then the site passes the screen and additional evaluation of radionuclide exposure and risk is unwarranted. If the sum is >1, however, the evaluation moves to the next stage of the graded approach in which more detailed information is incorporated to develop more realistic and site-specific exposure estimates.

The 200-ZP-1 OU groundwater data used in this screening assessment were obtained from the HEIS database, with the following exclusion criteria applied: field method results, rejected data, depth-discrete data, and data collected prior to January 1, 1988. This data set was prepared in the same manner as described in Section 4.2. There were 227 nonradiological analyses with a value reported of "zero." This corresponds to a rate of 0.18%. These "zero" results were excluded from the calculations until such time as data that reflects the real detection limits can be obtained. The radiological analyses were not excluded because there is a real potential for radiological analyses to be "zero" (including counting error). A list of these results is on file with the project. There are also variable sample sizes on an analyte-specific basis due to the different sampling designs for the various plumes and areas since 1988. The 200-ZP-1 RI/FS work plan (DOE-RL 2004c) consolidated information, focused the sampling, and established

specified analytes and frequencies of analyses by well. Based on the 200-ZP-1 RI/FS work plan, from the point of 2004 forward, more consistent numbers of results per analyte and per well will be obtained. The 200-ZP-1 DQO summary report (FH 2003c) provided logic for not analyzing for select analytes. In addition, past work has focused on the eight major human health risk drivers discussed in Section 1.4.

The results of this data query are presented in Table 5-1. Note that a description of the statistical term "bootstrapping" is presented in Section 4.2. In addition, numerous analytes were detected infrequently. The EPA's *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final* (EPA 1997) indicates that contaminants detected at a frequency of 5% or less are unlikely to be risk drivers; consequently, infrequently detected analytes can be removed from further consideration. Table 5-2 lists the summary statistics for groundwater COCs with detection frequencies of less than or equal to 5%.

There are also contaminants for which ecological screening values are unavailable, including lithium, uranium (listed as pCi/L in HEIS), neptunium-237, nitrogen in ammonia, nitrogen in nitrate, and nitrogen in nitrite/nitrate, as listed in Table 5-3. These analytes are considered further in the uncertainty assessment.

The screening assessment is segregated into three exposure scenarios of undiluted groundwater (worst-case), application of a 0.5 dilution factor (hyporheic water), and a 0.01 dilution factor (200-ZP-1 OU groundwater in Columbia River surface water) in the subsections that follow.

5.2.4.1 Scenario for No Dilution. Table 5-4 lists the ecological screening results for groundwater COPCs. Rows that are shown in bold/italic print indicate HQs (radionuclide sum of fractions) >1, which qualify as COPECs. Arsenic, acetone, and PCE are not COPECs (HQ <1) under worst-case conditions and are not considered further. In addition, no individual radionuclide exceeds its screening threshold and the radionuclide sum of fraction under worst-case conditions is less than one. Consequently, radionuclides are not risk drivers in groundwater of the 200-ZP-1 OU.

In summary, the COPECs for the worst-case scenario of maximum contaminant concentrations and no dilution are as follows:

- Chromium
- Hexavalent chromium
- Iron
- Lead
- Magnesium
- Manganese
- Nickel
- Selenium
- Total uranium
- Vanadium
- Carbon tetrachloride
- Chloroform
- Methylene chloride
- TCE
- Cyanide
- Fluoride.

5.2.4.2 Scenario for 0.5 Dilution Factor. Table 5-5 lists the ecological screening results for groundwater COPCs for the 0.5 dilution scenario that is representative of groundwater mixing with Columbia River water in the hyporheic zone. Rows shown in bold/italic print indicate HQs >1, which qualify as COPECs. The COPECs for the 0.5 dilution factor of maximum contaminant concentrations are as follows:

- Chromium
- Hexavalent chromium
- Iron
- Lead
- Manganese
- Nickel
- Selenium
- Total uranium
- Vanadium
- Carbon tetrachloride
- Chloroform
- Cyanide
- Fluoride.

5.2.4.3 Scenario for 0.01 Dilution Factor. Table 5-6 lists the ecological screening results for groundwater COPCs for the 0.01 dilution factor scenario that is representative of groundwater exiting the riverbed into Columbia River water. Rows shown in bold/italic print indicate HQs >1, which qualify as COPECs. The COPECs for the 0.01 dilution factor of maximum contaminant concentrations are as follows:

- Iron
- Lead
- Total uranium
- Carbon tetrachloride.

5.2.5 Uncertainty Assessment

Two major uncertainties exist with regard to this assessment, which primarily involve the use of representative groundwater concentrations in the dilution scenarios. Another, less significant, concern is contaminants without screening thresholds. These issues are considered further in the following subsections.

5.2.5.1 Results for Representative Groundwater Concentrations. Even after 99% dilution in the Columbia River, four contaminants (iron, lead, total uranium, and carbon tetrachloride) qualify as COPECs from the 200-ZP-1 OU. The dilution scenarios are based on maximum concentrations recorded in groundwater. As contaminants move from the 200-ZP-1 OU through the subsurface to the Columbia River, it is realistic to assume that isolated contaminant maxima at 200-ZP-1 become mixed with the plume. This mixing within the contaminant plume represents an averaging of concentrations. As such, characteristics of the average concentration best represent contamination from the OU over the course of the plume traveling to the river.

Table 5-7 shows how HQs compare to the average; specifically, the UCL on the mean calculated by "bootstrapping." Bootstrapping is a resampling technique that provides a nonparametric approach to calculating UCLs when strong distributional assumptions cannot be made about the

data set of interest. In these instances, bootstrapping allows for UCLs on the mean to be calculated by using the data itself to find the UCL. Specifically, the 95% bootstrapped UCL for the mean is calculated by resampling the data 1,000 times and computing the mean for each of those 1,000 resamples. A resample consists of a random sample of the same size and taken with replacement from the original data set. The value of the UCL is then the 95th percentile of the distribution of the resampled means. Table 5-7 includes HQ calculations for all three of the exposure scenarios relative to the 95% UCL of mean concentrations (i.e., no dilution, 0.5 dilution factor, and 0.01 dilution factor scenarios).

5.2.5.1.1 Scenario for No Dilution and Average Concentrations. As shown in Table 5-7, HQs based on the 95% UCL of the mean are often orders of magnitude lower than HQs based on maximum concentrations. The COPECs (HQ >1) based on average (UCL) concentrations in the scenario of no dilution are as follows:

- Hexavalent chromium
- Lead
- Selenium
- Total uranium
- Vanadium
- Carbon tetrachloride
- Cyanide.

5.2.5.1.2 Scenario for 0.5 Dilution Factor and 95% UCL Concentrations. The COPECs based on 95% UCL of the mean concentrations in the 0.5 dilution factor scenario are as follows (Table 5-7):

- Hexavalent chromium
- Total uranium
- Carbon tetrachloride
- Cyanide.

5.2.5.1.3 Scenario for 0.01 Dilution Factor and 95% UCL Concentrations. There are no COPECs based on 95% UCL of the mean concentrations in the 0.01 dilution factor scenario (Table 5-7).

5.2.5.2 Constituents with No Screening Benchmarks. There are contaminants for which ecological screening values are unavailable (i.e., lithium, uranium [listed as pCi/L in HEIS], neptunium-237, nitrogen in ammonia, nitrogen in nitrate, and nitrogen in nitrite/nitrate, as listed in Table 5-3). These analytes are considered further in the uncertainty assessment:

- **Lithium:** This analyte was detected in 6 of 121 samples for a detection frequency of 5%. While there is no ecological screening value for this constituent, it would be eliminated from further consideration based on infrequency of detection.
- **Uranium (in pCi/L):** Data in the HEIS database were recorded as uranium in pCi/L. There is no screening threshold for non-isotopic uranium in terms of pCi/L. However, both total uranium (for metal toxicity) and isotopic uranium are accounted in the assessment, and total uranium in pCi/L would be covered by consideration of these constituents.

- **Neptunium-237:** Neptunium-237, with a half-life of over 2 million years, has a low activity. Although neptunium-237 was sampled relatively infrequently, it was only detected once. It would not appear that this radionuclide represents a significant risk to ecological receptors associated with Columbia River.
- **Nitrogen in ammonium, nitrate, and nitrite:** Ammonium, nitrate, and nitrite were detected frequently, but no ecological screening thresholds exist for these constituents. These nitrogenous compounds are common in the aquatic environment and are not typically considered as having the potential for exerting adverse effects in open bodies of water such as the Columbia River.

5.2.6 Data Gaps and Potential Lines of Investigation

Using groundwater concentrations representative of the average, there is no evidence for potential ecological risk for 200-ZP-1 OU contaminants in the Columbia River. There is an indication of the potential for adverse ecological effects in the hyporheic zone using representative groundwater concentrations, specifically from hexavalent chromium, total uranium, carbon tetrachloride, and cyanide. Therefore, a more detailed ecological risk assessment is needed. There are a number of data gaps that will need to be addressed in the next step of the ecological evaluation. Screening levels are missing for a number of chemicals and radionuclides detected at these sites, and toxicity threshold values for these chemicals and radionuclides should be developed. This more detailed ecological risk assessment, performed in the FS, will provide information for decision making regarding the remaining COPECs for the 200-ZP-1 OU and will determine whether additional investigation or remediation is necessary.

Table 5-1. Summary Statistics for Groundwater Contaminants of Concern. (2 sheets)

	Detection Frequency	Number of Samples	Number of Detects	Min. Detect	Median Detect	Max. Detect	Number of ND	Min. ND	Median ND	Max. ND	Mean	Bootstrap UCL
Inorganic Metal (µg/L)												
Arsenic	0.489	846	414	0.6	2.965	101	432	0.4	5	73	5.3	5.8
Chromium	0.777	2,215	1,720	0.406	19.45	6,180	495	0.6	5.7	20	52.1	58.4
Hexavalent chromium	0.931	29	27	3	10.9	730	2	3	3	3	75.0	124.1
Iron	0.731	2,228	1,628	5.1	54.45	328,000	600	5.55	30	384	518	824.2
Lead	0.198	1,314	260	0.0486	1.9	340	1,054	0.01	1.5	37	3.7	4.2
Magnesium	0.999	2,233	2,231	2930	14,800	148,000	2	19	19	19	16,790	17,140
Manganese	0.691	2,210	1,528	0.193	4.65	2,320	682	0.072	4.44	10	19.8	23.1
Nickel	0.303	2,195	665	1	23.5	1,400	1,530	0.1	13.4	74	24.6	26.3
Selenium	0.253	851	215	0.312	3	22.2	636	0.3	5	163	7.2	8.3
Total uranium	0.990	704	697	0.008	1.2	454	7	0.1	0.1	1.02	6.5	8.8
Vanadium	0.883	2,211	1,952	2.2	28	1,140	259	0.2	30	72.5	31.0	32.0
Radionuclides (pCi/L)												
C-14	0.300	10	3	5.34	6.25	8.66	7	-1.84	-1.28	59.2	7.8	19.0
Cs-137	0.086	794	68	0	2.59	17	726	-8.9	-0.06535	20	0.34	0.5
I-129	0.126	792	100	0.012	1.296	50.8	692	-1.92	0.0649	35.7	1.4	1.7
Sr-90	0.116	387	45	0.0165	1.5	5.5	342	-1.26	0.0398	5.2	0.4	0.4
Tc-99	0.894	1,391	1,244	0.016	163.5	27,400	147	-8.87	2.57	15.4	573.8	664.8
Tritium	0.687	2,297	1,579	0.2	4,030	2,940,000	718	-923	85.7	400	43,790	52,460
U-233/234	1.000	1	1	0.46	0.46	0.46	0	N/A	N/A	N/A	0.5	N/A
U-234	1.000	10	10	0.0318	1.66	2.48	0	N/A	N/A	N/A	1.4	1.8
U-235	0.364	11	4	0.0103	0.03945	0.066	7	-0.0687	0.0288	0.0987	0.03	0.05
U-238	0.727	11	8	0.0175	0.5505	0.796	3	-0.0137	0.257	0.574	0.4	0.6

Table 5-1. Summary Statistics for Groundwater Contaminants of Concern. (2 sheets)

	Detection Frequency	Number of Samples	Number of Detects	Min. Detect	Median Detect	Max. Detect	Number of ND	Min. ND	Median ND	Max. ND	Mean	Bootstrap UCL
Detected Organic Compounds (µg/L)												
Acetone	0.222	1,335	296	0.42	2	870	1,039	0.21	4	2,000	43.3	51.4
Carbon tetrachloride	0.787	1,679	1,321	0.02	520	8,700	358	0.025	0.6	770	810.9	860.9
Chloroform	0.694	1,692	1,175	0.047	6.5	1,100	517	0.028	1	500	13.7	15.7
Methylene chloride	0.247	1,643	405	0.06	1.7	4,100	1,238	0.056	0.4	250	13.0	18.0
Tetrachloroethylene (PCE)	0.214	1,652	354	0.039	0.65	37	1,298	0.031	0.57	500	6.5	7.6
Trichloroethylene (TCE)	0.447	1,661	743	0.069	3.5	58	918	0.028	0.77	500	8.2	9.3
General Inorganic Compounds (µg/L)												
Cyanide	0.128	384	49	1	6	33.6	335	0.94	10	400	14.9	18.0
Fluoride	0.955	2,221	2,121	94	480	10,500	100	18	500	500	842.5	877.4

N/A = not applicable
ND = nondetect
UCL = upper confidence limit

Table 5-2. Summary Statistics for Groundwater Contaminants of Concern with Detection Frequencies of Less than or Equal to 5%. (2 sheets)

	Detection Frequency	Number of Samples	Number of Detects	Detected Concentrations			Number of ND	Min. ND	Median ND	Max. ND
				Min	Median	Max				
Inorganic Metal (µg/L)										
Antimony	0.029	2,195	63	2.4	4.3	77	2,132	1.1	42.5	212
Cadmium	0.037	2,217	81	0.0424	2.6	328	2,136	0.078	2.6	14.5
Mercury	0.038	1,326	51	0.021	0.127	0.54	1,275	0.019	0.1	0.25
Silver	0.038	2,195	83	0.91	4.1	171	2,112	0.1	4.5	33.5
Radionuclides (pCi/L)										
Pa-231	0.000	10	0	N/A	N/A	N/A	10	-33.2	0.061	46.4
Se-79	0.000	10	0	N/A	N/A	N/A	10	-7.14	6.55	16.3
Detected Organic Compounds (µg/L)										
1,1,1-trichloroethane	0.020	1,475	29	0.06	0.3	62	1,446	0.028	0.23	500
1,2-dichloroethane	0.007	1,457	10	0.089	0.2	100	1,447	0.018	0.2	500
2-butanone	0.018	1,398	25	0.48	4.2	66	1,373	0.1	1	2,000
4-methyl-2-pentanone	0.002	1,236	3	0.35	0.35	8.8	1,233	0.1	0.9	2,000
Benzene	0.017	1,515	26	0.062	0.29	7	1,489	0.013	0.23	500
Carbon disulfide	0.042	1,032	43	0.22	0.7	270	989	0.06	0.43	500
Chlorobenzene	0.000	372	0	N/A	N/A	N/A	372	0.05	5	500
cis-1,2-dichloroethylene	0.012	993	12	0.06	0.115	1.38	981	0.025	0.127	100
Ethylbenzene	0.025	673	17	0.043	0.081	0.32	656	0.034	0.14	500
n-Butylbenzene	0.000	14	0	N/A	N/A	N/A	14	0.12	0.2	1
Toluene	0.028	1,513	42	0.02	0.47	82	1,471	0.016	0.26	500
Total cresols	0.004	233	1	21	21	21	232	1.7	10	10
Total petroleum hydrocarbons (kerosene range)	0.000	76	0	N/A	N/A	N/A	76	4.03	10,000	10,000
Trans-1,2-dichloroethylene	0.005	1,111	5	0.24	0.43	0.48	1,106	0.031	0.17	100
Xylenes (total)	0.007	1,471	11	0.06	0.36	3	1,460	0.035	0.61	500

Table 5-2. Summary Statistics for Groundwater Contaminants of Concern with Detection Frequencies of Less than or Equal to 5%. (2 sheets)

	Detection Frequency	Number of Samples	Number of Detects	Detected Concentrations			Number of ND	Min. ND	Median ND	Max. ND
				Min	Median	Max				
General Inorganic Compounds (µg/L)										
Nitrogen in ammonia	0.000	7	0	N/A	N/A	N/A	7	3	41.12	41.12
Nitrogen in nitrite	0.050	1,763	89	7.4	99	11,000	1,674	1	7.4	304.5
Phosphate	0.009	652	6	282	779	2,200	646	22	340	1,000

N/A = not applicable
ND = nondetect

Table 5-3. Summary Statistics for Groundwater Contaminants of Concern without Benchmark Values.

	Detection Frequency	Number of Samples	Number of Detects	Min. Detect	Median Detect	Max. Detect	Number of ND	Min. ND	Median ND	Max. ND
Inorganic Metal (µg/L)										
Lithium	0.050	121	6	9.7	26	41.6	115	1	10	14.7
Radionuclides (pCi/L)										
Uranium	0.990	98	97	0.448	1.1	207	1	7.65	7.65	7.65
Np-237	0.083	12	1	0.021	0.021	0.021	11	-0.0137	0	0.164
General Inorganic Compounds (µg/L)										
Nitrogen in ammonium	0.241	282	68	15.53	77.65	11,650	214	15	38.82	77.65
Nitrogen in nitrate	0.992	2,381	2,362	4.518	17,100	1,720,000	19	22	564.7	564.7
Nitrogen in nitrite and nitrate	1.000	5	5	4,180	5,420	10,100	0	N/A	N/A	N/A

N/A = not applicable
ND = nondetect

Table 5-4. Ecological Screening Results for Groundwater Contaminants of Concern (Zero Dilution Factor).

	Maximum Concentration	Benchmark	Benchmark Source	HQ for No Dilution
Inorganic Metal (µg/L)				
Arsenic	101	150	EPA 2002b	0.67
Chromium	6,180	74	EPA 2002b	***83.51***
Hexavalent chromium	730	10	WAC 173-201A	***73***
Iron	328,000	1,000	EPA 2002b	***328***
Lead	340	2.5	WAC 173-201A	***136***
Magnesium	148,000	82,000	Suter and Tsao 1996	***1.80***
Manganese	2,320	120	Suter and Tsao 1996	***19.33***
Nickel	1,400	52	EPA 2002b	***26.92***
Selenium	22.2	5	WAC 173-201A	***4.44***
Total uranium	454	2.6	Suter and Tsao 1996	***174.62***
Vanadium	1,140	20	Suter and Tsao 1996	***57***
Radionuclides (pCi/L)				
C-14	8.66	8,100	DOE-RL 2005a	0.0011
Cs-137	17	40	DOE 2002	0.4250
I-129	50.8	40,000	DOE 2002	0.0013
Sr-90	5.5	300	DOE 2002	0.0183
Tc-99	27,400	700,000	DOE 2002	0.0391
Tritium	2,940,000	300,000,000	DOE 2002	0.0098
U-233/234	0.46	200	DOE 2002	0.0023
U-234	2.48	200	DOE 2002	0.0124
U-235	0.066	200	DOE 2002	0.0003
U-238	0.796000004	200	DOE 2002	0.0040
Detected Organic Compounds (µg/L)				
Acetone	870	1,500	Suter and Tsao 1996	0.58
Carbon tetrachloride	8,700	9.8	Suter and Tsao 1996	***887.76***
Chloroform	1,100	28	Suter and Tsao 1996	***39.29***
Methylene chloride	4,100	2,200	Suter and Tsao 1996	***1.86***
Tetrachloroethylene (PCE)	37	98	Suter and Tsao 1996	0.38
Trichloroethylene (TCE)	58	47	Suter and Tsao 1996	***1.23***
General Inorganic Compounds (µg/L)				
Cyanide	33.6	5.2	LANL 2005	***6.46***
Fluoride	10,500	1,600	LANL 2005	***6.56***

NOTE: Data listed in bold/italic print indicates HQ >1.
HQ = hazard quotient.

Table 5-5. Ecological Screening Results for Groundwater Contaminants of Concern (0.5 Dilution Factor).

	Max. Concentration	0.5 Dilution	Benchmark	Benchmark Source	HQ for 0.5 Dilution
Inorganic Metal (µg/L)					
Arsenic	101	50.5	150	EPA 2002b	0.34
Chromium	6,180	3,090	74	EPA 2002b	***41.76***
Hexavalent chromium	730	365	10	WAC 173-201A	***36.50***
Iron	328,000	164,000	1,000	EPA 2002b	***164.00***
Lead	340	170	2.5	WAC 173-201A	***68.00***
Magnesium	148,000	74,000	82,000	Suter and Tsao 1996	0.90
Manganese	2,320	1,160	120	Suter and Tsao 1996	***9.67***
Nickel	1,400	700	52	EPA 2002b	***13.46***
Selenium	22.2	11.1	5	WAC 173-201A	***2.22***
Total uranium	454	227	2.6	Suter and Tsao 1996	***87.31***
Vanadium	1,140	570	20	Suter and Tsao 1996	***28.50***
Detected Organic Compounds (µg/L)					
Acetone	870	435	1,500	Suter and Tsao 1996	0.29
Carbon tetrachloride	8,700	4,350	9.8	Suter and Tsao 1996	***443.88***
Chloroform	1,100	550	28	Suter and Tsao 1996	***19.64***
Methylene chloride	4,100	2,050	2,200	Suter and Tsao 1996	0.93
Tetrachloroethylene (PCE)	37	18.5	98	Suter and Tsao 1996	0.19
Trichloroethylene (TCE)	58	29	47	Suter and Tsao 1996	0.62
General Inorganic Compounds (µg/L)					
Cyanide	33.6	16.8	5.2	LANL 2005	***3.23***
Fluoride	***10,500***	***5,250***	***1,600***	***LANL 2005***	***3.28***

NOTE: Data in bold/italic print indicates HQ >1.
HQ = hazard quotient

Table 5-6. Ecological Screening Results for Groundwater Contaminants of Concern (0.01 Dilution Factor).

	Max. Concentration	0.01 Dilution	Benchmark	Benchmark Source	HQ for 0.01 Dilution
Inorganic Metal (µg/L)					
Arsenic	101	1.01	150	EPA 2002b	0.01
Chromium	6,180	61.8	74	EPA 2002b	0.84
Hexavalent chromium	730	7.3	10	WAC 173-201A	0.73
Iron	328,000	3,280	1,000	EPA 2002b	***3.28***
Lead	340	3.4	2.5	WAC 173-201A	***1.36***
Magnesium	148,000	1,480	82,000	Suter and Tsao 1996	0.02
Manganese	2,320	23.2	120	Suter and Tsao 1996	0.19
Nickel	1,400	14	52	EPA 2002b	0.27
Selenium	22.2	0.222	5	WAC 173-201A	0.04
Total uranium	454	4.54	2.6	Suter and Tsao 1996	***1.75***
Vanadium	1,140	11.4	20	Suter and Tsao 1996	0.57
Detected Organic Compounds (µg/L)					
Acetone	870	8.7	1,500	Suter and Tsao 1996	0.01
Carbon tetrachloride	8,700	87	9.8	Suter and Tsao 1996	***8.88***
Chloroform	1,100	11	28	Suter and Tsao 1996	0.39
Methylene chloride	4,100	41	2,200	Suter and Tsao 1996	0.02
Tetrachloroethylene (PCE)	37	0.37	98	Suter and Tsao 1996	0.00
Trichloroethylene (TCE)	58	0.58	47	Suter and Tsao 1996	0.01
General Inorganic Compounds (µg/L)					
Cyanide	33.6	0.336	5.2	LANL 2005	0.06
Fluoride	10,500	105	1,600	LANL 2005	0.07

NOTE: Data in bold/italic print indicates HQ >1.
HQ = hazard quotient

Table 5-7. Hazard Quotients for Maximum and Upper Confidence Limits of Mean Groundwater Contaminants of Concern Under Worst-Case Conditions (No Dilution), 0.5 Dilution Factor Scenario, and the 0.01 Dilution Factor Scenario.

	HQ Using Max. Concentration	HQ Using UCL of Mean Concentration, No Dilution	HQ Using UCL of Mean Concentration, 0.5 DF Scenario	HQ Using UCL of Mean Concentration 0.01 DF Scenario
Inorganic Metal (µg/L)				
Chromium	***84***	0.8	0.4	0.01
Hexavalent chromium	***73***	***12.4***	***6.2***	0.12
Iron	***328***	0.8	0.4	0.01
Lead	***136***	***1.7***	0.85	0.02
Magnesium	***1.8***	0.2	0.1	0.002
Manganese	***19.3***	0.2	0.1	0.002
Nickel	***26.9***	0.5	0.25	0.01
Selenium	***4.4***	***1.7***	0.85	0.02
Total uranium	***175***	***3.4***	***1.7***	0.03
Vanadium	***57***	***1.6***	0.8	0.02
Detected Organic Compounds (µg/L)				
Carbon tetrachloride	***888***	***87.8***	***43.9***	0.88
Chloroform	***39.2***	0.6	0.3	0.01
Methylene chloride	***1.9***	0.0		
Trichloroethylene (TCE)	***1.2***	0.2	0.1	0.002
General Inorganic Compounds (µg/L)				
Cyanide	***6.5***	***3.5***	***1.8***	0.04
Fluoride	***6.6***	0.55	0.3	0.01

NOTE: Data in bold/italic print indicates HQ >1.
DF = dilution factor
HQ = hazard quotient
UCL = upper confidence limit

6.0 RISK EVALUATION

6.1 OVERVIEW OF HUMAN HEALTH EVALUATION

As described in Section 1.4.1, an approach has been agreed upon to group the COCs into two groups (Group A and Group B). Group A includes the major risk drivers that are currently in plumes and for which an abbreviated human health risk screening was performed, as discussed in Section 6.1.2. Group B includes the other COCs from Table 1-5 that are not Group A analytes, which is based on Table A1-7 of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c).

Section 4.2 described the screening of both Group A and Group B analytes based on the PRGs, which are based on any one of the following:

- Primary MCLs from drinking water regulations
- Secondary MCLs from drinking water regulations
- Cleanup levels and risk calculations under WAC 173-340-720 (screening for potential groundwater impacts was performed using cleanup levels as published on Ecology's Internet site [https://fortress.wa.gov/ecy/clarc/Reproting/CLARCReporting/aspx]).

The above PRGs are based on drinking water-level risk screening or residential screening levels from Ecology (2005); as such, these results are extremely conservative. The PRGs were agreed upon in the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) and were updated when new information was obtained from Ecology (2005).

Section 6.1.1 summarizes the results of the COC screening to determine which analytes require additional risk assessment in the FS. Section 6.1.2 presents a preliminary risk screening based on existing plume maps and calculations of risk. Additional detailed risk modeling will be performed in the FS.

6.1.1 Existing Groundwater Data Compared to Preliminary Remediation Goals

The results of both the Group A and Group B screening evaluation performed in Section 4.2 are summarized in this section. The Group A or potential major risk drivers each have as least one result greater than two times the PRG. Note that total uranium and radioactive uranium are consolidated. Table 6-1 lists the potential major risk drivers.

The Group B, or other, analytes were screened and the two subgroups are presented in Table 6-1. As shown in Table 6-1, three analytes have fewer than 10% of detects above the PRG and the 95% UCL, as calculated by bootstrapping, above the PRG. Section 4.2 describes the bootstrapping technique, which is an acceptable approach by EPA. The second subgroup contains those analytes with greater than 10% of detects above the PRG and with 95% UCL also above the PRG.

Fluoride is the only analyte that has more than 10% of detects greater than the PRG, but the 95% UCL is below the PRG. Thus, fluoride is not recommended for further human health evaluation.

6.1.2 Evaluation of Major Risk Drivers

This section provides the results of the human health risk assessment based on existing conditions for some key indicator COCs. The evaluation consists of (1) a discussion of the general background on the scope and approach for the risk calculations, (2) the methods and approach used to develop unit risk and dose factors for scaling concentration levels to impact metrics, (3) the results of the estimated human health risk impacts for selected hazardous chemicals (i.e., carbon tetrachloride and uranium), and (4) dose and risk analysis for selected radionuclides (i.e., technetium-99, iodine-129, and uranium-238). A summary of the risk evaluation characterizes maximum site risks from existing conditions to determine if remedial actions are warranted and to support evaluation of remedial alternatives in an upcoming FS.

6.1.2.1 Background. A baseline risk assessment was described in the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) that was focused on the fate, transport, and human health risk of key COCs. The selected key hazardous and radiological COCs that exceed DWSs within the 200-ZP-1 OU area were as follows:

- **Chemical contaminants:** carbon tetrachloride, chromium, nitrate, TCE, chloroform, and fluoride
- **Radiological contaminants:** technetium-99, uranium, iodine-129, and tritium.

The technical analysis in Section 6.1.1 that evaluates monitoring data with risk factors calculated using default WAC 173-340-720, Method B factors may identify other COCs for further analysis in the baseline risk assessment that will be performed as part of the FS.

This analysis, as outlined in the 200-ZP-1 RI/FS work plan (DOE-RL 2004c), will evaluate the migration of current plumes as they might be affected by discontinuing the pump-and-treat system. The assessment was not expected to explicitly model the development of existing plumes following cessation of pumping and reinjection, but rather to approximate the rebound of existing plumes using a combination of current plume interpretations supplemented by historical information of contaminant concentrations observed in vicinity of pumping areas prior to initiation of pumping in the late 1980s and early 1990s.

Selection of some of the existing interpretations of plumes may not be appropriate for initial conditions in this analysis because they reflect current pumping conditions that may rebound to higher levels after cessation of pumping. Current plume distributions from the early 1990s, modified with information on concentration levels prior to pumping, will be used as conservative surrogate plumes for future equilibrated plumes after pumping stops.

In the planned baseline risk analysis, the development of plume data will involve (1) digitizing current plume maps modified with historical concentration observed prior to pumping, (2) interpolating the digitized plumes into gridded concentration files, and (3) processing the gridded files to develop initial condition files for use in the model. Assumptions on the depth of contamination for each COC plume based on field observations will need to be developed as a part of the analysis.

Given the uncertainties about the current understanding of past and continuing sources from the vadose zone to groundwater for the key COCs (i.e., carbon tetrachloride, technetium-99, iodine-129, and uranium) and ongoing drilling and field characterization that will update current understanding of existing plumes, an agreement was reached between RL and EPA, as documented in an attachment to the October 2005 200 Area Unit Managers' Meeting minutes

(FH 2005a), to defer detailed modeling and analysis of the baseline risk until the current characterization efforts and re-interpretation of plume behavior are updated. Information from characterization efforts that are expected to be completed in the coming months will be included to the extent possible in a baseline risk assessment developed as part of the planned FS of selected remedial alternatives later in FY06. In accordance with an agreement between RL and EPA, discussion of risk in this RI report is limited to the following two risk areas:

- Discussion of estimates of existing risks based on current interpretations of contaminant plumes that originate within the 200-ZP-1 OU and that exceed drinking standards. The plume interpretations are developed in the annual groundwater monitoring report for FY05 (PNNL 2006). This discussion only focuses on a few indicator COCs that include carbon tetrachloride, technetium-99, iodine-129, and uranium.
- Discussion of preliminary risks associated with the carbon tetrachloride plume based on information developed in a previous modeling study of carbon tetrachloride in *Recent Site-Wide Transport Modeling Related to Carbon Tetrachloride Plume at the Hanford Site* (Bergeron and Cole 2005).

6.1.2.2 Development of Unit Risk and Dose Factors. A set of calculations were performed with risk modules to develop unit risk and dose factors for groundwater use. Preliminary risk information presented are developed from existing plume concentration levels that exceed DWSs and from past-predicted concentration levels of carbon tetrachloride estimated by Bergeron and Cole (2005) and measured concentrations of the selected indicator COCs (i.e., technetium-99, iodine-129, and uranium). Risk estimates will be based on standard exposure scenarios similar to those defined in the HSRAM (DOE-RL 1995b) scenarios. During the period of institutional control (through 2150), land use in the Central Plateau (in accordance with the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* [DOE 1999]) is assumed to be an exclusive industrial use that will preclude any impacts from the use of groundwater. The industrial scenario considered for this RI report is approximately the same as that in the Columbia River comprehensive impact assessment version of the scenario (DOE-RL 1998), which was adapted with slight modification from the HSRAM (DOE-RL 1995b). This version does not include groundwater use in the near term, thus, no actual risks were calculated for the industrial scenario. For purposes of the risk discussion presented in this RI, estimated risks consider a drinking water only and a residential farmer scenario. A broader set of exposure scenarios may be considered over a longer term in the baseline risk assessment that will be evaluated in the upcoming FS.

Risk and dose factors were developed using the drinking water only and residential farmer scenarios and steady-state assumptions for groundwater use where the groundwater has a unit concentration of each contaminant. These results can be scaled and applied to water use at different concentration levels. The specific factors desired are the following:

- **Carbon tetrachloride:** cancer risk and HQ using the RfD (see Table 6-2 for reference sources)
- **Total uranium:** HQ using the RfD
- **Technetium-99:** dose (in mrem) and risk of latent cancer fatality
- **Iodine-129:** dose (in mrem) and risk of latent cancer fatality

- **Uranium:** dose (in mrem) and risk of latent cancer fatality largely from uranium-234, uranium-235, and uranium-238.

6.1.2.3 Description of Evaluated Scenarios. The following three scenarios were considered:

- Exclusive industrial
- Groundwater only
- Residential farmer.

The exclusive industrial scenario represents exposures that may occur to a person whose job onsite is primarily indoors but would also include some outdoor activities (e.g., building and grounds maintenance). The industrial scenario considered for this RI report is approximately the same as that in the Columbia River comprehensive impact assessment version of the scenario (DOE-RL 1998), which was adapted with slight modification from the HSRAM (DOE-RL 1995b). The worker is assumed to spend 8 hr/day in activities in the 200-ZP-1 OU, to consume drinking water from the Columbia River, to ingest incidental quantities of soil, and to breathe materials suspended from the soils.

For application to sites on the plateau, the water source is assumed to be surface water (Columbia River water) for the period from present through the year 2150; thereafter it may be assumed to include local groundwater. As noted in the previous section, because groundwater will not be used for some time in the future, there is no pathway of exposure for a worker at present; thus, no dose or risk was calculated. During the FS, this scenario may be evaluated under conditions of future groundwater use.

While groundwater under the 200-ZP-1 OU will not be a primary source of drinking water for Hanford Site workers during the period of institutional control, comparison to DWSs provides an important perspective for exposure to current contaminant levels in groundwater. The drinking water scenario used to calculate risks and doses in this RI report assumes a person weighing 70 kg and consuming 2 L of groundwater every day for a period of 30 years (DOE-RL 1995b).

Because the Columbia Basin area is extensively farmed, a scenario to account for potentially increased exposures as a result of living on a farm affected by Hanford contaminants provides another perspective for exposure to current contaminant levels in groundwater. The residential farmer scenario in this RI report, which is consistent with the agricultural resident scenario established in the HSRAM (DOE-RL 1995b), involves consumption of locally produced food and animal products in addition to the external exposure, inhalation, and soil ingestion pathways. It is assumed that the food products are grown in the same soil to which the residential farmer is exposed for external and inhalation exposures. The Washington State Department of Health (WDOH) has defined a set of input parameters for the residential farmer scenario (WDOH 1997), and many of these parameters were deemed appropriate for this RI report because they were determined to be applicable to local conditions. These included breathing rates of 20 m^3/day, milk intake, meat and fowl intake, and soil ingestion rate. The ingestion rates of locally grown farm products are the also WDOH values, and they have been apportioned into specific categories as suggested by *Exposure Scenarios and Unit Dose Factors for the Hanford Tank Waste Performance Assessment* (Rittmann 2003). The values of these input parameters are listed in Table 6-3.

The parameters in the Columbia River comprehensive impact assessment version of the residential farmer scenario (DOE-RL 1998) were adapted from the HSRAM (DOE-RL 1995b) tables. The Columbia River comprehensive impact assessment and HSRAM intake rates of soil (200 mg/day) are twice those of the WDOH recommendations (100 mg/day) because they assume intake of both surface soil and riparian sediments. Because the riparian sediments are many miles from most of the Hanford upland areas, the WDOH values were considered more applicable.

Overall, the WDOH values are reasonable and, because they have been determined to be applicable to local conditions, the values are used in these risk calculations. A different value was used for the atmospheric mass loading, for which an annual average value of 50 $\mu g/m^3$ is recommended. A key parameter for the inhalation pathway is the amount of material in the air from local sources on the ground. A value for this that has been commonly used is 100 $\mu g/m^3$. This value has been used at Hanford for many years based on historical measurements indicating that the total dust loading in the Hanford vicinity averaged approximately 85 $\mu g/m^3$. More recent measurements of a specific size fraction (PM_{10}) indicate that the particles less than 10 µm in aerodynamic median activity diameter (respirable size) account for only a fraction of the total dust loading. The manual for a commonly used DOE risk model (RESRAD) (Yu et al. 2000) presents a distribution taken from the EPA's Aerometric Information Retrieval System. The RESRAD distribution, verified by download from EPA's web site (www.epa.gov/airs/airs.html), indicates that the United States' average concentration of PM_{10} is only about 23 $\mu g/m^3$. Recent data from a particulate sampler located in the Hanford 200 Areas for the period of February 2001 through June 2002 is available (Napier and Snyder 2002, Appendix C). The mean air concentration of PM_{10} particulate in the 200 Areas, in an outdoor area influenced by the Hanford 24 command wildfire in 2000, is only 21 $\mu g/m^3$. The 95th percentile daily value is only 36.5 $\mu g/m^3$; thus, a default of 100 $\mu g/m^3$ is probably excessive. The RESRAD manual states that "...use of a high, short-term loading will result in an overestimate of the annual dose. A time average mass loading factor should be used in RESRAD for a more realistic dose estimate..." (Yu et al. 2000, pp. 4-15). Because the dust in frequented areas (e.g., dirt roads) might be enhanced due to mechanical disturbances, an annual average value of 50 $\mu g/m^3$ was deemed appropriate.

The input parameters of significance are presented in Table 6-3, and it should be noted that these were also consistent with the recommendations for the Hanford Reach National Monument agricultural residential scenario (Napier and Snyder 2002). The selected parameters differ slightly from, but are consistent with, those of HSRAM (DOE-RL 1995b) and WDOH (1997), as well as scenarios applied to tank waste (Rittmann 2003) and low-level radioactive waste disposal sites (Thatcher 2003). The parameters are also of the same magnitude as those recommended for an agricultural screening scenario developed by the National Council on Radiation Protection and Measurements (NCRP 1999).

6.1.2.3.1 Other Data and Assumptions. The concentrations of constituents in soil are based on a time-dependent model (Eslinger et al. 2004) of soil accumulation. The model uses an irrigation amount of 76 cm of water applied over a 6-month growing period. A net fraction of 20% of the irrigation water is assumed to infiltrate deeper than the root zone. The soil concentrations are representative of the concentrations after 50 years of crop irrigation. They are representative of steady-state conditions because steady-state conditions are achieved by 5 years of irrigation for the sorption values of the four constituents in this study.

Concentrations of constituents in food products were calculated using the Ecological Contaminant Exposure Model (Eslinger et al. 2004). This model uses a food-chain approach to model the in growth of constituents into foods consumed by humans.

Data for RfDs [units of mg (intake)/(kg (bodyweight) day)] were obtained from the references listed in Table 6-2. Data for slope factors for carcinogenic materials [units of risk per mg (intake)/(kg (bodyweight)/day)] were obtained from the references in Table 6-4.

6.1.2.3.2 Results of Unit Dose and Risk Factors. The dose and risk factors resulting from a unit concentration of a constituent in the groundwater are provided in Table 6-5. A dose to risk conversion factor of 6.0E-7 (risk/mrem) for radionuclides was used in preparing these results. These factors are taken from DOE (2002).

6.1.2.4 Human Health Risk Evaluation Results for Hazardous Contaminants. As discussed earlier, this limited risk analysis focuses the fate, transport, and risk of a few key indicator chemical and radiological COCs that currently exceed DWSs within the 200-ZP-1 OU area. The key chemical contaminant evaluated is carbon tetrachloride. The key indicator radiological constituents evaluated include technetium-99, uranium, and iodine-129. The noncarcinogenic risk associated with uranium as a chemical constituent is also evaluated. The hazardous chemical impacts estimated for carbon tetrachloride are discussed below.

6.1.2.4.1 Current Conditions. According to the groundwater quality conditions for FY05 summarized in PNNL (2006), carbon tetrachloride contamination is found at levels greater than the DWS (5 µg/L) in groundwater under most of the 200 West Area (Figure 6-1). The main sources are believed to be the 216-Z Cribs and Trenches, which received waste from PFP. Other possible carbon tetrachloride sources exist in the northern portion of the OU. Carbon tetrachloride and other VOCs were detected in the trenches and vadose zone within LLWMA-4 during FY02 (PNNL 2005a), which has been the subject of an ongoing investigation and associated waste retrieval. The maximum carbon tetrachloride levels in groundwater are found near PFP and range up to 5,300 µg/L in individual samples.

Carbon tetrachloride remediation is the subject of the 200-ZP-1 interim ROD (EPA et al. 1995). The target for remediation is the area with concentrations greater than 2,000 to 3,000 µg/L in the vicinity of the 216-Z Cribs and Trenches. Significant features of the carbon tetrachloride plume at the top of the aquifer are discussed in the following paragraphs.

The area of carbon tetrachloride greater than 4,000 µg/L in the vicinity of the 216-Z Cribs and Trenches is decreasing due to remediation. An area of carbon tetrachloride at levels greater than 2,000 µg/L extends north to the vicinity of WMA-TX/TY. The west side of this lobe is defined by new monitoring well 299-W15-43, where the average concentration was 1,200 µg/L, which was lower than in FY03 and FY04 (this well was drilled early in FY03). Sampling for carbon tetrachloride at well 299-W15-44, located northeast of extraction well 299-W15-34, showed an average concentration of 2,600 µg/L in FY05, which is above levels measured in FY04. Carbon tetrachloride contamination reaches the northern portion of WMA-TX/TY, where concentrations in well 299-W15-765 averaged 2,400 µg/L, lower than measured in FY04. The contamination at levels above 2,000 µg/L extends beyond the capture zone of the initial 200-ZP-1 remediation system. The remediation system was expanded in FY05 to capture this northern extension of the contamination.

Levels of carbon tetrachloride greater than 1,000 µg/L are seen in the northern portion of the 200-ZP-1 OU. Well 299-W11-10, located near the eastern boundary of the 200 West Area, has consistently shown high carbon tetrachloride concentrations and was at 610 µg/L. The extent beyond the area boundary for this high concentration has not been determined because there are no wells for approximately 2 km (1.2 mi) downgradient.

In the past several years, increasing concentrations of carbon tetrachloride have been seen in the vicinity of the tank farms in WMA-S/SX (in the 200-UP-1 OU). Concentrations appear to have leveled off or declined in several wells in this area, but more time is needed to confirm the trends.

The extent of carbon tetrachloride at the DWS (5 µg/L) did not change significantly from the previous year (Figure 6-1). Carbon tetrachloride concentrations in some locations are higher at depth than at the top of the unconfined aquifer. Carbon tetrachloride may have moved deeper in the aquifer as a dense nonaqueous liquid or under hydrodynamic gradients when dissolved. The depth distribution of carbon tetrachloride is part of an ongoing investigation under the 200-ZP-1 RI/FS. Characterization sampling during drilling of new monitoring wells has increased understanding of the depth-distribution of carbon tetrachloride.

Information on the vertical distribution of carbon tetrachloride is also available from vertical profiling in wells with long, screened intervals (e.g., PNNL 1998, 1999, 2002; BHI 1996, 1997c [these reports document areas where the maximum carbon tetrachloride concentration is lower at the water table than found at depth]). The available data set is insufficient to map out the depth distribution of carbon tetrachloride.

Estimated cancer risk from current interpreted concentration levels of carbon tetrachloride in the upper portion of the aquifer for the drinking water only and residential farmer scenarios are presented in Figure 6-2. For the drinking water only scenario, risks exceeding $1x10^{-6}$ extend over most of the eastern half of 200 West Area. The maximum calculated risk is $2.2x10^{-4}$ in the area where well concentrations are highest and suspected sources are entering the aquifer from the vadose zone. For the residential farmer scenario, risks exceeding $1x10^{-6}$ extend over a larger area than calculated for the drinking water only scenario. The maximum calculated risk for this scenario is $1.1x10^{-3}$ in suspected source areas where well concentrations are highest.

Estimated HQs from current interpreted concentration levels of carbon tetrachloride in the upper portion of the aquifer for the drinking water only and residential farmer scenarios are presented in Figure 6-3. For the drinking water only scenario, HQs >0.1 extend over most of the east half of 200 West Area. The maximum calculated HQ is 171 in the area where well concentrations are highest and suspected sources are entering the aquifer from the vadose zone. For the residential farmer scenario, HQs >0.1 extend over a larger area than calculated for the drinking water only scenario. The maximum calculated HQ for this scenario is 815 in suspected source areas where well concentrations are highest.

6.1.2.4.2 Projected Conditions from Past Modeling. The Hanford Carbon Tetrachloride ITRD Program provided an initial evaluation of the nature and extent of carbon tetrachloride contamination in the unconfined aquifer in the 200 West Area of the Hanford Site (Truex et al. 2001). After the ITRD Program ended, subsequent studies by Bergeron and Cole (2005) more closely examined the transport of carbon tetrachloride in the unconfined aquifer system. Those studies, documented in Bergeron and Cole (2005), were undertaken to support strategic planning

and provide guidance for the more robust modeling needed to obtain a final ROD for the carbon tetrachloride plume.

The ITRD modeling study examined carbon tetrachloride concentrations at a boundary between the 200 East and 200 West Areas (Truex et al. 2001) selected for the analysis. After that work was completed, questions arose concerning the concentrations reaching the Columbia River, as well as about the impact of remediation options involving source removal or absence. To address these questions, additional modeling studies were conducted using the groundwater model with the modeling domain extended to the Columbia River. The downgradient boundary between the 200 East and 200 West Areas selected for the analysis was retained to provide a consistent location of analysis for all calculations. This modeling analysis, summarized in Bergeron and Cole (2005) resulted in the conclusions discussed below.

With the assumption of a continuing source with no sorption or K_a (Case 1a, Bergeron and Cole 2005), the following was observed:

- A substantial carbon tetrachloride plume has developed from source areas in the 200 West Area and migrated to the Columbia River. Predicted concentrations reached approximately 200 µg/L at the selected downgradient boundary chosen for this analysis and approximately 34 µg/L along the Columbia River during the 1,000-year period of analysis (Figure 6-4). Both of these values exceed the benchmark MCL of 5 µg/L
- The equilibrium carbon tetrachloride release estimate in the source area was approximately 73 kg/yr.
- Initial conditions yielded an initial mass of approximately 542 kg in the aquifer, which grew to 58,050 kg after 1,000 years (i.e., the year 3000).

With the assumption of a continuing source with median value estimates of sorption and K_a (Case 1b, Bergeron and Cole 2005), the following was observed:

- There was limited development and migration of a carbon tetrachloride plume from source areas within the general vicinity of the 200 West Area. Predicted concentrations reached approximately 4.5 µg/L at the boundary chosen for this analysis (Figure 6-5). Concentrations at discharge areas along the Columbia River did not reach any substantial levels during the 1,000-year period of analysis.
- The combination of sorption and K_a rate significantly limits aquifer source loading and the aquifer area and volume affected by the carbon tetrachloride plume migration. The more important parameter of the two is the K_a rate because retardation alone will not reduce concentrations other than through hydrodynamic dispersion.

The most probable value of 0.12 L/kg and the median value of K_d of approximately 0.18 L/kg considered in the original analysis by Truex et al (2001) and in Bergeron and Cole (2005) are found to be within the range of K_ds for carbon tetrachloride (0.106 to 0.367 L/kg) determined for contaminated aquifer sediments collected from a borehole near the 261-Z-9 Trench by Riley et al. (2005).

Without a continuing source of carbon tetrachloride and no sorption or K_a, results were observed that were very similar whether the source area with the highest concentrations in the plume (i.e., above 3,000 µg/L) was assumed to be removed from the aquifer (Case 2, Bergeron and

Cole 2005) or the existing plume was considered an initial condition of aquifer contamination (Case 3, Bergeron and Cole 2005). In both cases, the following was observed:

- A more limited development and migration of a carbon tetrachloride plume outside the 200 West Area toward the Columbia River than with the continuing source assumption evaluated in Case 1a.
- A predicted concentration profile reaching about 6.5 µg/L at the chosen boundary over a period of approximately 600 years (between the years 2100 and 2700) (Figures 6-6 and 6-7). This contrasts with the rapidly rising and plateauing profile of carbon tetrachloride concentrations predicted under the continuing source assumption evaluated in Case 1a.
- A concentration profile at discharge areas along the Columbia River that is well below the benchmark MCL level of 5 µg/L during the 1,000-year period of analysis.

In summary, the results of these analyses illustrate the importance of developing field-scale estimates of sorption constants (K_d) and abiotic degradation constants (K_a) values for carbon tetrachloride. With K_d and K_a values of "zero," carbon tetrachloride concentrations will exceed the compliance limit of 5 µg/L outside the 200 Area Plateau WMA, and the aquifer source loading and area of the aquifer affected will continue to grow until river arrival rates equal source release rates of an estimated 73 kg/yr. Results of this modeling analysis show that natural attenuation parameters K_d and K_a are critical (especially K_a) in predicting the future movement of carbon tetrachloride from the 200 West Area. Results also show the significant change in predictions between continual source release from the vadose zone and complete source removal.

Of all the cases simulated as a part of this previous analysis, Case 1a (Bergeron and Cole 2005), with its assumed continuing source with no adsorption and degradation, represents the most conservative scenario from a risk perspective. Estimated cancer risks from projected concentration levels of carbon tetrachloride based Case 1a (Bergeron and Cole 2005) for the drinking water only and residential farmer scenarios are presented in Figure 6-8. For the drinking water only scenario, calculated risk of 1.1×10^{-5} was estimated at the selected boundary. Calculated risk for the drinking water only scenario decreases to 1.8×10^{-6} at maximum concentration locations along the Columbia River. For the residential farmer scenario, calculated risk of 5.1×10^{-5} was estimated at the selected boundary. Calculated risk for the same scenario decreases to 8.5×10^{-6} at maximum concentration locations along the Columbia River.

Estimated HQs from projected concentration levels of carbon tetrachloride for the same Case 1a (Bergeron and Cole 2005) for the drinking water only and residential farmer scenarios are presented in Figure 6-9. For the drinking water only scenario, calculated HQs of about 8.3 are estimated at the selected boundary. Calculated HQs decrease to about 1.4 at locations of maximum predicted concentration along the Columbia River. For the residential farmer scenario, calculated HQs of about 39.4 at the selected boundary. Calculated HQs for the same scenario decrease to about 6.6 at locations of maximum predicted concentration along the Columbia River.

6.1.2.5 Human Health Risk Evaluation Results for Radiological Contaminants. The following subsections provide a discussion of the impact from radiological constituents estimated from current concentration levels of technetium-99, iodine-129, and uranium.

6.1.2.5.1 Technetium-99. Technetium-99 within the 200-ZP-1 OU is found at levels above the DWS (900 pCi/L) on the downgradient side of WMA-T and WMA-TX/TY (Figure 6-10). However, evidence points to multiple sources of technetium-99 within those areas.

Near WMA-T, technetium-99 concentrations decreased slightly in the first part of FY05 before returning to an increasing trend in wells on the eastern side (downgradient) of the T Tank Farm. Well 299-W11-39, located near the northeastern corner of the WMA, had the highest concentration in the area for water table wells, with values in FY05 averaging 17,000 pCi/L. Higher concentrations were found at depth nearby during drilling of well 299-W11-25B, where the highest level detected was greater than 180,000 pCi/L. Technetium-99 concentrations east of WMA-TX/TY in well 299-W14-13 continued to be much higher than in surrounding wells and showed a generally increasing trend. The FY05 average concentration in this well was approximately 7,100 pCi/L. This contamination is associated with elevated levels of chromium, nitrate, tritium, and iodine-129.

Estimated radiological doses from current interpreted concentration levels of technetium-99 (Figure 6-10) in the upper portion of the aquifer for the drinking water only and residential farmer scenarios are presented in Figure 6-11. For the drinking water only scenario, doses exceeding 1 mrem extend over a very small area in the north central portion of the 200 West Area. The maximum calculated dose is 38.5 mrem in the area where well concentrations are highest and suspected sources are entering the aquifer from the vadose zone. For the residential farmer scenario, doses exceeding 1 mrem extend over a larger area than calculated for the drinking water only scenario. The maximum calculated dose for this scenario is 490 mrem in suspected source areas where well concentrations are highest.

Estimated cancer risk from current interpreted concentration levels of technetium-99 (Figure 6-10) in the upper portion of the aquifer for the drinking water only and residential farmer scenarios is presented in Figure 6-12. For the drinking water only scenario, risks exceeding $1x10^{-6}$ extend over a small area in the north central portion of the 200 West Area. As shown in Table 6-6, the maximum calculated risk is $2.3x10^{-5}$ in the area where well concentrations are highest and suspected sources are entering the aquifer from the vadose zone. For the residential farmer scenario, risks exceeding $1x10^{-6}$ extend over a larger area in the central portion of the 200 West Area than calculated for the drinking water only scenario. As shown in Table 6-6, the maximum calculated risk for this scenario is $2.9x10^{-4}$ in suspected source areas where well concentrations are highest.

6.1.2.5.2 Iodine-129. An iodine-129 plume is found in the 200-ZP-1 OU emanating from the vicinity of WMA-TX/TY and extending to the northeast (Figure 6-13). The highest concentration detected in FY05 was in well 299-W14-13, where the average concentration was 18 pCi/L near WMA-TX/TY. Iodine-129 contamination at levels above the drinking DWS does not appear to extend beyond the 200 West Area boundary.

Estimated radiological doses from current interpreted concentration levels of iodine-129 (Figure 6-13) in the upper portion of the aquifer for the drinking water only and residential farmer scenarios are presented in Figure 6-14. For the drinking water only scenario, doses exceeding 1 mrem extend over an area in the northeast portion of the 200 West Area. The maximum calculated dose is 3.6 mrem in the area where well concentrations are highest and suspected sources are entering the aquifer from the vadose zone. For the residential farmer scenario, doses exceeding 1 mrem extend over a larger area than calculated for the drinking

water only scenario. The maximum calculated dose for this scenario is 220 mrem in suspected source areas where well concentrations are highest.

Estimated cancer risk from current interpreted concentration levels of iodine-129 (Figure 6-13) in the upper portion of the aquifer for the drinking water only and residential farmer scenarios are presented in Figure 6-15. For the drinking water only scenario, risks exceeding $1x10^{-6}$ extend over an area in the northeastern portion of the 200 West Area. As shown in Table 6-6, the maximum calculated risk is $2.2x10^{-6}$ in the area where well concentrations are highest and suspected sources are entering the aquifer from the vadose zone. For the residential farmer scenario, risks exceeding $1x10^{-6}$ extend over a larger area in the central portion of the 200 West Area than calculated for the drinking water only scenario. As shown in Table 6-6, the maximum calculated risk for this scenario is $1.31x10^{-4}$ in suspected source areas where well concentrations are highest.

6.1.2.5.3 Uranium. The extent of current uranium concentration levels from FY05 sampling (in µg/L) is shown in Figure 6-16. This interpretation does include uranium data analyses during FY03 and FY04. Uranium was detected above the 30 µg/L DWS in wells 299-W11-14 and 299-W11-37 in the northeastern portion of the 200 West Area. The uranium concentration detected in well 299-W11-14 when it was last was sampled in FY04 was approximately 42 µg/L. The uranium concentration detected in well 299-W11-37 when sampled in FY05 was approximately 180 µg/L. Uranium was just below the DWS near the southwestern corner (upgradient) of LLWMA-4 in well 299-W18-21. The concentration in well 299-W18-21 was approximately 26 µg/L when sampled in FY05.

Estimated HQs from these interpreted concentration levels of uranium (Figure 6-16) in the upper portion of the aquifer for the drinking water only and residential farmer scenarios are presented in Figure 6-17. For the drinking water only scenario, HQs >0.1 extend over a small area in the northeastern portion of the 200 West Area. The maximum calculated HQ is about 9 in the area where well concentrations are highest and suspected sources are entering the aquifer from the vadose zone. For the residential farmer scenario, HQs >0.1 extend over a larger area than calculated for the drinking water only scenario. The maximum calculated HQ for this scenario is about 52. The maximum calculated risk for this scenario is 0.7 in suspected source areas where well concentrations are at their highest.

Estimated radiological doses from uranium concentration levels (Figure 6-16) in the upper portion of the aquifer for the drinking water only and residential farmer scenarios are presented in Figure 6-18. With an assumption that uranium isotopes reflect natural abundance, the calculated doses primarily reflect dose contributions from both uranium-234 and uranium-238.

For the drinking water only scenario, doses exceeding 1 mrem extend over a very small area in the north central portion of the 200 West Area. The maximum calculated dose is approximately 24.5 mrem in the area where well concentrations are highest and suspected sources are entering the aquifer from the vadose zone. For the residential farmer scenario, doses exceeding 1 mrem extend over a larger area than calculated for the drinking water only scenario. The maximum calculated dose for this scenario is approximately 142 mrem in suspected source areas where well concentrations are highest.

Estimated cancer risk from these uranium concentration levels for the drinking water only and residential farmer scenarios are presented in Figure 6-19. For the drinking water only scenario, risks exceeding $1x10^{-6}$ extend over a small area in the northeastern portion of the 200 West Area.

As shown in Table 6-6, the maximum calculated risk for the uranium isotopes evaluated is approximately 1.47×10^{-5} in the area where well concentrations are highest and suspected sources are entering the aquifer from the vadose zone. For the residential farmer scenario, risks exceeding 1×10^{-6} extend over a larger area in the northeastern portion of the 200 West Area than calculated for the drinking water only scenario. As shown in Table 6-6, the maximum calculated risk for this scenario is approximately 8.5×10^{-5} in suspected source areas well concentrations is highest.

6.1.2.6 Summary of Current Risk Evaluation. Preliminary maximum risk and HQ estimates are based on current interpretations of contaminant plumes that originate within the 200-ZP-1 OU and exceed DWSs. The preliminary risks and evaluated constituents are summarized in Tables 6-6, 6-7, and 6-8. A summary of maximum total radiological doses and associated cancer risks for the evaluated constituents is provided in Table 6-6.

The maximum dose/risk values provided in Table 6-7 are not simply the summation of individual constituent maximums found in Tables 6-6 and 6-8, but rather reflect the maximum values of dose and risk resulting from the summation of the geographic distributions of these parameters calculated from each constituent. In addition, the maximum risk associated with the location of the maximum total radiological dose does not correspond to the location of the maximum overall risk, which is mainly attributable to the location of the maximum concentration of carbon tetrachloride.

For the drinking water only scenario, the maximum radiological dose is 43.2 mrem and maximum risk associated with the radiological constituents is 2.59E-05 (refer to Table 6-7). The maximum overall risk (at a different location than the maximum radiological dose), found at the location of the highest concentration of carbon tetrachloride, is 2.26E-04 (see Tables 6-7 and 6-8). Similarly, for the resident farmer scenario, the maximum dose is 570.8 mrem and maximum risk from the radiological components is 3.43E-04 (refer to Table 6-7). For this scenario, the maximum overall risk (at a different location than the maximum radiological dose) which is found at the location of the highest concentration of carbon tetrachloride, is mainly attributable to carbon tetrachloride and is 1.07E-03 (see Tables 6-7 and 6-8.)

Individual constituent maximum cancer risks and HQs for the hazardous chemicals and maximum doses and cancer risks for the radionuclides are provided in Tables 6-6 and 6-8, respectively. As expected, the largest risks are associated with ingestion of and exposure to groundwater containing carbon tetrachloride. This risk analysis shows that ingestion of and exposure to groundwater containing the highest levels of carbon tetrachloride in the upper portions of the unconfined aquifer would result in maximum estimated cancer risks of approximately 2.2×10^{-4} and 1.1×10^{-3} for the drinking water only and residential farmer exposure scenarios, respectively (Table 6-8). Ingestion of and exposure to groundwater containing the highest levels of carbon tetrachloride in the upper portions of the unconfined aquifer resulted in calculated HQs of 171 and 815 for the same exposure scenarios (Table 6-8). Ingestion and exposure to groundwater containing the highest levels of uranium in the uppermost aquifer yields HQs of 8.57 and 49.5 for these scenarios.

Significant radiological doses and associated incremental cancer risk are also associated with ingestion of and exposure to groundwater containing elevated levels of technetium-99, iodine-129, uranium-234, uranium-235, and uranium-238. This risk analysis shows that ingestion of and exposure to groundwater containing the highest levels of technetium-99 in the

upper portions of the unconfined aquifer would result in maximum estimated cancer risks of $2.3x10^{-5}$ and $2.9x10^{-4}$ for the drinking water only and residential farmer exposure scenarios, respectively. Maximum doses would be 38.5 and 490 mrem, respectively. For maximum concentration levels of iodine-129, maximum estimated cancer risks would be $2.2x10^{-6}$ and $1.3x10^{-4}$, respectively, for these same exposure scenarios. Maximum doses from iodine-129 would be 3.6 and 220 mrem, respectively. For maximum concentration levels of uranium, estimated cancer risks (from all uranium isotopes) would be $1.5x10^{-5}$ and $8.5x10^{-5}$, respectively, for these same exposure scenarios. The corresponding maximum risks and associated doses attributable to the key uranium isotopes are also provided in Table 6-6.

6.2 ECOLOGICAL EVALUATION

There are no direct exposure pathways from Central Plateau groundwater to ecological receptors; the main concern regarding ecological exposure involves the Columbia River. To characterize ecological risks associated with contaminated 200-ZP-1 groundwater, a bounding analysis is performed with three exposure scenarios. The three scenarios are (1) no dilution, (2) 50% dilution of groundwater with the Columbia River, and (3) a scenario that addresses a mass-balance dilution of groundwater in Columbia River water and assumes a mixing ratio of 1% of the analyte-specific maximum OU groundwater concentration and 99% Columbia River water (i.e., the 0.01 dilution scenario). Section 5.2 presents the ecological evaluation and details of the scenarios, the values used for risk screening, and their technical origin and the results. The results are summarized below.

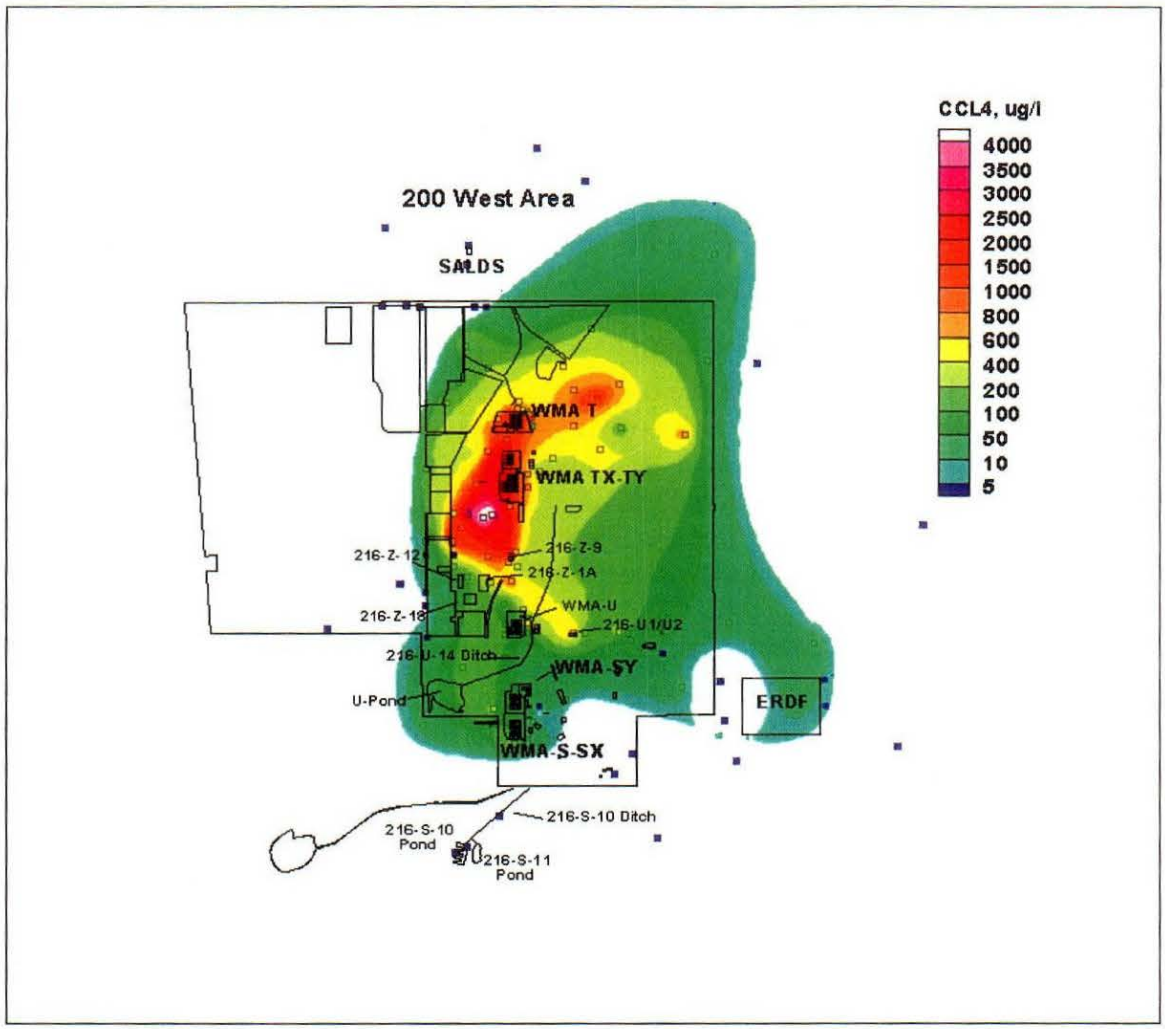
It must be noted that the dilution scenarios are based on maximum concentrations recorded in groundwater. As contaminants move from the 200-ZP-1 OU through the subsurface to the Columbia River, it is realistic to assume that isolated contaminant maxima 200-ZP-1 become mixed with the plume. This mixing within the contaminant plume represents an averaging of concentrations. As such, characteristics of the average concentration best represent contamination from the OU over the course of the plume traveling to the river.

Table 5-7 presents the HQs for maximum and UCLs of mean groundwater contaminants of concern versus screening levels for each scenario. The results of the risk evaluation using the average concentration and the dilution scenarios are as follows:

- **No dilution:** seven analytes exceed the HQ of 1
- **0.5 dilution factor:** four analytes exceed the HQ of 1
- **0.01 dilution factor:** no analytes exceed the HQ of 1.

Using groundwater concentrations representative of the average, there is no evidence for potential ecological risk for 200-ZP-1 OU contaminants in the Columbia River. There is an indication of the potential for adverse ecological effects in the hyporheic zone using representative groundwater concentrations (specifically, from hexavalent chromium, total uranium, carbon tetrachloride, and cyanide). Therefore, a more detailed ecological risk assessment is needed for these four analytes.

Figure 6-1. Current (Fiscal Year 2005) Interpreted Concentration Levels of Carbon Tetrachloride at the Water Table.[a]



[a] Distribution of wells used in the interpretation is depicted in squares color-coded to the concentration legend. This figure is adapted from PNNL 2006.

Figure 6-2. Cancer Risk from Current (Fiscal Year 2005) Interpreted Concentration Levels of Carbon Tetrachloride for Drinking Water Only and Residential Farmer Scenarios. (2 sheets)

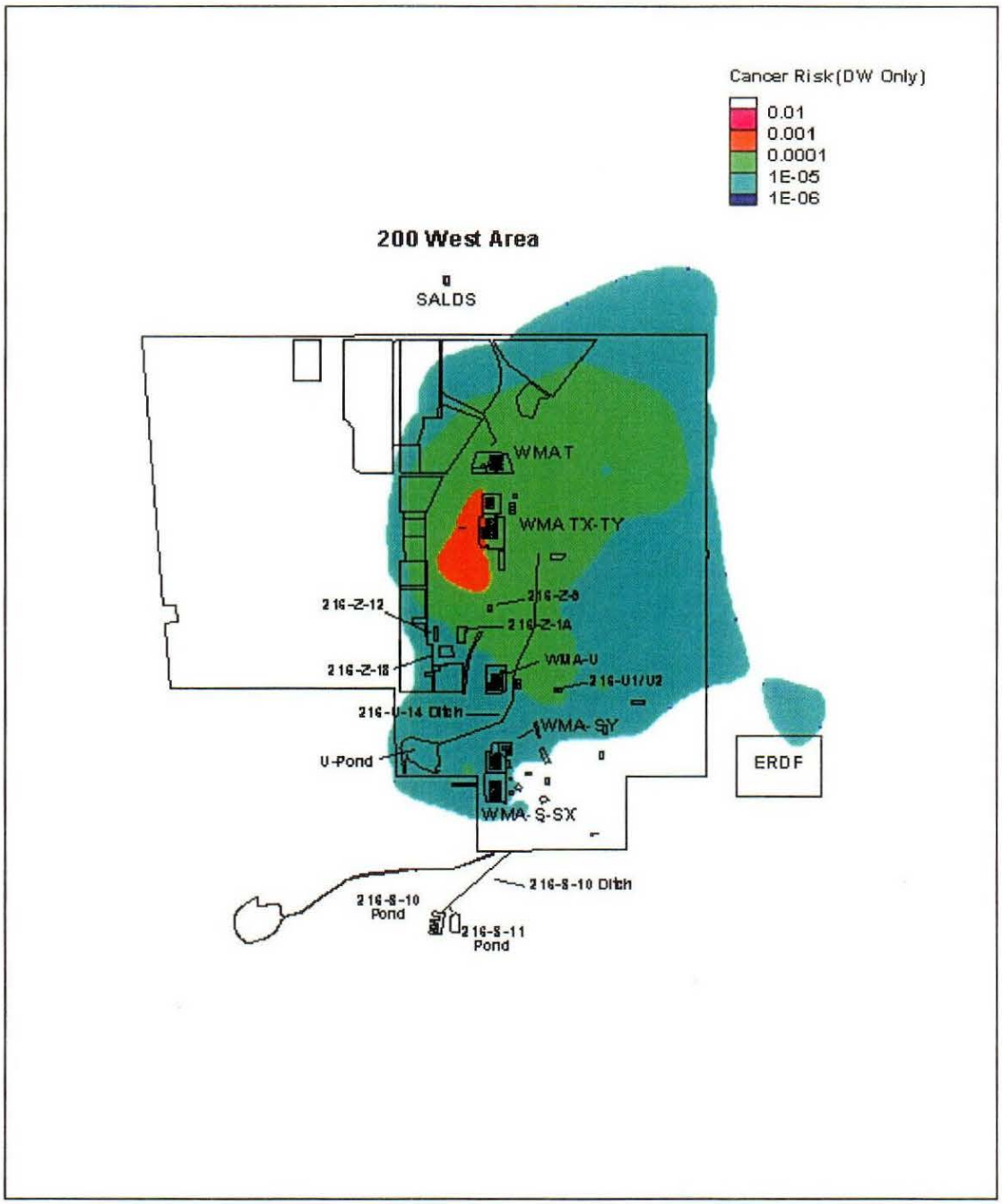


Figure 6-2. Cancer Risk from Current (Fiscal Year 2005) Interpreted Concentration Levels of Carbon Tetrachloride for Drinking Water Only and Residential Farmer Scenarios. (2 sheets)

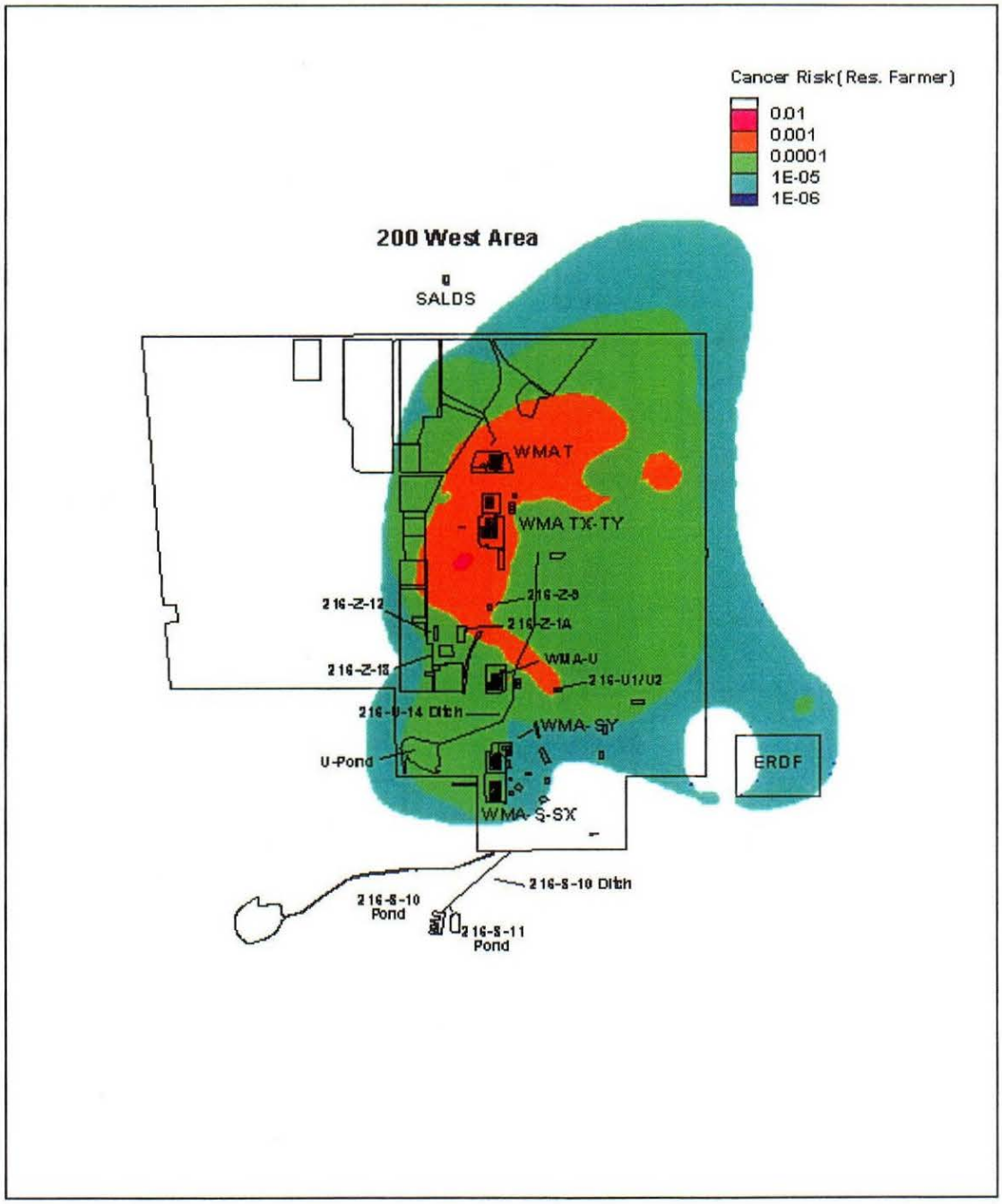


Figure 6-3. Hazard Quotient from Current (Fiscal Year 2005) Interpreted Concentration Levels of Carbon Tetrachloride for Drinking Water Only and Residential Farmer Scenarios. (2 sheets)

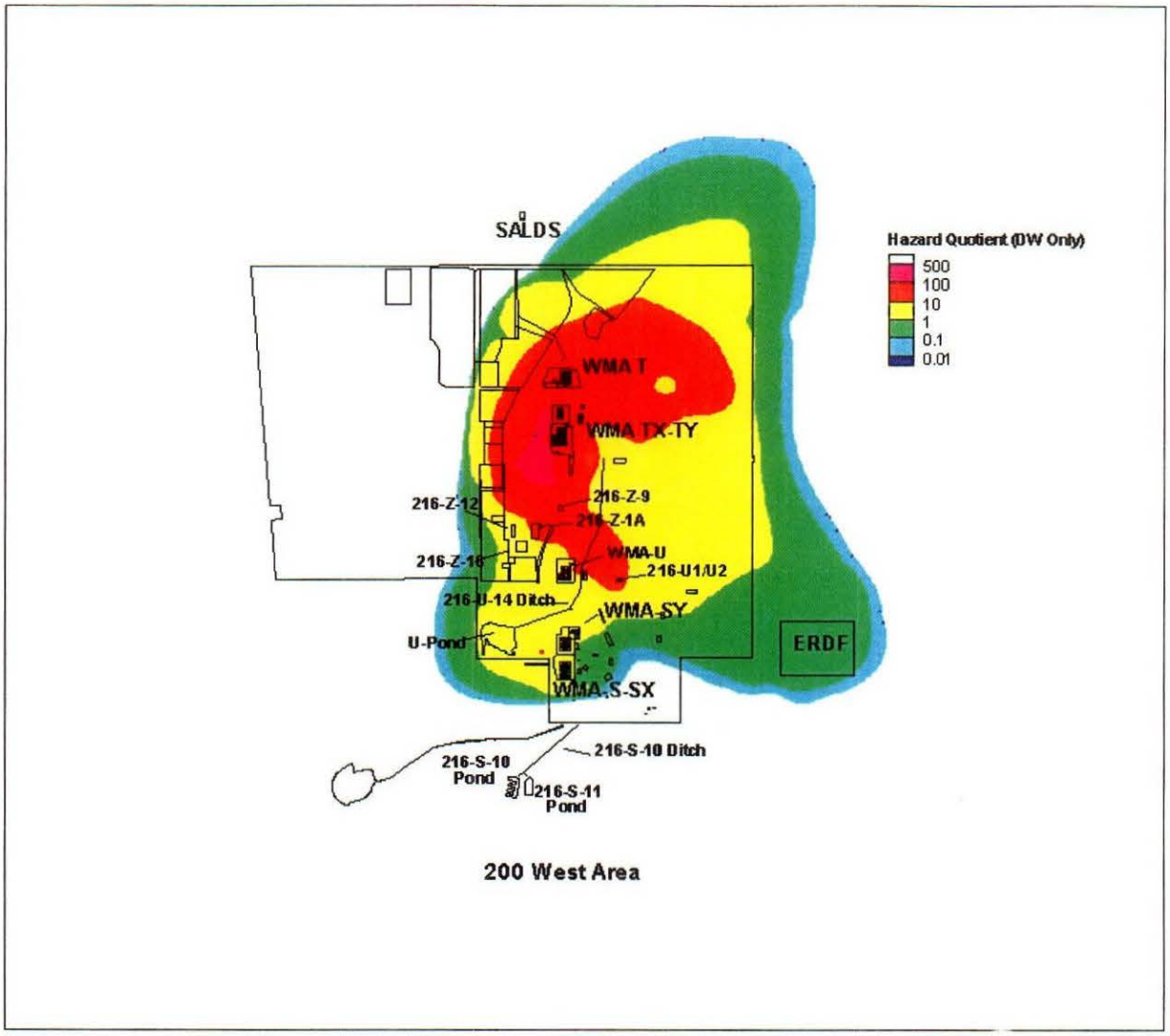


Figure 6-3. Hazard Quotient from Current (Fiscal Year 2005) Interpreted Concentration Levels of Carbon Tetrachloride for Drinking Water Only and Residential Farmer Scenarios. (2 sheets)

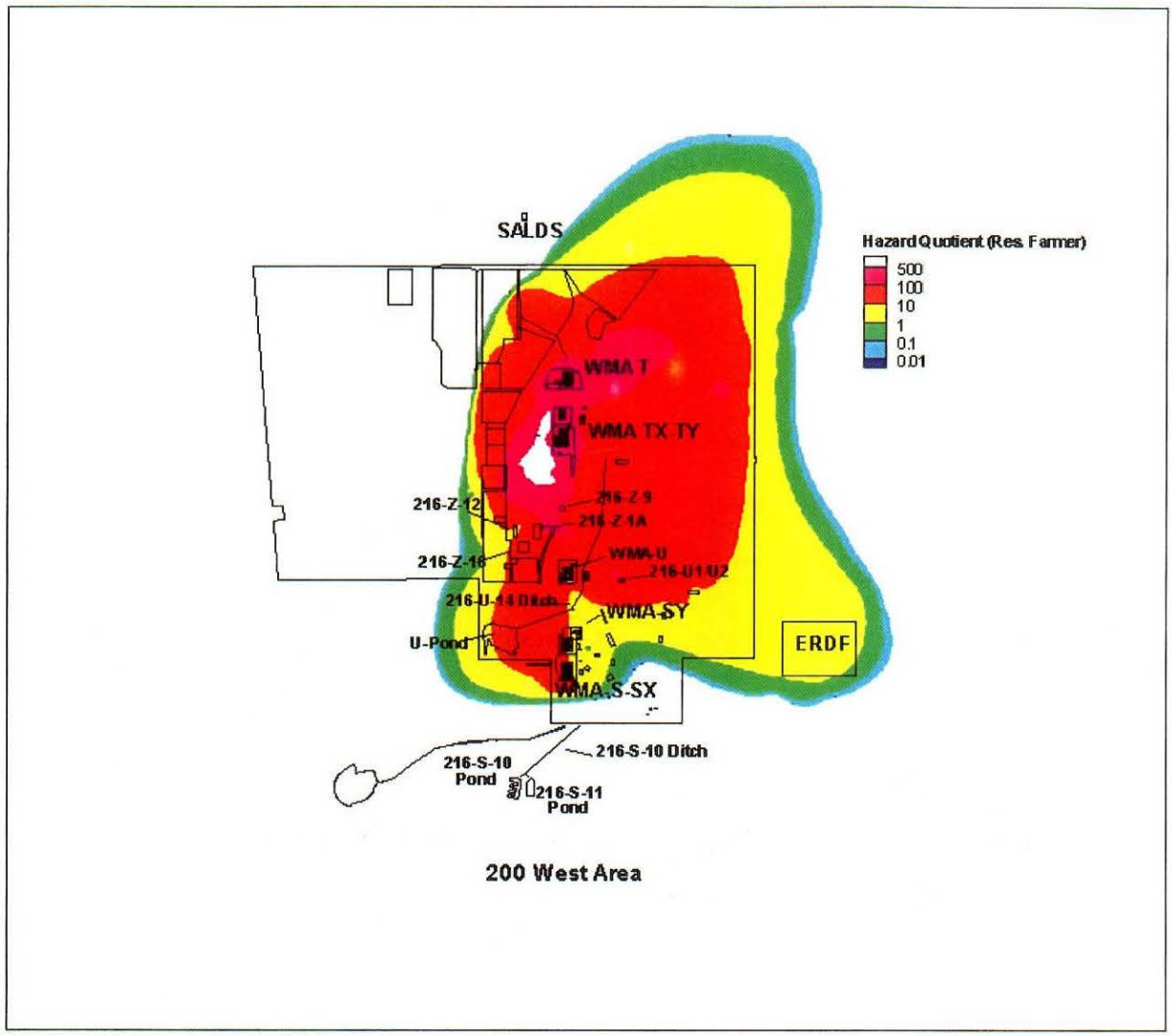
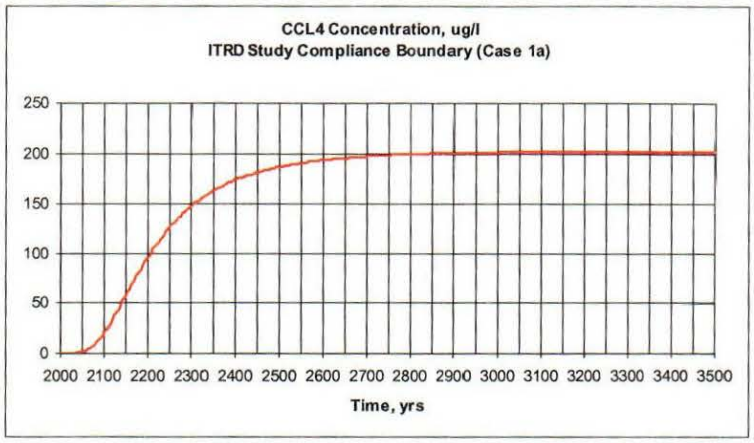


Figure 6-4. Carbon Tetrachloride Concentrations at (a) ITRD Study Compliance Boundary and (b) Along Columbia River for Case 1a.

(a)



(b)

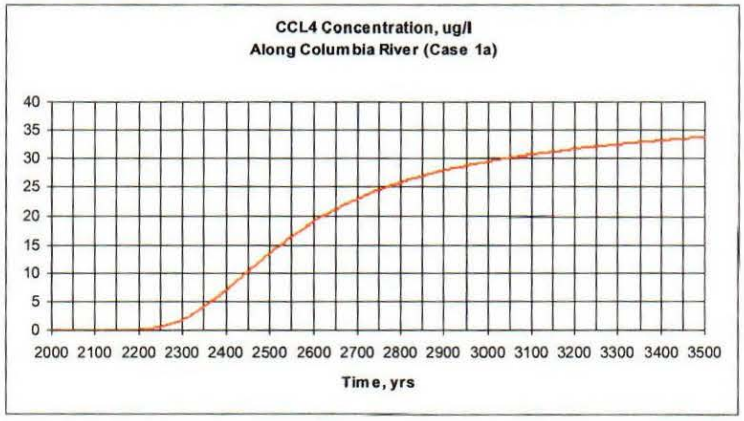
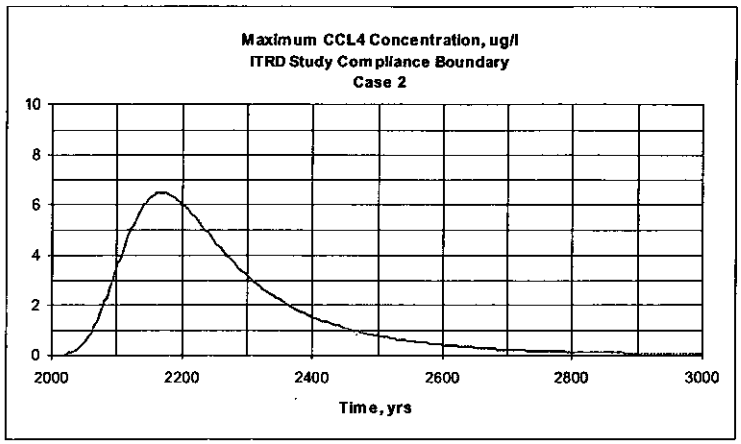


Figure 6-5. Carbon Tetrachloride Concentration at ITRD Study Compliance Boundary (μg/L) for Case 1b.

Figure 6-6. Maximum Carbon Tetrachloride Concentration (μg/L) at (a) ITRD Study Compliance Boundary and (b) Along Columbia River for Case 2.

(a)



(b)

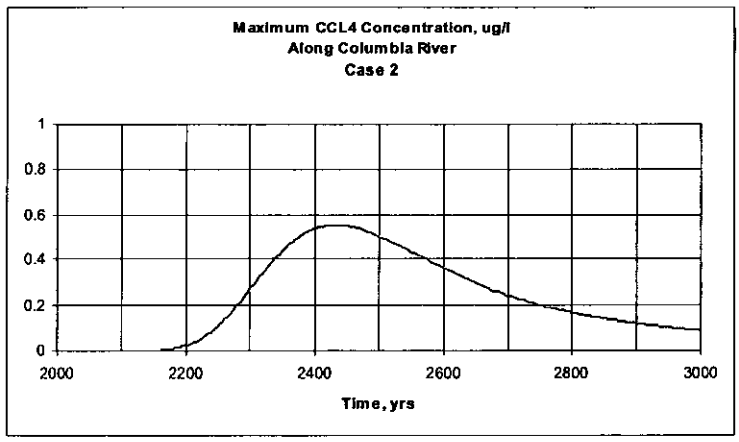
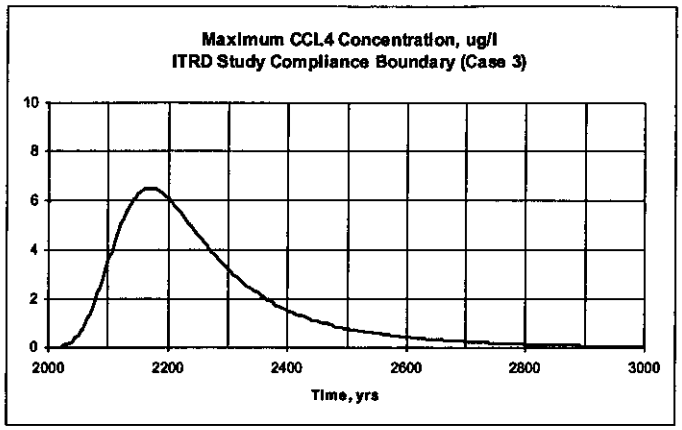


Figure 6-7. Maximum Carbon Tetrachloride Concentration (μg/L) at (a) ITRD Study Compliance Boundary and (b) Along Columbia River for Case 3.

(a)



(b)

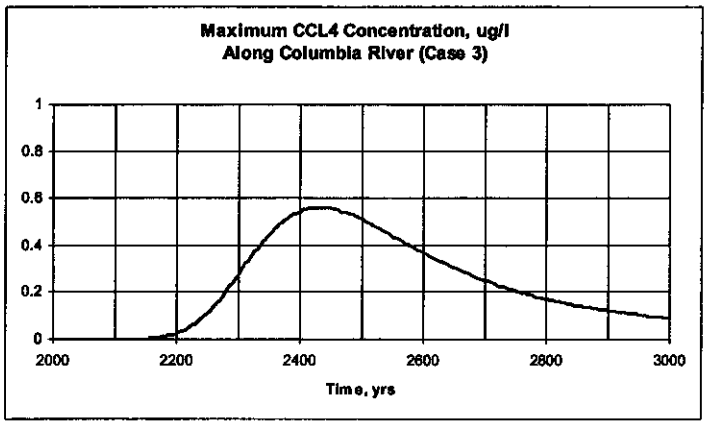
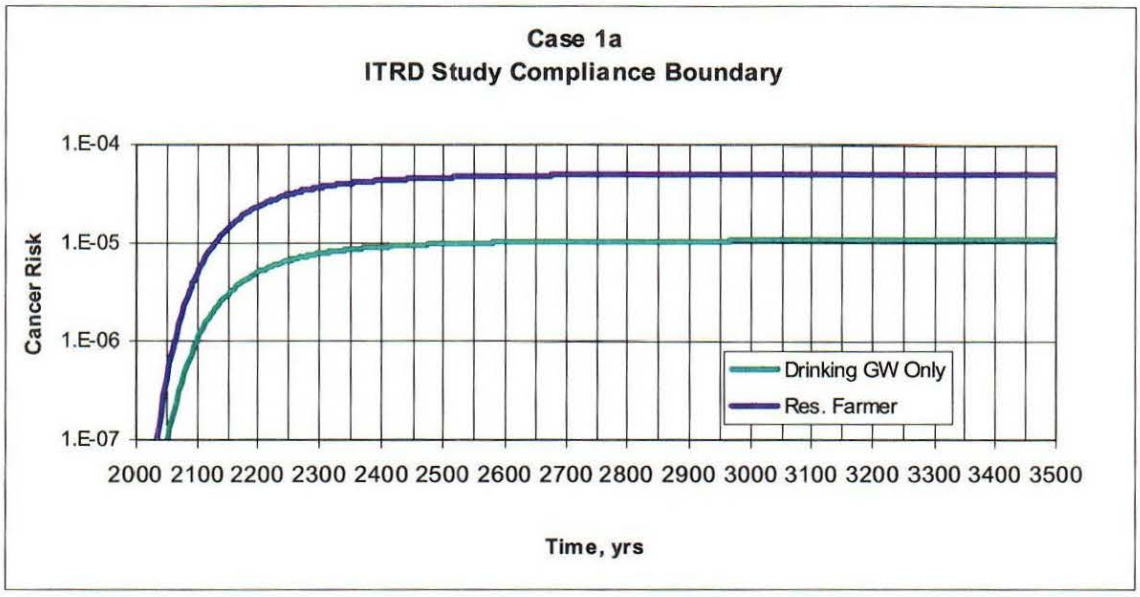


Figure 6-8. Cancer Risk from Drinking Water Only and Residential Farmer Scenarios at ITRD Boundary and Along the Columbia River.



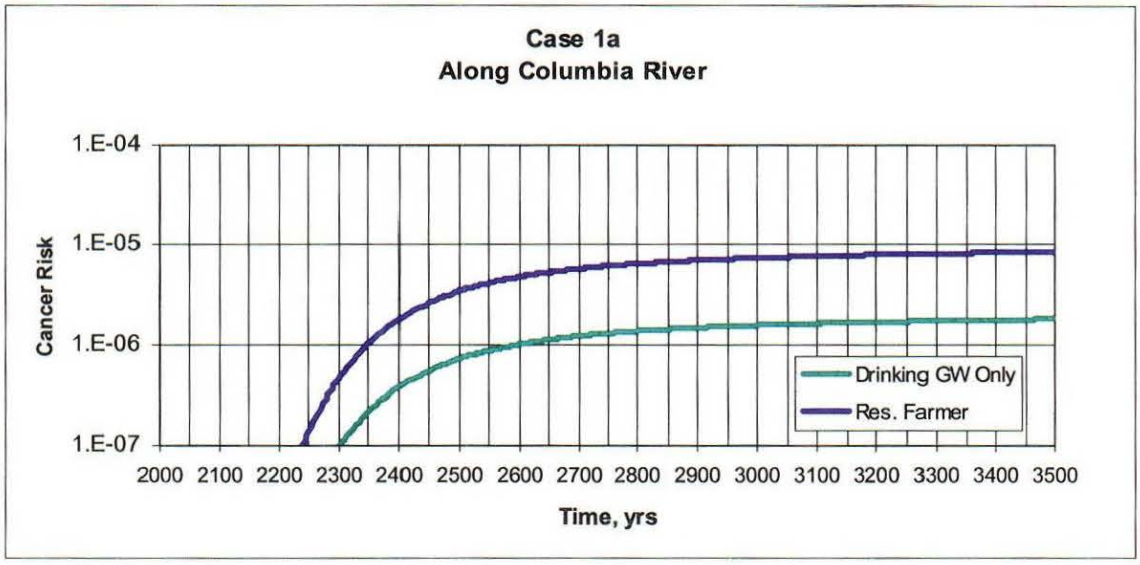
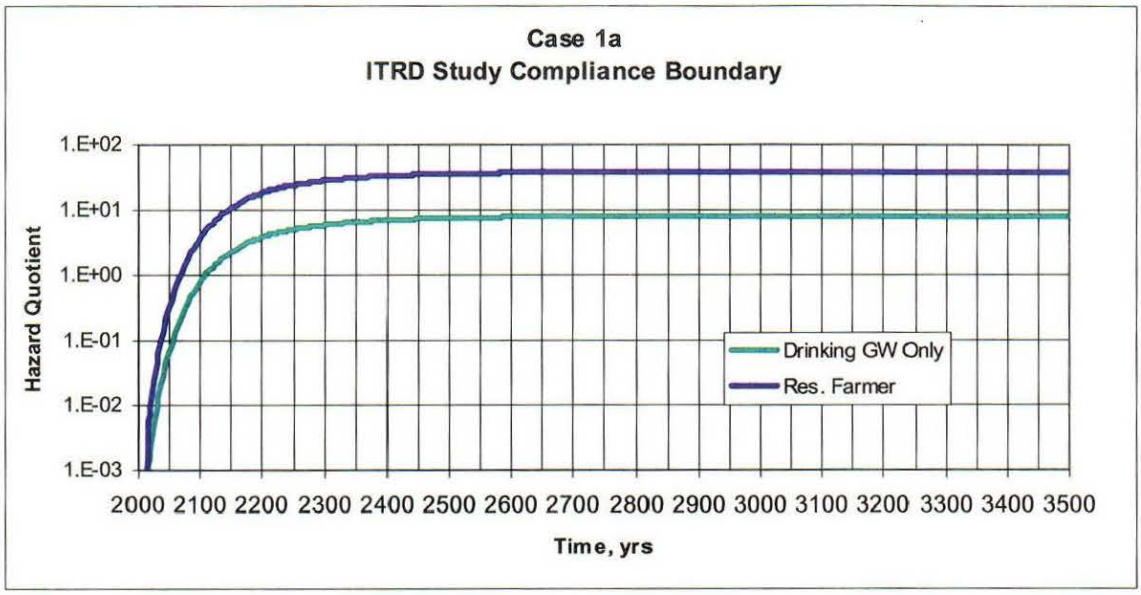


Figure 6-9. Hazard Quotients from Drinking Water Only and Residential Farmer Scenarios at ITRD Boundary and Along the Columbia River.



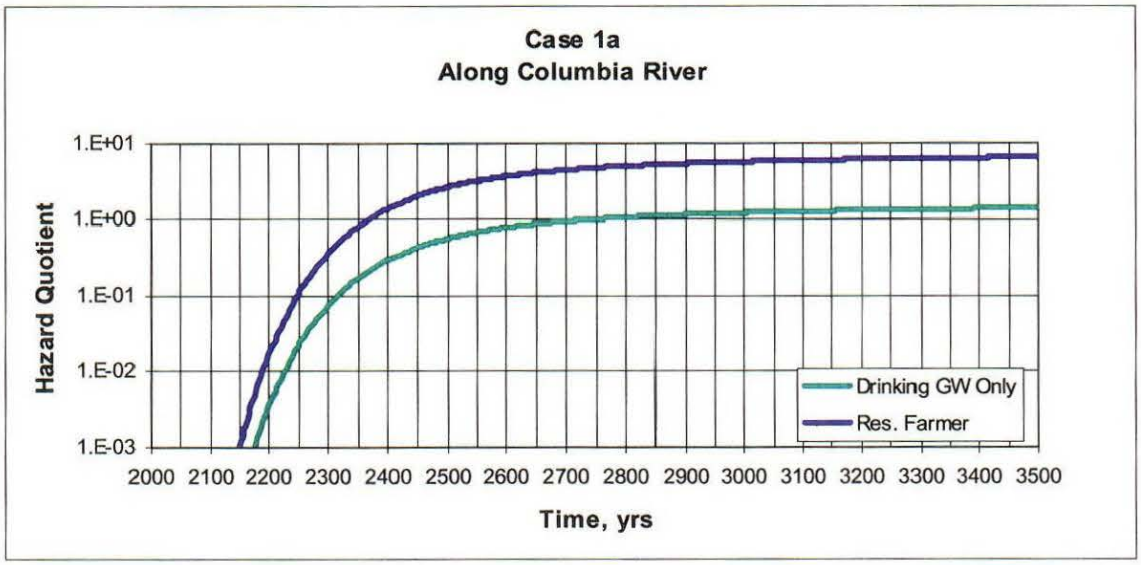
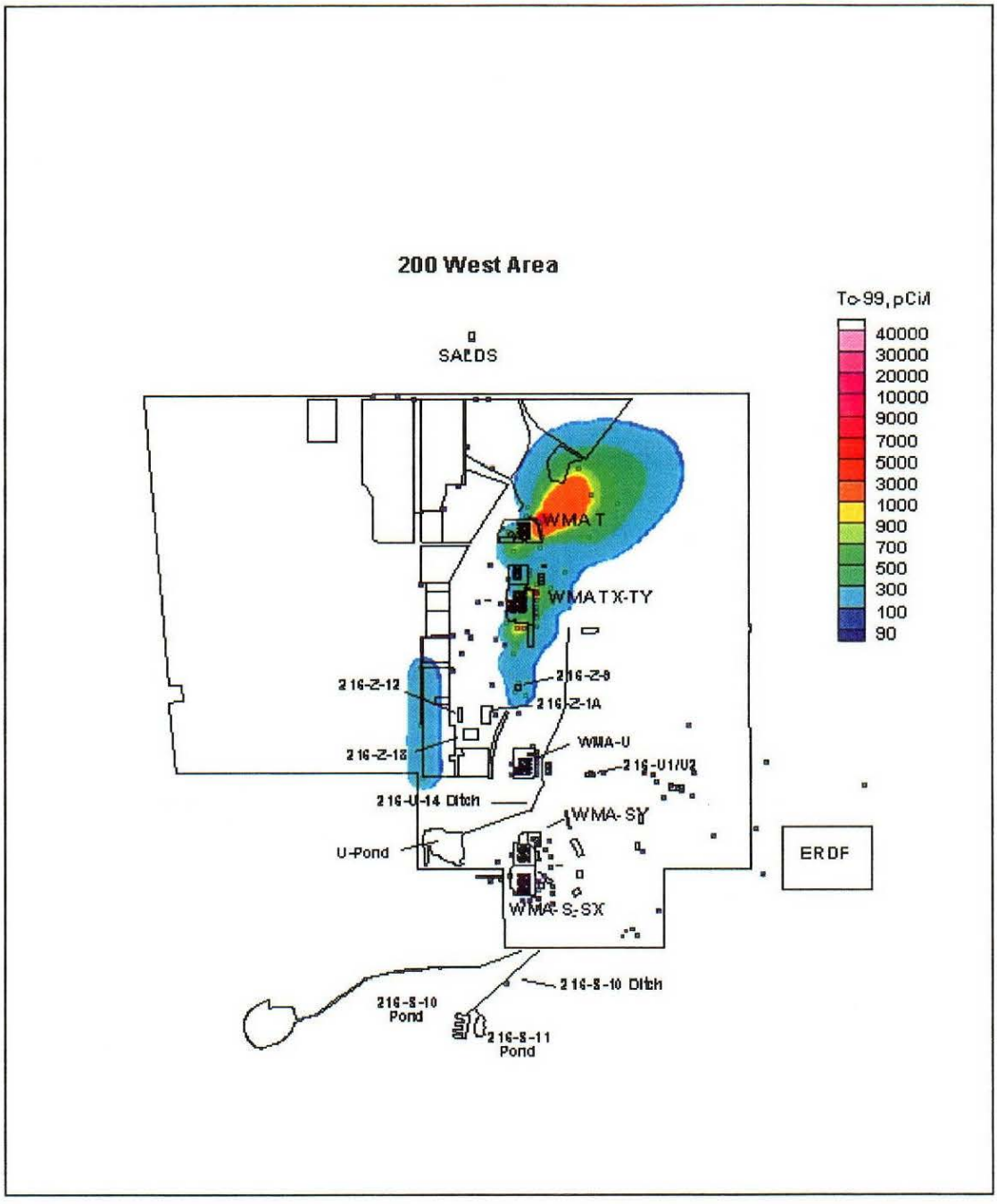


Figure 6-10. Current (Fiscal Year 2005) Interpreted Concentration Levels of Uranium at the Water Table.[a]



[a] Distribution of wells used in the interpretation is depicted in squares color-coded to the concentration legend. This figure is adapted from PNNL 2006.

Figure 6-11. Radiological Dose (in mrem) from Current (Fiscal Year 2005) Interpreted Concentration Levels of Technetium-99 for Drinking Water Only and Residential Farmer Scenarios. (2 sheets)

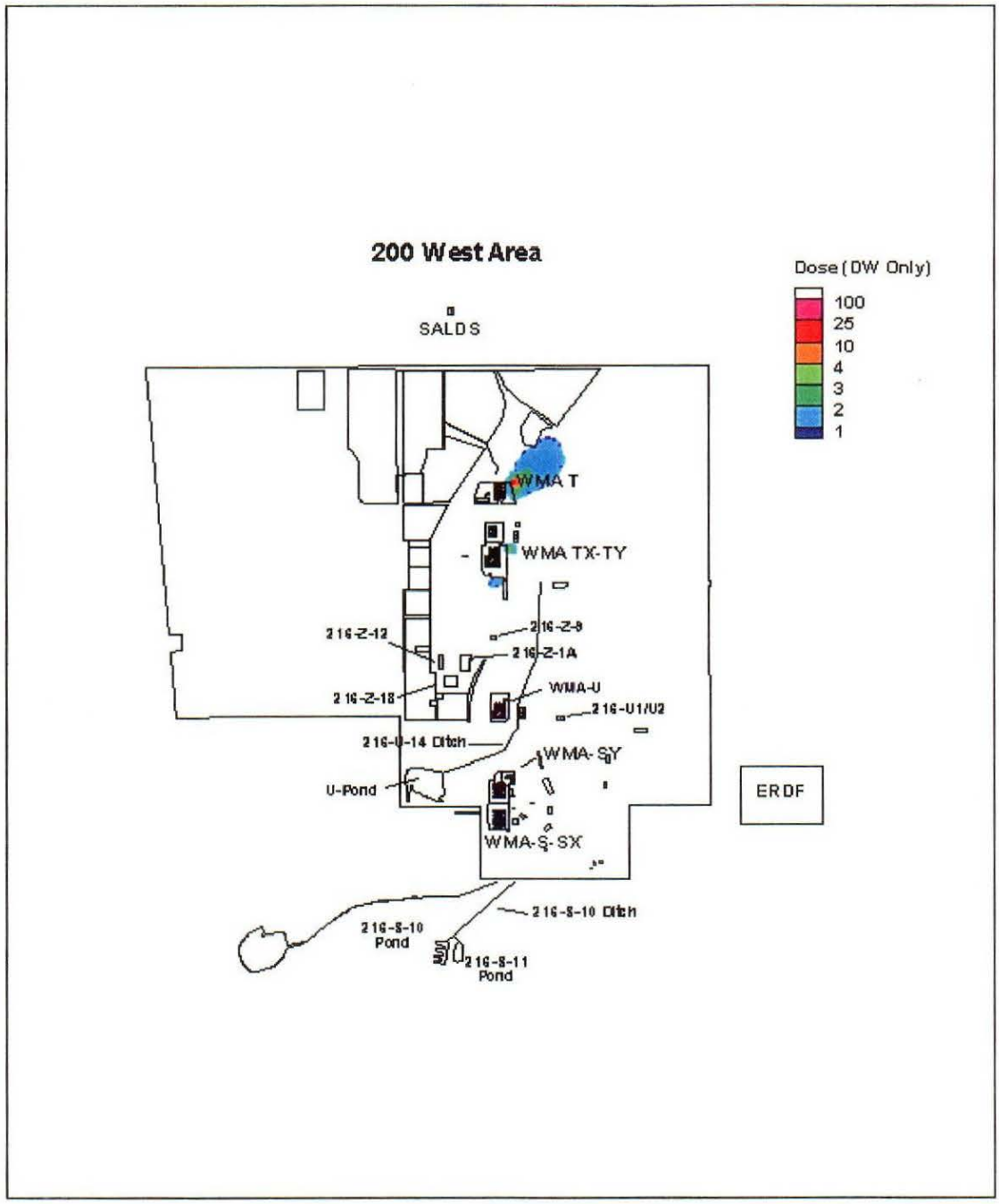


Figure 6-11. Radiological Dose (in mrem) from Current (Fiscal Year 2005) Interpreted Concentration Levels of Technetium-99 for Drinking Water Only and Residential Farmer Scenarios. (2 sheets)

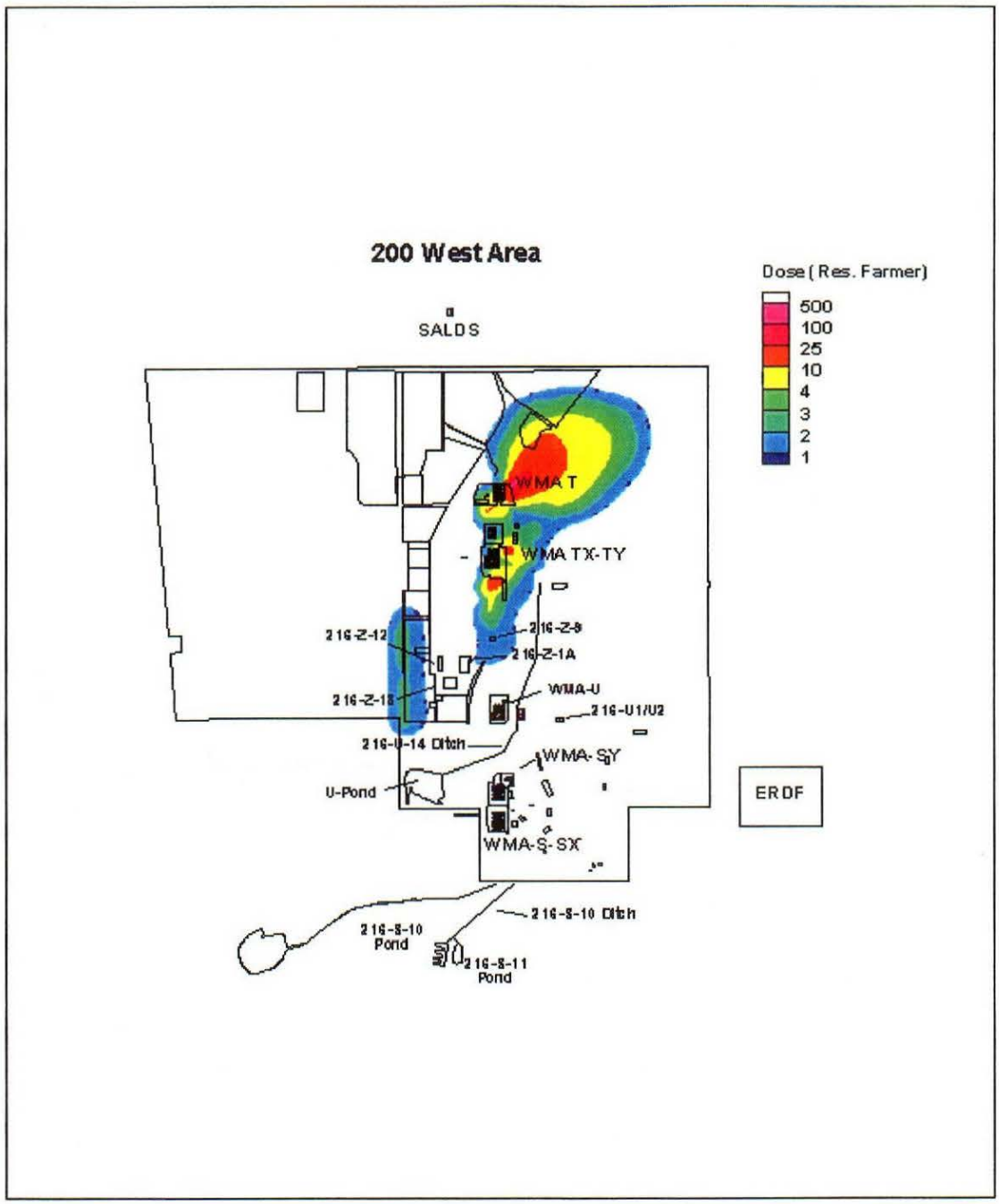


Figure 6-12. Cancer Risk from Current (Fiscal Year 2005) Interpreted Concentration Levels of Technetium-99 for Drinking Water Only and Residential Farmer Scenarios. (2 sheets)

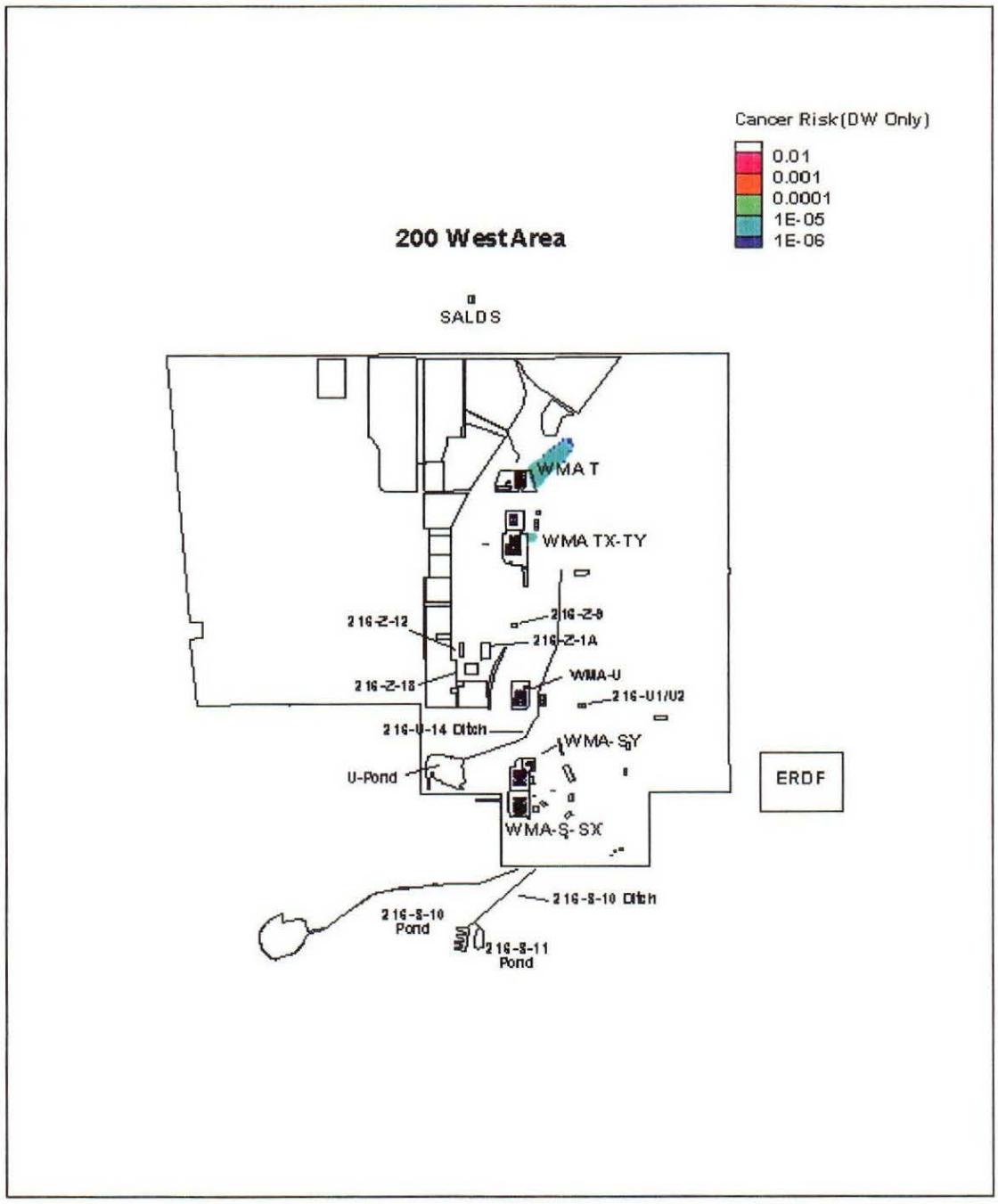


Figure 6-12. Cancer Risk from Current (Fiscal Year 2005) Interpreted Concentration Levels of Technetium-99 for Drinking Water Only and Residential Farmer Scenarios. (2 sheets)

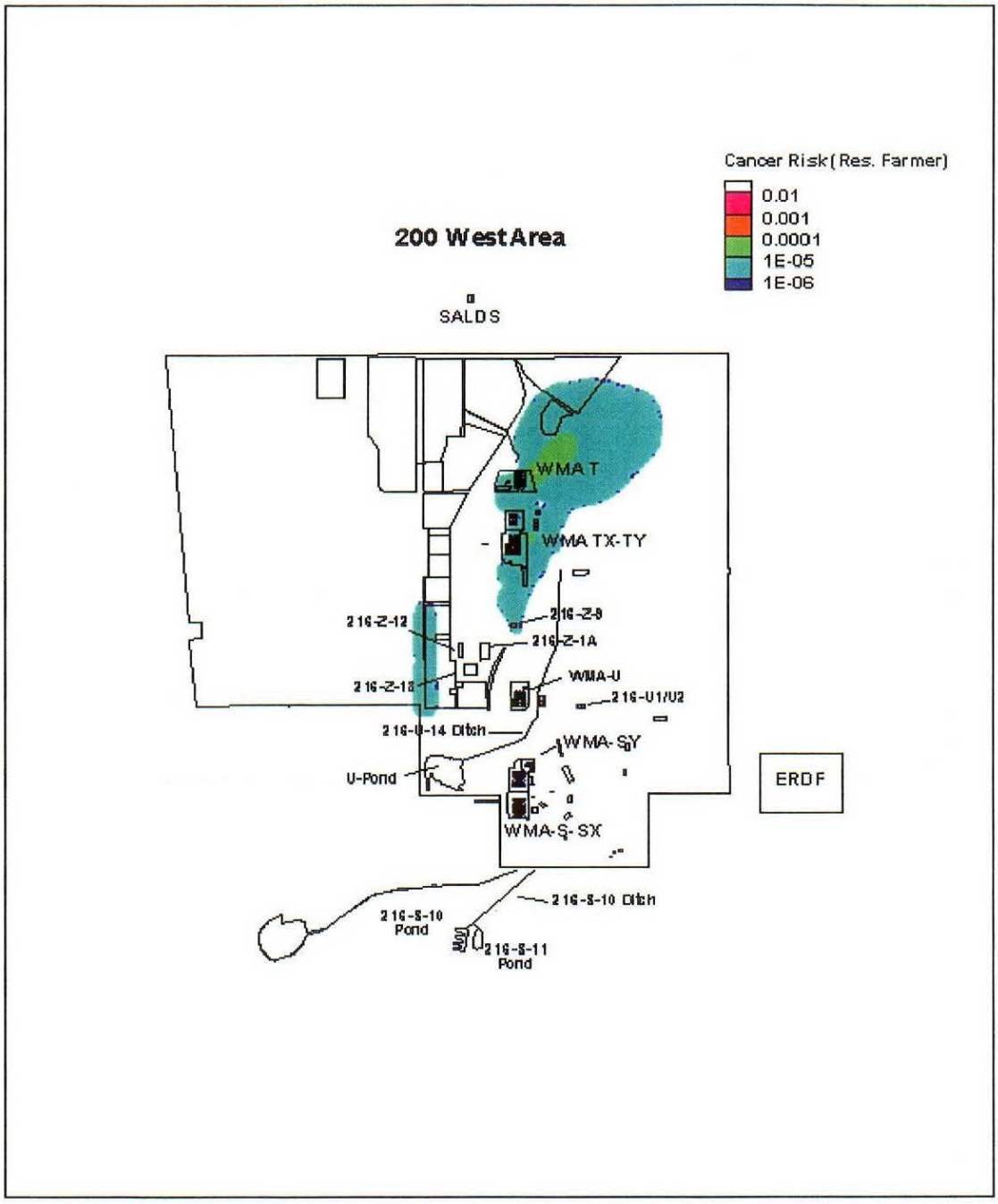
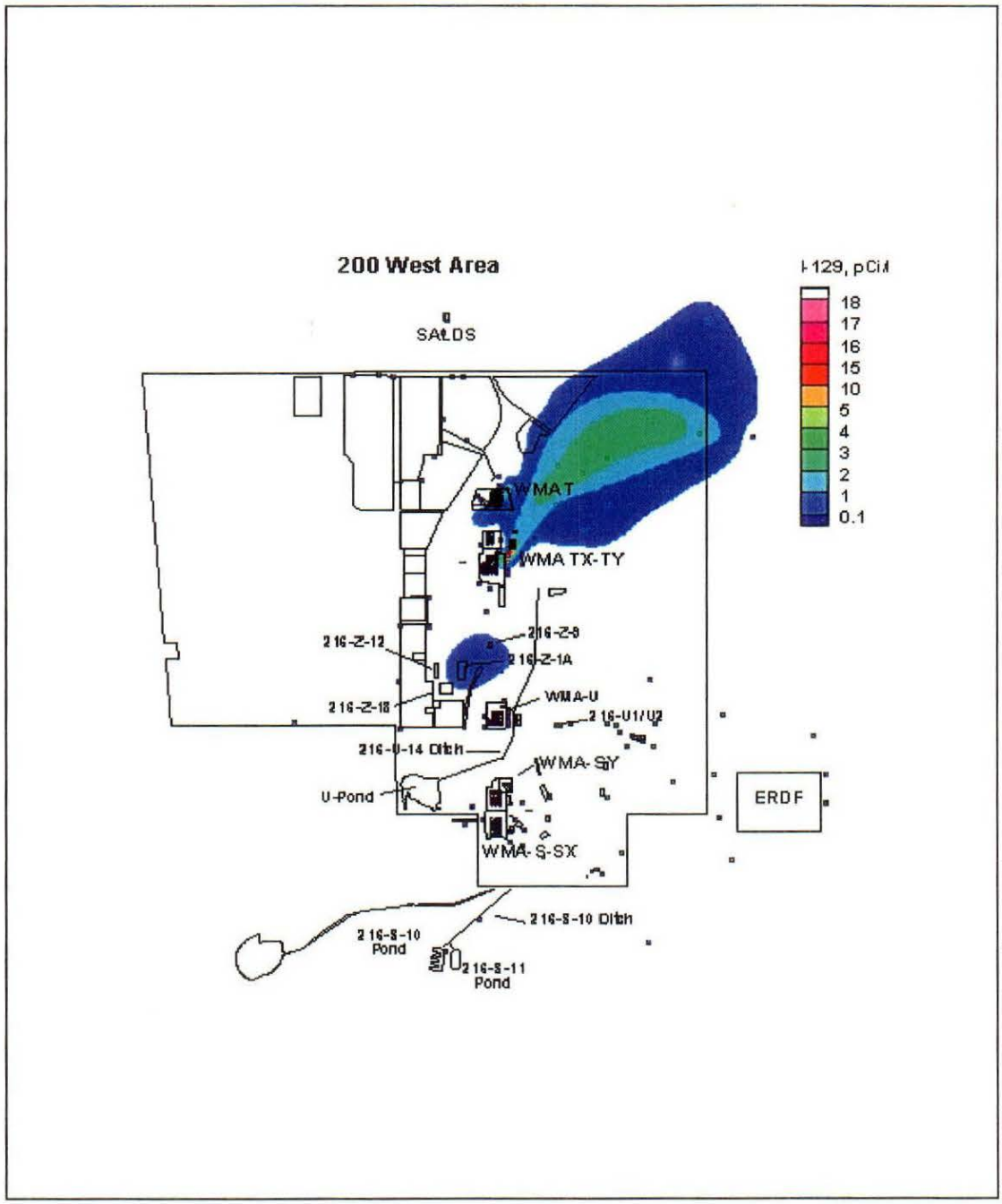


Figure 6-13. Current (Fiscal Year 2005) Interpreted Concentration Levels of Iodine-129 at the Water Table.[a]



[a] Distribution of wells used in the interpretation is depicted in squares color-coded to the concentration legend. This figure is adapted from PNNL 2006.

Figure 6-14. Radiological Dose (in mrem) from Current (Fiscal Year 2005) Interpreted Concentration Levels of Iodine-129 for Drinking Water Only and Residential Farmer Scenarios. (2 sheets)

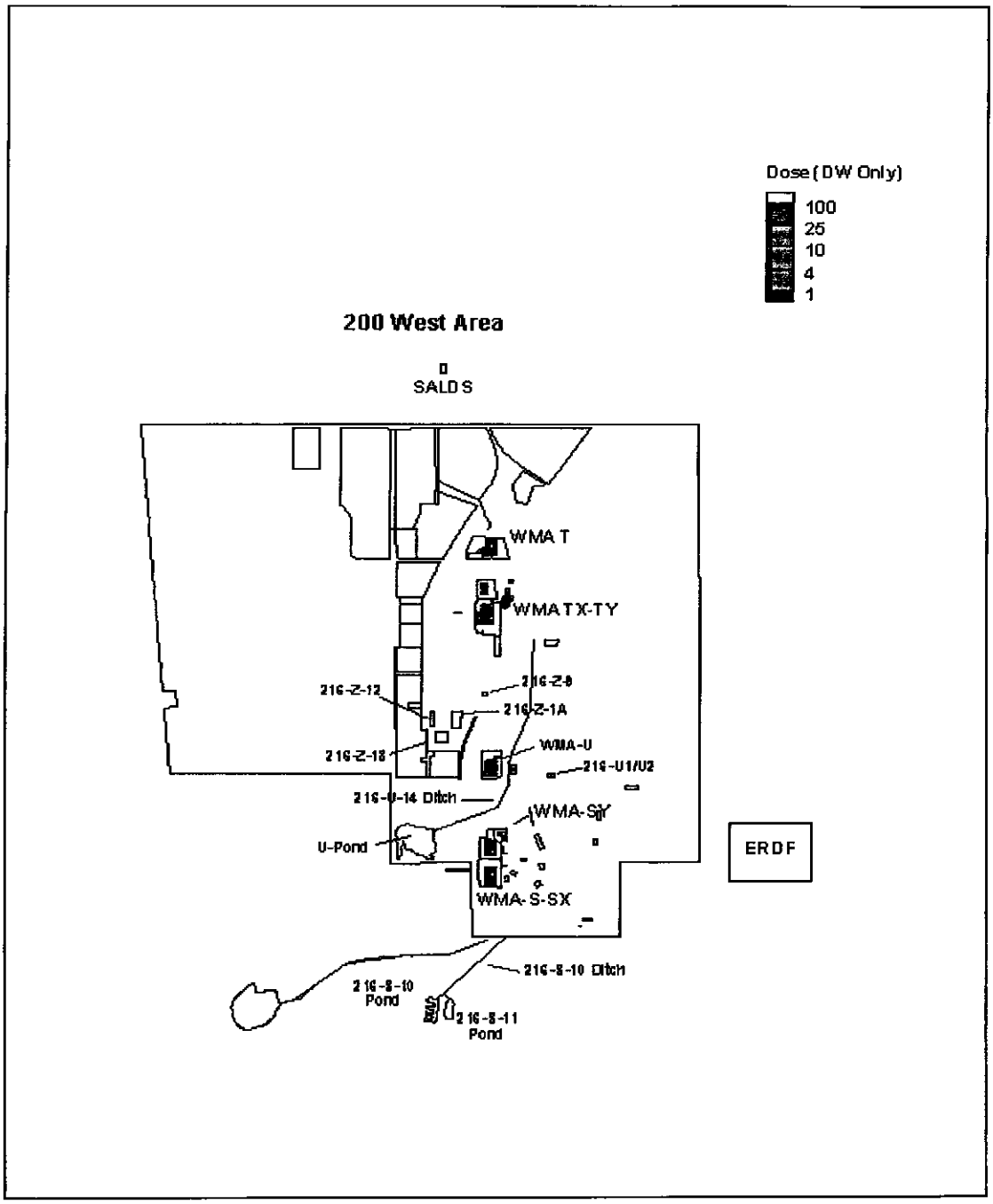


Figure 6-14. Radiological Dose (in mrem) from Current (Fiscal Year 2005) Interpreted Concentration Levels of Iodine-129 for Drinking Water Only and Residential Farmer Scenarios. (2 sheets)

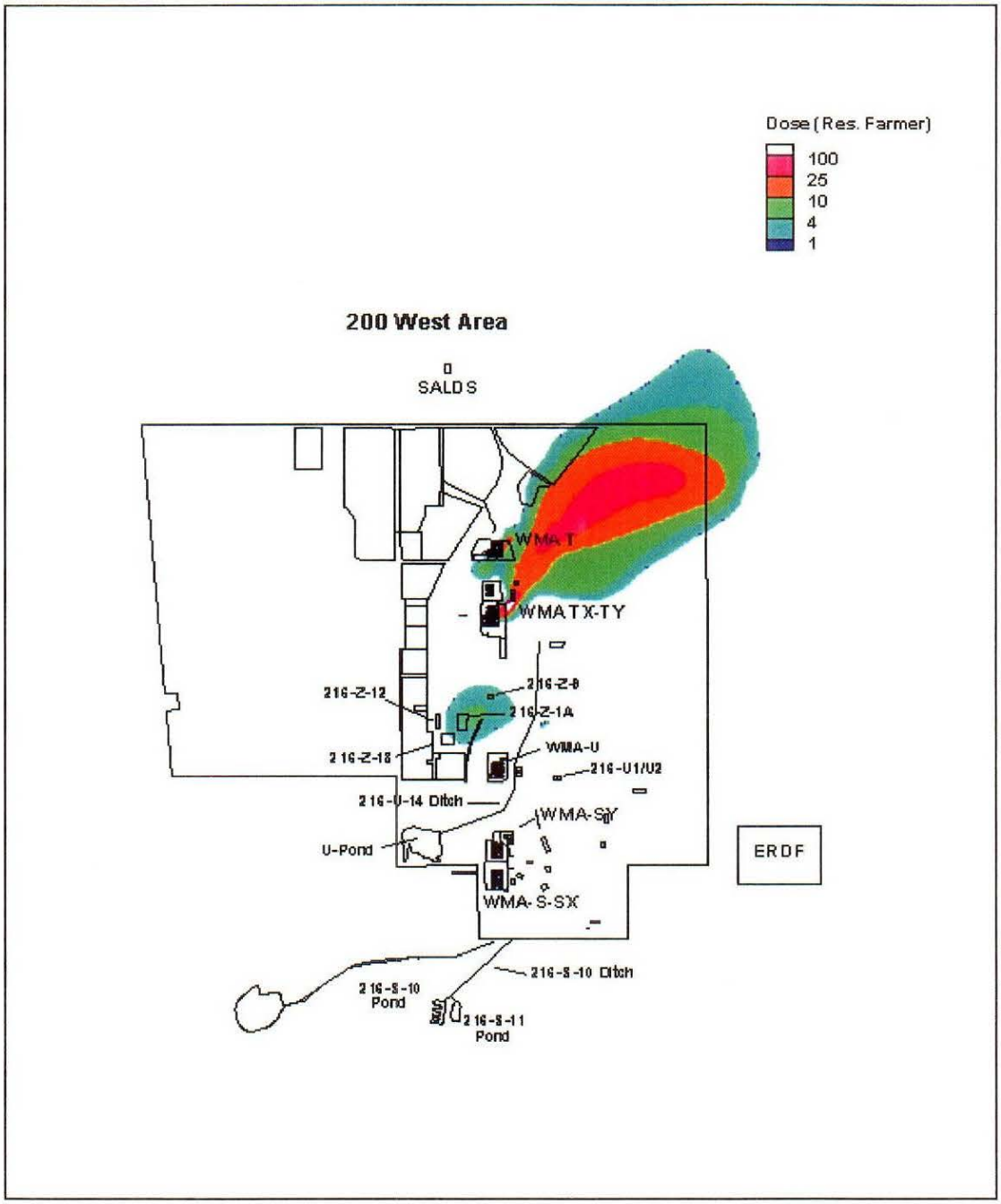


Figure 6-15. Cancer Risk from Current (Fiscal Year 2005) Interpreted Concentration Levels of Iodine-129 for Drinking Water Only and Residential Farmer Scenarios. (2 sheets)

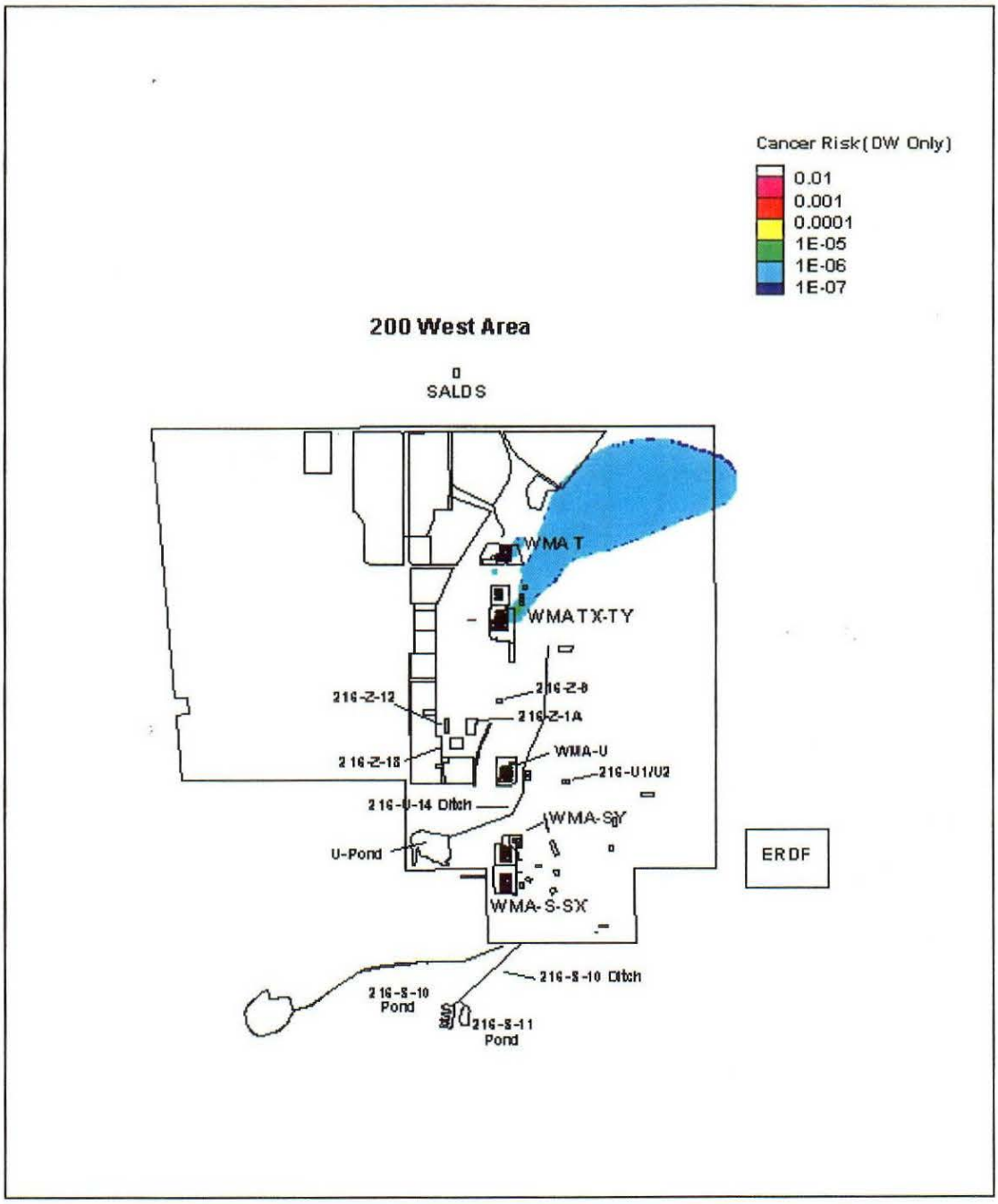


Figure 6-15. Cancer Risk from Current (Fiscal Year 2005) Interpreted Concentration Levels of Iodine-129 for Drinking Water Only and Residential Farmer Scenarios. (2 sheets)

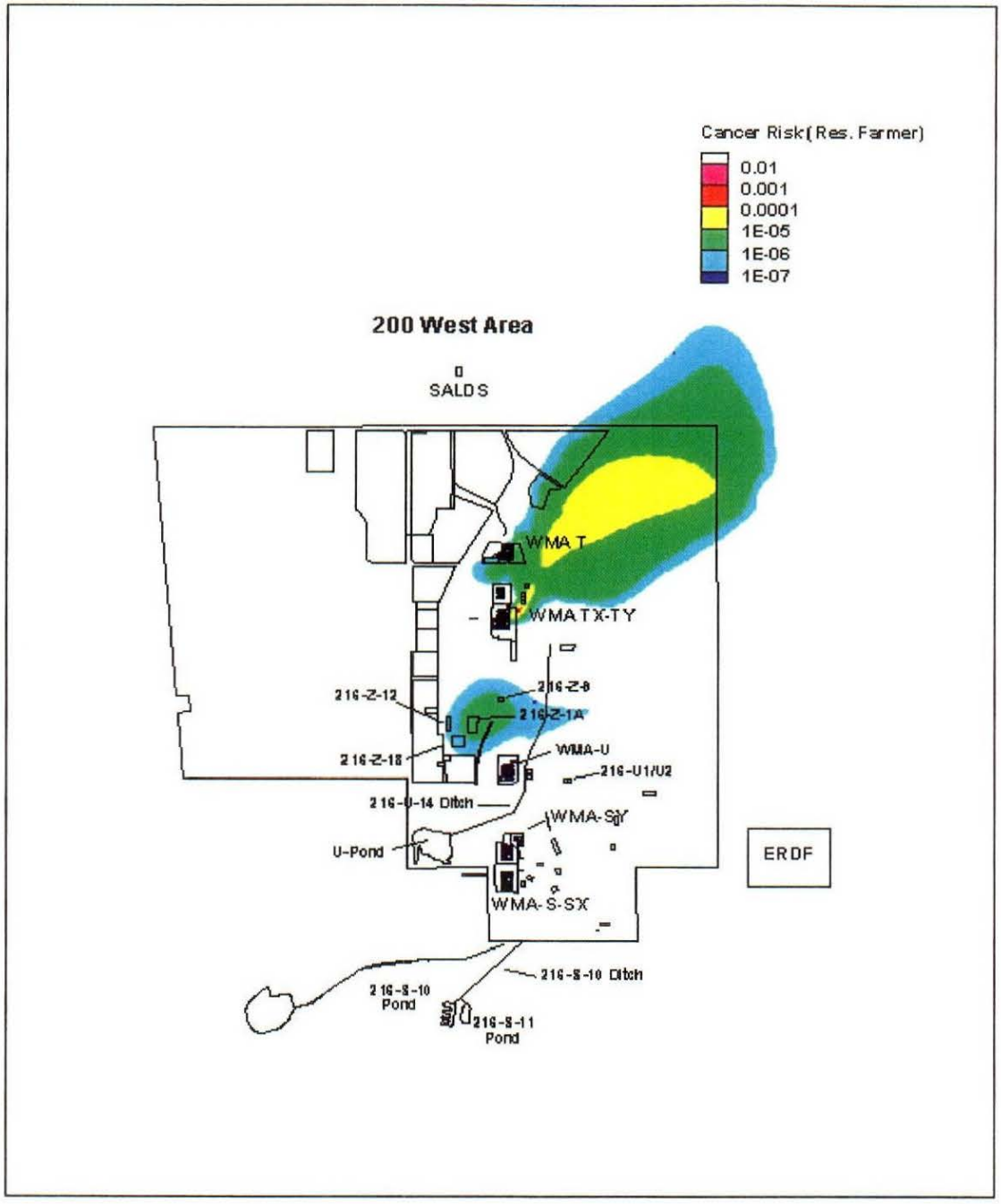
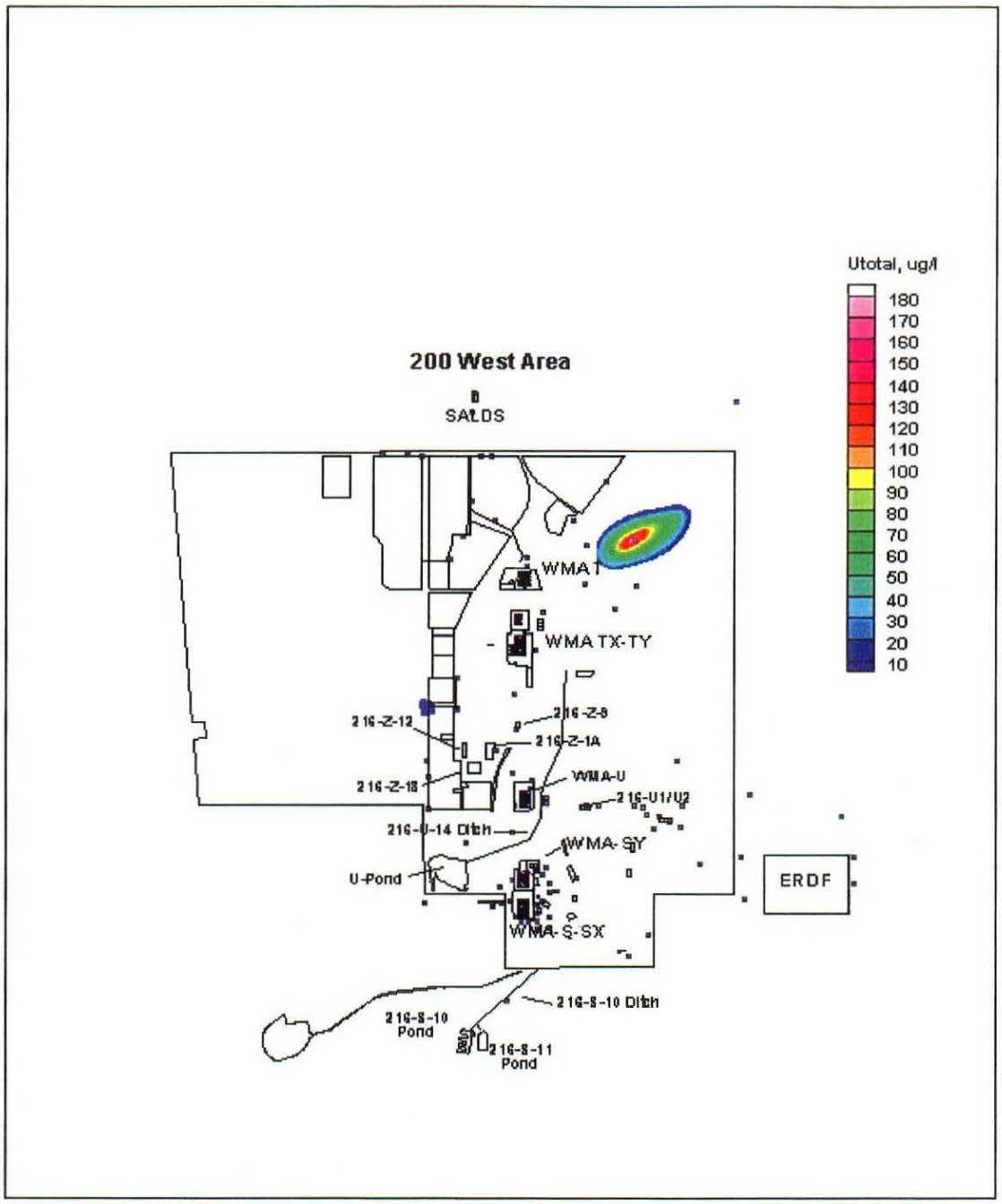


Figure 6-16. Current (Fiscal Year 2005) Interpreted Concentration Levels of Uranium at the Water Table.[a]



[a] Distribution of wells used in the interpretation is depicted in squares color-coded to the concentration legend. This figure is adapted from PNNL 2006.

Figure 6-17. Hazard Quotient from Current (Fiscal Year 2005) Interpreted Concentration Levels of Uranium for Drinking Water Only and Residential Farmer Scenarios. (2 sheets)

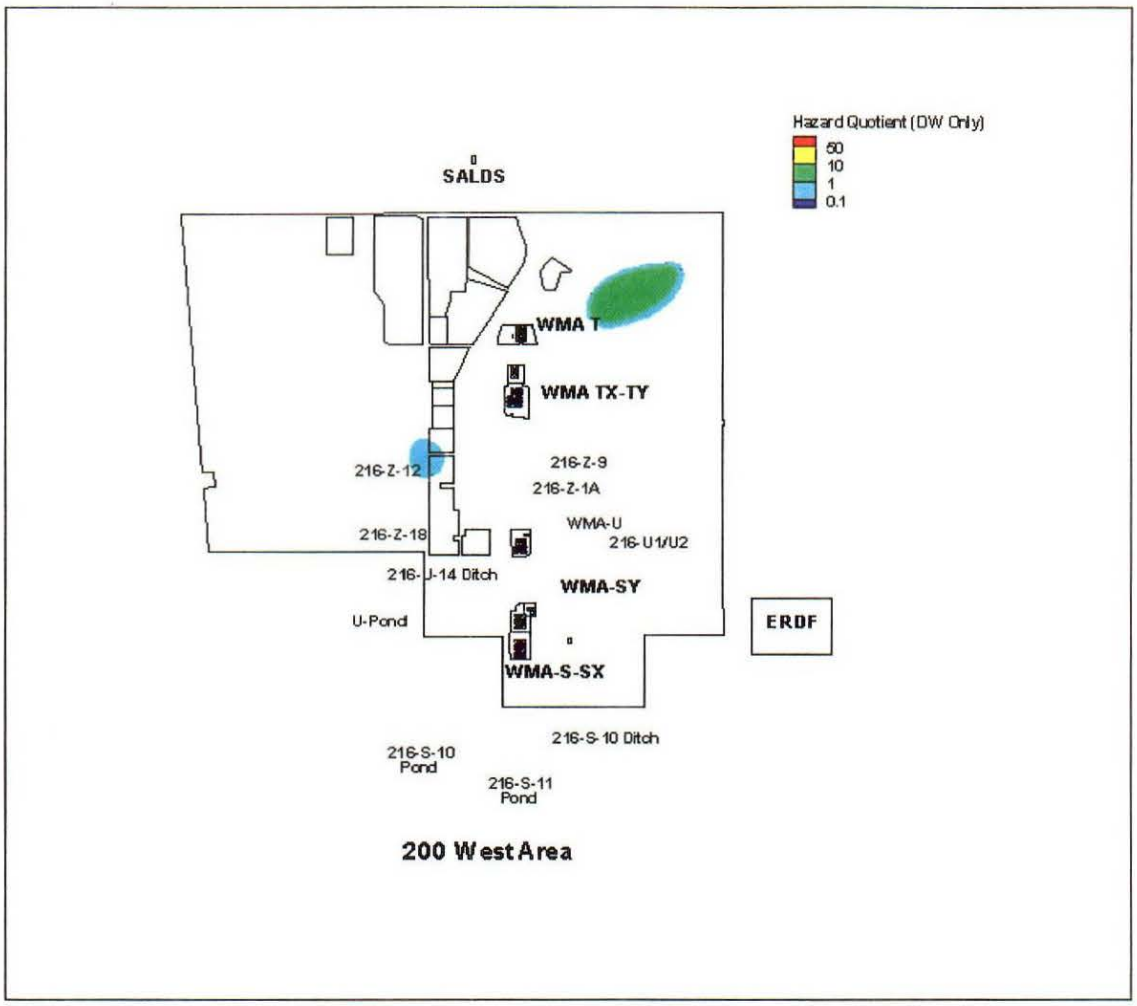


Figure 6-17. Hazard Quotient from Current (Fiscal Year 2005) Interpreted Concentration Levels of Uranium for Drinking Water Only and Residential Farmer Scenarios. (2 sheets)

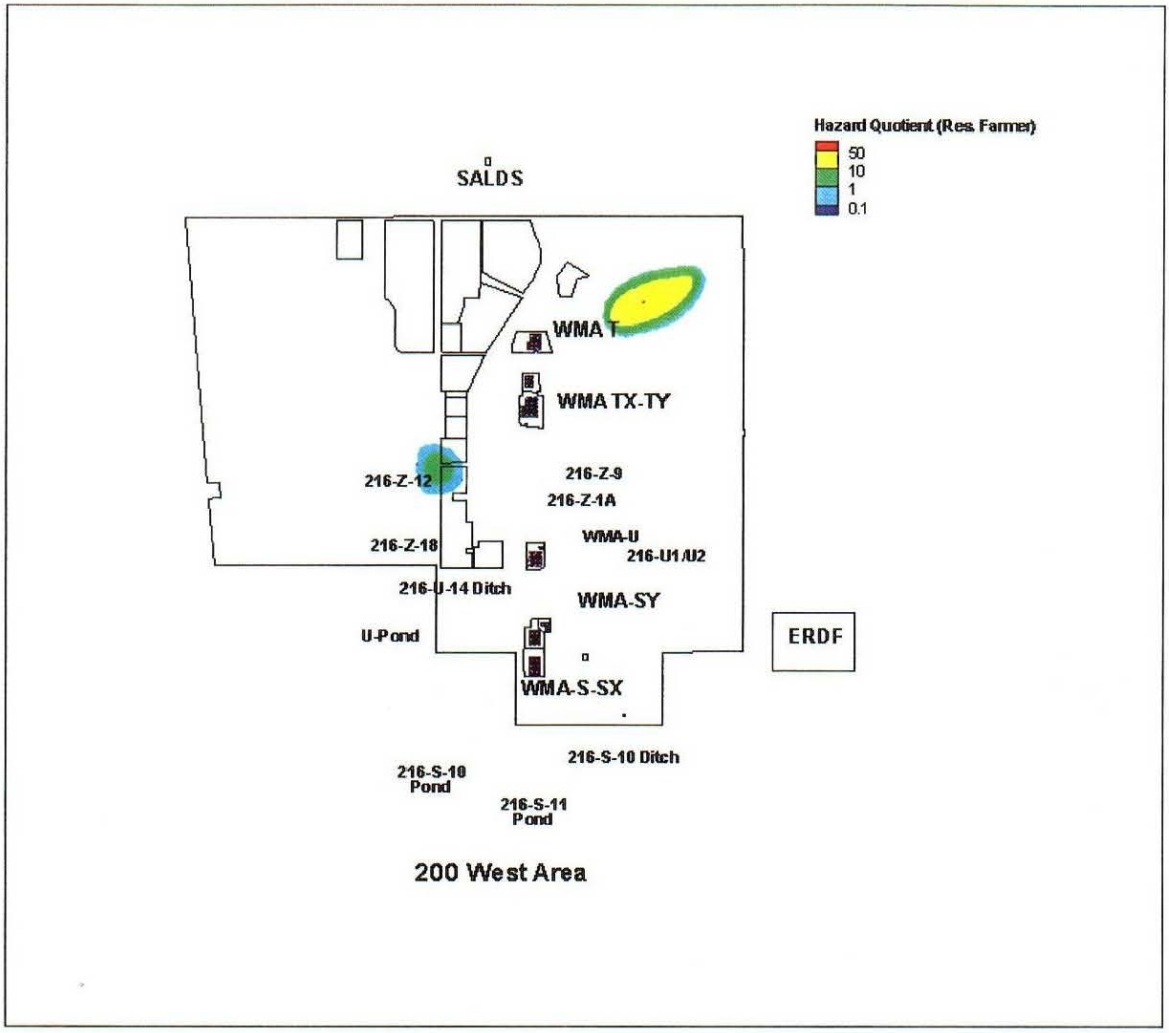
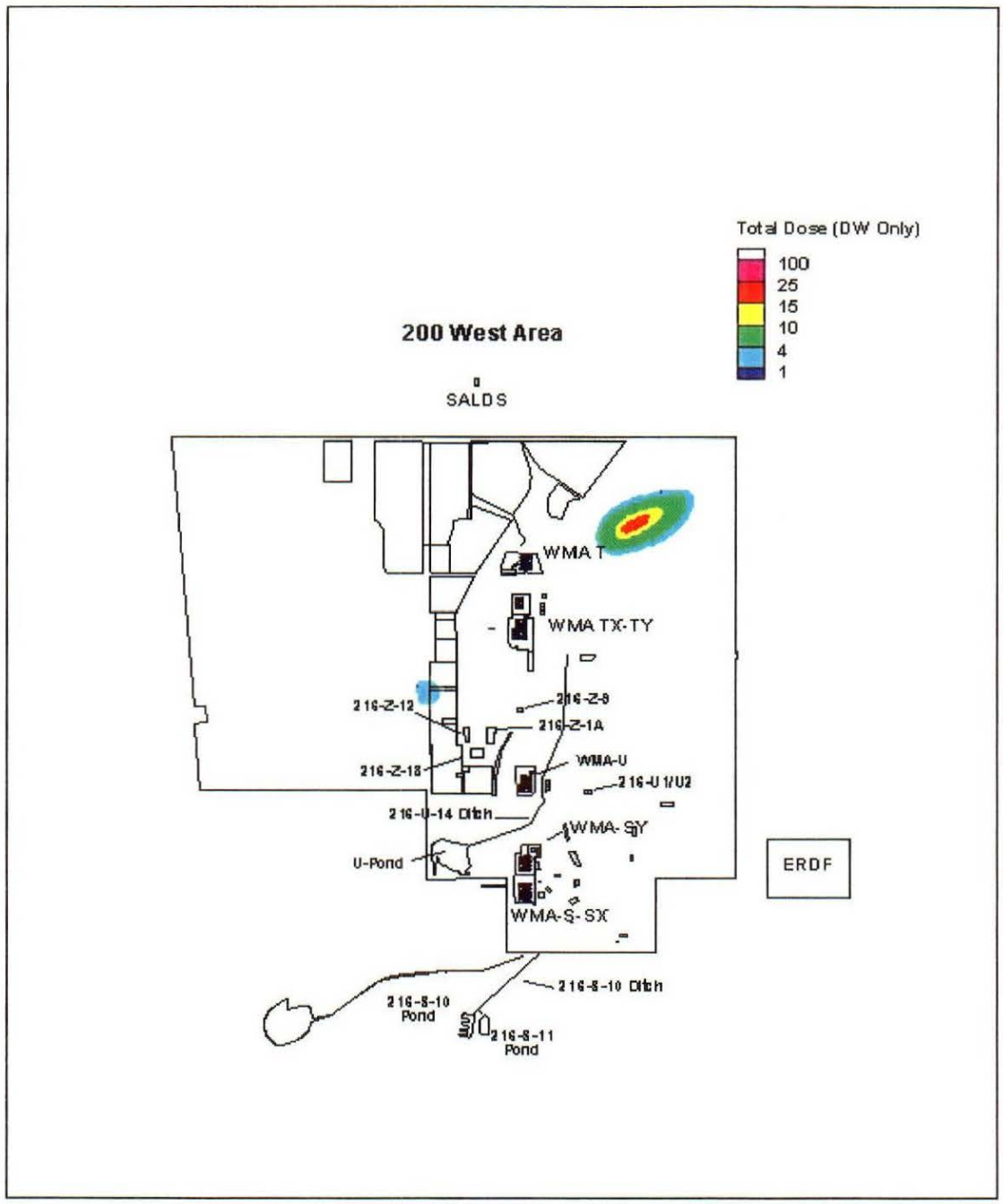
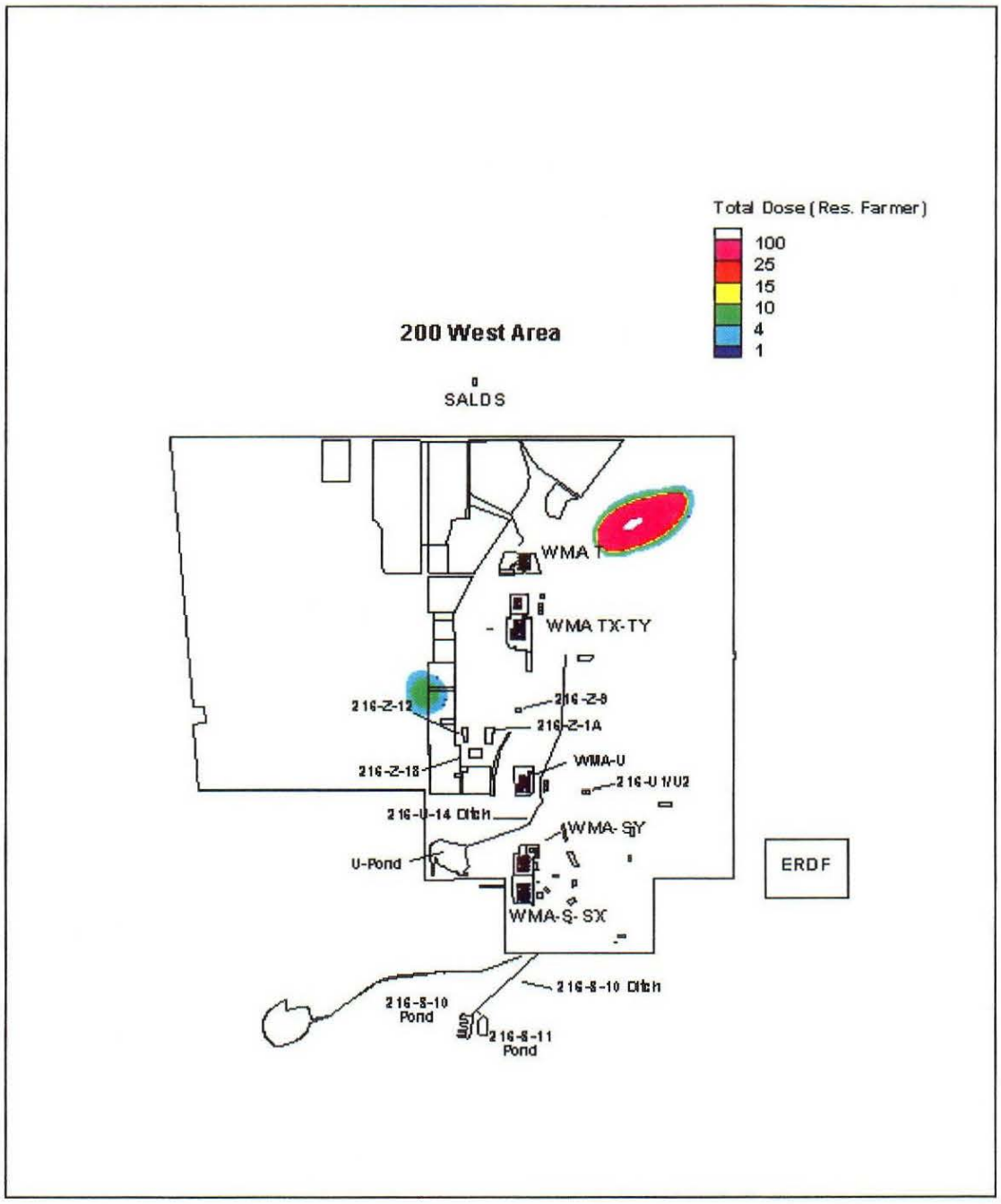


Figure 6-18. Radiological Dose (in mrem) from Current (Fiscal Year 2005) Interpreted Concentration Levels of Uranium for Drinking Water Only and Residential Farmer Scenarios.[a] (2 sheets)



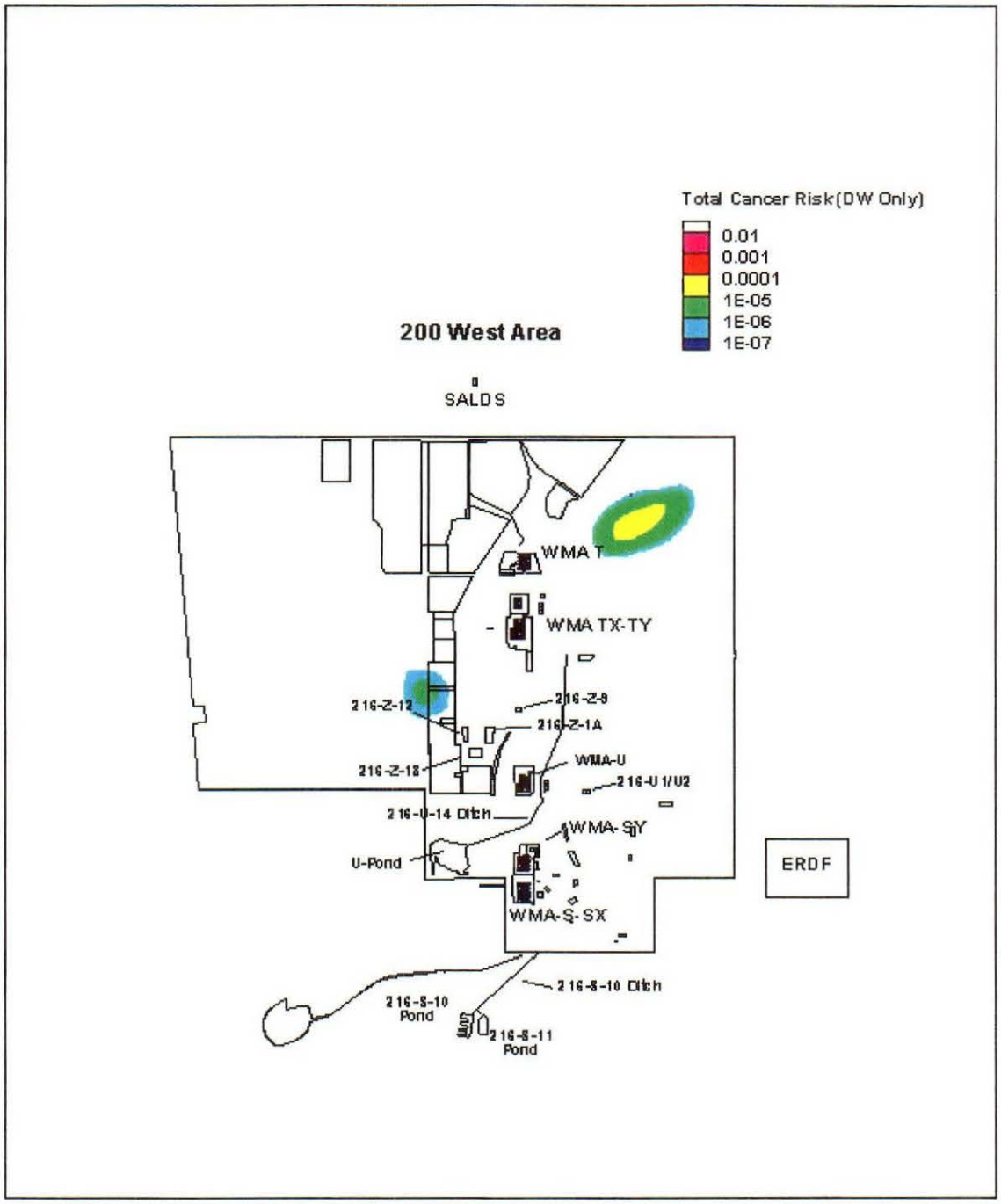
[a] Total dose reflects dose contributions from uranium-234, uranium-235, and uranium-238.

Figure 6-18. Radiological Dose (in mrem) from Current (Fiscal Year 2005) Interpreted Concentration Levels of Uranium for Drinking Water Only and Residential Farmer Scenarios.[a] (2 sheets)



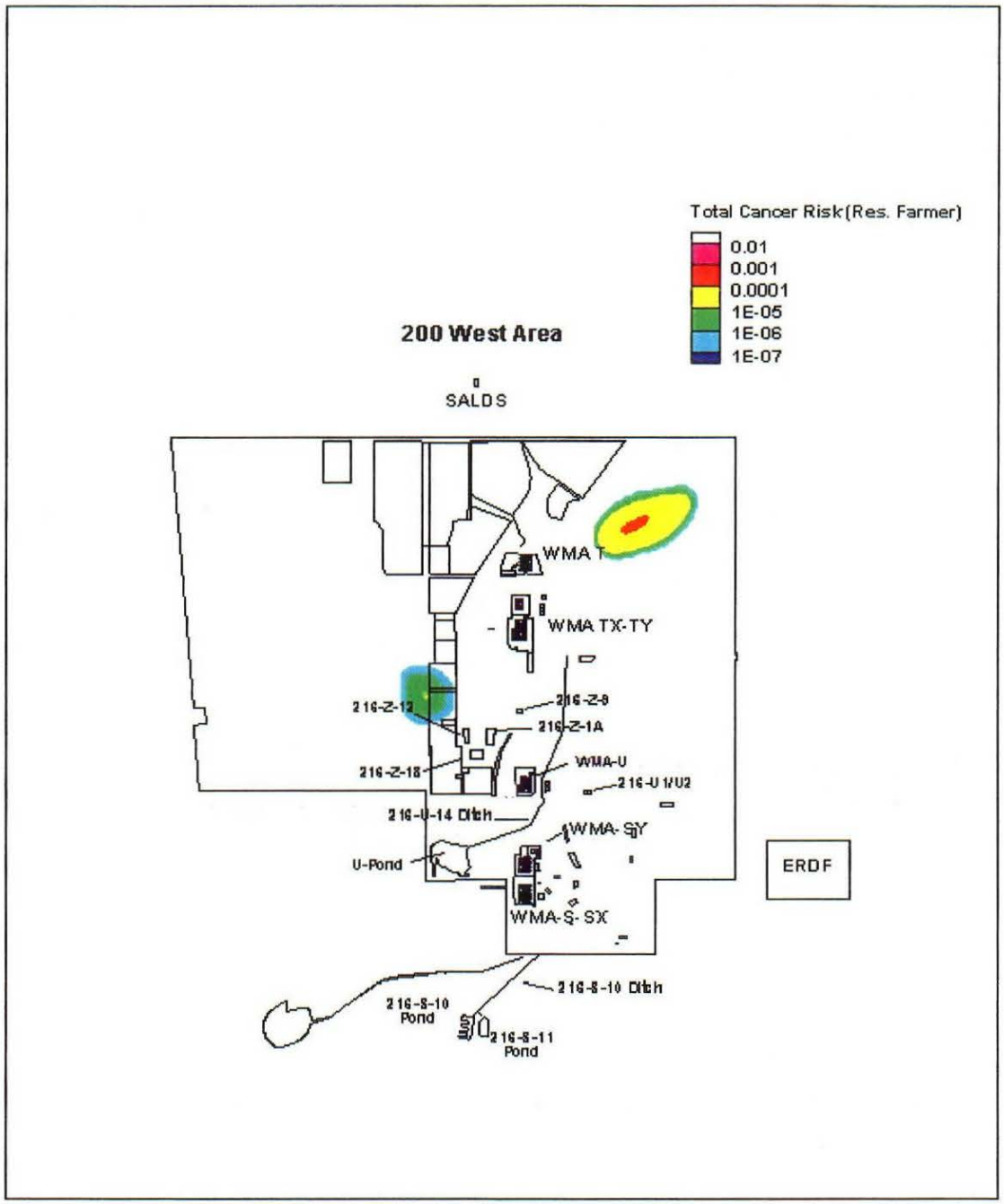
[a] Total dose reflects dose contributions from uranium-234, uranium-235, and uranium-238.

Figure 6-19. Cancer Risk from Current (Fiscal Year 2005) Interpreted Concentration Levels of Uranium for Drinking Water Only and Residential Farmer Scenarios.[a] (2 sheets)



[a] Total dose reflects dose contributions from uranium-234, uranium-235, and uranium-238.

Figure 6-19. Cancer Risk from Current (Fiscal Year 2005) Interpreted Concentration Levels of Uranium for Drinking Water Only and Residential Farmer Scenarios.[a] (2 sheets)



[a] Total dose reflects dose contributions from uranium-234, uranium-235, and uranium-238.

Table 6-1. Analytes For Risk Evaluation in the Feasibility Study.

Group A (Potential Major Risk Driver) Analytes	Group B Analytes With <10% of Results > PRG and 95% UCL of Results > PRG	Group B Analytes With >10% of Results > PRG and 95% UCL of Results > PRG
Carbon tetrachloride	Antimony	Hexavalent chromium
Chromium (total)	1,2-dichloroethane	Iron
I-129	Tetrachloroethylene	Chloroform
Nitrate		
Tc-99		
Trichloroethylene		
Tritium		
Uranium (total)[a]		
Uranium (radioactive)[a]		

[a] For purposes of this discussion, the total and radioactive uranium are considered to be one contaminant of concern.
PRG = preliminary remediation goal
UCL = upper confidence limit

Table 6-2. Reference Doses for Inhalation and Ingestion.

Constituent	Modifier	Description	Value	Comments or Reference Citation
Carbon tetrachloride	RfDINH	Carbon tetrachloride RfD for inhalation	5.70E-03	Subchronic (web site www.risk.lsd.ornl.gov/cgi-bin/tox/TOX_select?select=nrad)[a]
Carbon tetrachloride	RfDING	Carbon tetrachloride RfD for ingestion	7.00E-04	Chronic (web site www.risk.lsd.ornl.gov/cgi-bin/tox/TOX_select?select=nrad)[a]
Uranium	RfDINH	Uranium RfD for inhalation	4.43E-05	From threshold limit values (ACGIH)[a]
Uranium	RfDING	Uranium RfD for ingestion	6.00E-04	Web site www.risk.lsd.ornl.gov/cgi-bin/tox/TOX_select?select=csf[a]

[a] ACGIH refers to the American Conference of Industrial Hygienists (on the Internet at www.acgih.org/home.htm).
[a] The Oak Ridge National Laboratory website is also known as the Risk Assessment Information System (RAIS).
RfD = reference dose

Table 6-3. Key Exposure Parameters for the Residential Farmer Scenario.

Pathway Parameters	Residential Farmer	
	Deterministic Value	Range
Soil External Exposure		
Hours/day	16	8 to 24
Days/yr	317	270 to 365
Shielding	0.8	0.8
Inhalation		
Breathing rate, m^3/day[a]	20	15 to 30
Soil mass loading, g/m^3	0.00005	0.00005
Volatiles from water, hr/yr	3,960	270 to 8,760
Soil Ingestion		
Ingestion rate, g/yr[a]	36.5	3.65 to 54.75
Food Ingestion		
Drinking water, L/yr	545[c]	0 to 1,095
Leafy vegetable, kg/yr[a]	2.7	1 to 15
Other vegetables, kg/yr[a]	73	25 to 85
Fruit, kg/yr[a]	37	10 to 50
Grain, kg/yr[a]	0	0
Milk, L/yr[a]	100	36.5 to 365
Meat, kg/yr[b]	30	0 to 100
Fowl, kg/yr[b]	6	0 to 15
Eggs, kg/yr	6.8	0 to 14
Fish, kg/yr	N/A	N/A

[a] As suggested by WDOH (1997)
[a] Value of 110 kg/yr from WDOH (1998) apportioned two-thirds to other vegetables, one-third to fruits, and 0 to grains, as suggested by Rittmann (2003).
[b] Combined meat and fowl same as meat and poultry (WDOH 1997).
[c] Equivalent to 1.5 L/day. Part of the daily consumption of drinking water is assumed to come from offsite (Rittmann 2003).
N/A = not applicable

Table 6-4. Slope Factors for Carcinogens.

Constituent	Modifier	Description	Value	Comments or Reference Citation[a]
Carbon tetrachloride	SFINH	Carbon tetrachloride slope factor for inhalation	0.0525	Web site www.risk.lsd.ornl.gov/ cgi-bin/tox/TOX_select?select=nrad
Carbon tetrachloride	SFING	Carbon tetrachloride slope factor for ingestion	0.13	Web site www.risk.lsd.ornl.gov/ cgi-bin/tox/TOX_select?select=nrad

[a] The Oak Ridge National Laboratory website is also known as the Risk Assessment Information System (RAIS).

Table 6-5. Unit Dose and Risk Factor Results.

Constituent	Type	Water Concentration	Water Units	Residential Farmer Scenario	Drinking Water Scenario	Result Units
Tc-99	Radionuclide	1	pCi/L	1.36E-02	1.07E-03	mrem
I-129	Radionuclide	1	pCi/L	1.22E+01	2.01E-01	mrem
U-234	Radionuclide	1	pCi/L	1.20E+00	2.07E-01	mrem
U-235	Radionuclide	1	pCi/L	1.12E+00	1.94E-01	mrem
U-238	Radionuclide	1	pCi/L	1.07E+00	1.86E-01	mrem
Tc-99	Radionuclide	1	pCi/L	8.16E-09	6.42E-10	risk
I-129	Radionuclide	1	pCi/L	7.32E-06	1.21E-07	risk
U-234	Radionuclide	1	pCi/L	7.17E-7	1.24E-7	risk
U-235	Radionuclide	1	pCi/L	6.74E-7	1.17E-7	risk
U-238	Radionuclide	1	pCi/L	6.42E-07	1.12E-07	risk
Carbon tetrachloride	Carcinogen	1	µg/L	2.52E-07	5.30E-08	risk
Carbon tetrachloride	Hazardous	1	µg/L	1.94E-01	4.08E-02	HQ – none
Uranium	Hazardous	1	µg/L	2.75E-01	4.76E-02	HQ – none

HQ = hazard quotient

Table 6-6. Radiological Dose and Cancer Risk Summary of Selected Radiological Constituents.

Constituent	Maximum Well Concentration (pCi/L)	Drinking Water Only		Residential Farmer	
		Maximum Estimated Radiological Dose (mrem)	Maximum Estimated Cancer Risk	Maximum Estimated Radiological Dose (mrem)	Maximum Estimated Cancer Risk
Tc-99	36,000[a]	3.85E+01	2.31E-05	4.90E+02	2.94E-04
I-129	18	3.62E+00	2.18E-06	2.20E+02	1.31E-04
U-234[a]	62	1.28E+01	7.65E-06	7.40E+01	4.42E-05
U-235[a]	3	5.55E-01	3.34E-07	3.17E+00	1.93E-06
U-238[a]	60	1.12E+01	6.67E-06	6.43E+01	3.87E-05
U, total		2.45E+01	1.47E-05	1.42E+02	8.49E-05

[a] Not including the results of well 299-W11-25B.
[a] Isotopic concentrations for these constituents are estimated based on the assumption that they occur in same composition as their natural abundance.

Table 6-7. Summary of Maximum Radiological Doses and Cancer Risks for Selected Constituents Evaluated at Two Locations.[a]

	Maximum Total from Drinking Water Only	Maximum Total from Residential Farmer
Location of Highest Total Radiological Dose/Risk		
Maximum dose (mrem)[b]	43.2	570.8
Maximum risk due to radiological dose	2.59E-05	3.43 E-4
Location of Highest Overall Risk		
Risk due to radiological dose	2.32E-08	2.95E-07
Risk due to carbon tetrachloride	2.26E-04	1.07E-03
Maximum overall risk[c]	2.26E-04	1.07E-03

[a] These maximum values are not the summation of individual constituent maximums found in Table 6-8 and Table 6-6, but rather reflect the maximum values of dose and risk resulting from the summation of the dose and/or risk at different geographic locations.
[b] Summed radiological dose from technetium-99, iodine-129, uranium-234, uranium-235, and uranium-238 at the location of maximum summed dose.
[c] Summed cancer risk from carbon tetrachloride, technetium-99, iodine-129, uranium-234, uranium-235, and uranium-238 at a specific geographical location. This overall risk is mainly attributable to carbon tetrachloride

Table 6-8. Cancer Risk and Hazard Quotient Summary of Selected Hazardous Chemical Constituents.

Hazardous Chemical Constituent	Maximum Well Concentration (µg/L)	Drinking Water Only		Residential Farmer	
		Maximum Estimated Hazard Quotient	Maximum Estimated Cancer Risk	Maximum Estimated Hazard Quotient	Maximum Estimated Cancer Risk
Carbon tetrachloride	4,200	1.71E+02	2.26E-04	8.15E+02	1.07E-03
Uranium	180	8.57E+00		4.95E+01	

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7.0 SUMMARY

This RI report presents the analytical and other data resulting from implementation of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c). A complete baseline risk assessment is not included in this report, but rather will be included as part of the FS. This RI report presents a discussion of estimates of existing risks based on current interpretations of contaminant plumes that originate within the 200-ZP-1 OU and that exceed DWSs. The plume interpretations are developed in the annual groundwater monitoring report for FY05 (PNNL 2006). This discussion only focuses on a few indicator COCs, which include carbon tetrachloride, technetium-99, iodine-129, and uranium. Also included is a discussion of preliminary risks associated with the carbon tetrachloride plume based on information developed in a previous modeling study of carbon tetrachloride (Bergeron and Cole 2005). The data evaluation was conducted according to the requirements of the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) and the DQO summary report (FH 2003c). The DQA presented in Appendix H demonstrates that the data meet the established DQOs.

The objectives of this RI report are as follows:

1. Define the nature and extent of groundwater contamination that currently exists within the 200-ZP-1 OU.
2. Integrate and evaluate information from CERCLA and RCRA efforts to identify potential saturated zone contaminants and characterize the subsurface hydrogeology and aquifer properties.
3. Determine if a FS and baseline risk assessment are required.
4. Determine if sufficient data have been collected to support the preparation of a baseline risk assessment and FS.
5. Present aquifer property and contaminant data to support fate and transport modeling.
6. Combine data from the 200-ZP-1 and 200-UP-1 OUs to develop a comprehensive distribution model of the carbon tetrachloride plume that underlies both areas.
7. Identify groundwater contaminants to be evaluated in human health and ecological risk assessments in the upcoming FS.

It was determined that the quantity and quality of the collected data were sufficient to support future risk assessment activities. The COCs were identified that pose a significant risk to human health and the environment and, as a result, it was determined that an FS is required to address the risks presented by the identified COCs. Site-specific factors were also identified that require consideration in an FS.

Data are presented in this RI report from all of the new CERCLA groundwater monitoring wells that the 200-ZP-1 RI/FS work plan required to be installed (DOE-RL 2004c). Four additional 200-ZP-1 RCRA wells (i.e., LLWMA-5, LLWMA-8, LLWMA-13, and LLWMA-17) that are planned for the monitoring well network are not yet completed; however, data from these wells were not required to complete either the human health or ecological data evaluations. The existing data demonstrate that risks to human health and the environment from 15 COCs (as listed in Table 7-1) are sufficient to warrant further baseline risk assessment in an FS. In addition to the human health baseline risk assessment, an ecological risk assessment is also

recommended in the FS to analyze the risk contribution from 200-ZP-1 groundwater to the Columbia River ecosystem.

The existing data further demonstrate that the 15 COCs identified in Table 7-1 pose sufficient risk to require the evaluation of remedial alternatives in an FS. The existing 200-ZP-1 pump-and-treat system is effective as an interim remedial action, but it is not designed to adequately address the long-term risks posed by all 15 of the identified COCs. The current 200-ZP-1 pump-and-treat system is designed to recover and treat contaminated groundwater in the upper 15 m (50 ft) of the unconfined aquifer within a highly contaminated area of the carbon tetrachloride plume; the current 200-ZP-1 pump-and-treat system is not designed to recover groundwater from deeper or less contaminated portions of the unconfined aquifer. As explained in the following subsections, recently acquired data, ongoing sampling, and proposed studies are expected to provide a basis for evaluating potential remedial alternatives in an FS.

The COC data support the current knowledge of the major plumes. The carbon tetrachloride plume emanates from the Z Plant area and underlies most of 200 West Area, spanning across both the 200-ZP-1 and 200-UP-1 OUs. This plume spans the entire approximate 61 m (200 ft) thickness of the unconfined aquifer and, in many cases, the highest concentrations of carbon tetrachloride are in the middle to lower portions of the aquifer. The nitrate plume underlies most of the operational area of 200 West Area in 200-ZP-1 OU.

More localized plumes of chromium and technetium-99 underlie WMA-T. Technetium-99 is undergoing further evaluation with respect to its depth in the 200-ZP-1 OU east of the WMA-T area. The uranium plume underlies the T Plant area. Iodine-129 and tritium are spreading east, to an area that is northeast of the TX-TY Tank Farms. Two localized plumes of uranium and technetium-99 are located just east of the TX-TY Tank Farms. The TCE plume begins north of Z Plant and underlies the TX-TY Tank Farms, extending north beyond WMA-T. Appendix A presents a plate map that summarizes these major plumes. Although a fluoride plume is noted in the annual Sitewide groundwater report (PNNL 2006), the risk evaluation did not note it as an identified risk driver.

7.1 CHARACTERIZATION

Sufficient data exist to establish a basis for risk assessment in a FS. Recent drilling and sampling activities were, and continue to be, directed at obtaining additional data to fully define the lateral and vertical distribution of COCs previously detected in the unconfined aquifer. One identified data gap is related to the issue that there are limited COC concentration data at the base of the unconfined aquifer. This data gap precluded a complete evaluation of the vertical distribution of COCs within the aquifer. The lateral distribution of COCs at depth in the unconfined aquifer was also incompletely defined. Supplemental drilling and sampling activities are currently scheduled to fill these data gaps. This information will be included as an appendix to the FS.

Depth-discrete sampling data are required to understand the vertical and lateral extent of the carbon tetrachloride and technetium-99 plumes. The previous section summarized the details presented in Section 4.3 and presents lateral extent of the contaminant. The following paragraphs summarize the depth-discrete data used to assess the vertical profile of the carbon tetrachloride and technetium-99 plumes. The carbon tetrachloride results are discussed first, followed by the technetium-99 data. Section 4.4 provides the well numbers and additional detail associated with these general trends.

The plate maps in Appendix C show vertical plots of the depth-discrete results for carbon tetrachloride and its degradation compounds (i.e., chloroform, methylene chloride, and chloromethane) for as many as 39 wells as well as selected concentration contours for the carbon tetrachloride plume. The data were generated by two methods: field screening and laboratory analysis. The data shown on the plate maps in Appendix C show different concentration results for individual sample depths due to differences between the field screening and laboratory methods (e.g., well 299-W15-42), as well as temporal differences. The temporal differences result from natural groundwater plume movement and the influence of the 200-ZP-1 OU pump-and-treat system. Despite these issues, the data represent the most complete depth-discrete groundwater results for defining the three-dimensional distribution of the carbon tetrachloride plume and its degradation products.

The vertical plot results for carbon tetrachloride are also shown on two hydrogeologic cross-sections on the plate maps in Appendix C and in Figures 4-37 and 4-38. The cross-sections illustrate a carbon tetrachloride groundwater plume that extends vertically from the top of the unconfined aquifer near the disposal source areas by PFP to the base of the unconfined aquifer at the top of the Ringold Lower Mud Unit (Unit 8). The plume extends through the Ringold Formation to the top of basalt where the Unit 8 confining layer is absent, as at well 299-W13-1. As the distance from the source area increases in a downgradient direction, the highest carbon tetrachloride concentrations occur deeper in the unconfined aquifer. A current hypothesis for higher carbon tetrachloride concentrations at greater depths, downgradient from the source area, is that recharge is diluting contaminants in the upper portion of the unconfined aquifer. Recharge results from both natural infiltration and less-contaminated former wastewater discharges that are still present in the overlying vadose zone. As described in Section 4.4.1, the dilution hypothesis will be further evaluated as needed in the FS in conjunction with vertical gradient data from at least three sets of paired wells. The vertical gradient data will be integrated into the carbon tetrachloride model in the FS.

Although not shown in the vertical depth plots on the plate maps in Appendix C, the approximate depth to groundwater in the wells shown ranges from about 67 to 76 m (220 to 250 ft) bgs, and the approximate depth to the Ringold Lower Mud Unit ranges from about 113 to 134 m (370 to 440 ft) bgs. In general, the elevation of the water table decreases from west to east and the elevation of the Lower Mud Unit increases from southwest to northeast.

Seven wells in the high-concentration portion of the carbon tetrachloride plume (from north to south: 299-W15-765, 299-W15-43, 299-W15-40, 299-W15-44, 299-W15-11, 299-W15-1, and 299-W15-7) showed the highest concentrations of carbon tetrachloride at depths of 6 to 21 m (20 to 70 ft) below the water table. The highest carbon tetrachloride concentrations in these wells ranged from about 2,700 to 4,152 µg/L. Well 299-W15-43 showed the highest carbon tetrachloride concentration (3,300 µg/L) at 21 m (70 ft) below the water table and then lower concentrations below that depth when the well was drilled in 2002, clearly defining the vertical concentration profile of the plume in this area. The data from the other six wells in this area all show increasing carbon tetrachloride concentrations with depth, indicating that the full thickness of the plume was not penetrated by these wells.

Three wells near the 216-Z-9 Trench (one of the primary carbon tetrachloride waste disposal sites near PFP) showed the highest concentration of carbon tetrachloride (2,000 to 3,700 µg/L) at depths of 18 to 33 m (60 to 110 ft) below the water table.

Data from wells located downgradient (east) of the high-concentration portion of the carbon tetrachloride plume show how the depth of the plume maximum increases with downgradient distance.

Three wells near the 216-Z-1A, 216-Z-12, and 216-Z-18 waste sites (the other primary carbon tetrachloride waste disposal sites near PFP) show significantly lower carbon tetrachloride maxima than those seen near the 216-Z-9 Trench (discussed above). Wells 299-W15-152, 299-W18-1, and 299-W18-16 are located about midway between the injection wells to the west and the extraction wells to the east of the pump-and-treat system and are likely showing the impacts of that system.

The carbon tetrachloride plume extends to the 200-UP-1 OU; therefore, depth-discrete data were presented from this OU. Four wells within the 200-UP-1 OU portion of the carbon tetrachloride plume illustrate the vertical distribution of carbon tetrachloride in the unconfined aquifer in this plume lobe. Wells 299-W15-37, 299-W19-49, and 299-W19-50 showed plume maximum concentrations (120 to 140 µg/L) at 6 to 30 m (20 to 100 ft) below the water table. To the east (downgradient) of these wells, well 699-38-70B penetrated the highest carbon tetrachloride concentration (480 µg/L) at the base of the unconfined aquifer (about 38 m [125 ft] below the aquifer).

Two wells near the T Tank Farm and one well near T Plant illustrate the vertical distribution of carbon tetrachloride in the unconfined aquifer in the northern plume area. Wells 299-W10-24 and 299-W11-25B showed plume maximum values (1,500 to 1,600 µg/L) at 21 to 24 m (70 to 80 ft) below the water table. Approximately 450 m (1,500 ft) downgradient, well 299-W11-43 penetrated a high carbon tetrachloride concentration (1,000 µg/L) at approximately 20 m (65 ft) below the water table and then lower concentrations deeper in the aquifer. However, the last depth-discrete groundwater sample from this well at a depth of about 56 m (185 ft) below the water table, near the base of the unconfined aquifer, had a carbon tetrachloride concentration of 1,100 µg/L.

In general, the depth of the maximum concentration of chloroform is similar to the depth of the maximum concentration of carbon tetrachloride in each well. A few of the wells show low levels of methylene chloride present within the aquifer. Fewer wells have detectable concentrations of chloromethane. The chloroform, methylene chloride, and chloromethane contaminants may be the result of carbon tetrachloride degradation. The reductive dechlorination process would occur in the following order: carbon tetrachloride to chloroform to methylene chloride, and to chloromethane. This would account for the decreasing concentrations of the three degradation products. The association of carbon tetrachloride and its potential degradation products in the 200-ZP-1 unconfined aquifer will be examined in the FS as needed, especially if monitored natural attenuation is selected as a remediation alternative.

The FS will consider a primary conceptual model and an alternative conceptual model for carbon tetrachloride. The primary model (i.e., the assumed current condition for which a remedy will be developed) will recognize that NAPL concentrations of carbon tetrachloride currently exist in the vadose zone but do not present a significant continuing source term to the groundwater. In the groundwater, the amount and spatial distribution of any NAPL sources are small relative to the magnitude of the dissolved phase present in the aquifer. In other words, the primary focus of the remedy in the FS will be to address the dissolved phase carbon tetrachloride in groundwater. The alternative model is that sources of NAPL carbon tetrachloride exist in the groundwater of

sufficient mass and/or spatial distribution to require a supplementary and/or alternative remedial action and that these sources would be discovered either during implementation of the remedy or as part of performance monitoring resulting in the need for an adaptive contingency response for the groundwater. Such a response will be anticipated as part of the remedial strategy developed in the FS for the 200-ZP-1 OU. A key component of the remedy design will be to collect data aimed at testing the likelihood that the conditions presumed for the alternative conceptual model exist.

WMA-T contains the T Tank Farm. A technetium-99 plume has been identified northeast of WMA-T. The technetium-99 plume was previously thought to be located at the water table. A new well (299-W11-25B) was located in the northeast corner of WMA-T to assess the vertical extent of the technetium-99 plume. Recent data from well 299-W11-25B indicate technetium-99 concentrations at 180,000 pCi/L at a depth of 10 m (approximately 30 ft) below the water table. It must be noted that the maximum depth of the nitrate concentrations is the same as the maximum depth of the technetium-99 concentrations

In order to assess the lateral extent of the technetium-99 plume in the deeper unconfined aquifer, well 299-W11-45 was drilled approximately 80 m (262.5 ft) downgradient (east) of well 299-W11-25B. Well 299-W11-45 was sampled every 1.5 m (4.9 ft) throughout the top 56 m (183.7 ft) of the aquifer. The nitrate and technetium-99 concentrations are shown in Figure 4-42. Again, the depth distributions of both contaminants are similar to that of well 299-W11-25B, however, the maximum concentrations are lower. Additional wells are planned in the area during FY06 to assess the lateral and vertical extent of the technetium-99 plume.

To supplement the 200-ZP-1 database, sediment sampling results for geochemical, hydrogeological, and physical parameters from the nearby 200-UP-1 OU are presented in this RI report. Additional sediment samples from the 200-ZP-1 OU are to be collected later in FY06 for K_d analysis, and these results will be presented in the FS.

Sediment samples were collected for COC analysis during well drilling. Vertical profiles and tables of these COC concentrations are presented in Appendix N and are discussed in Section 4.5. The sediment data will be evaluated in the FS, as needed, to analyze remedial alternatives.

Vertical plots of soil gas data from carbon tetrachloride in the vadose zone are presented in Appendix N and are discussed in Section 4.5. The soil gas data are also planned for evaluation in the FS, when required, for consideration of remedial alternatives.

Aquifer slug tests and other studies provided data that will be used in the FS to predict the movement of COCs in the saturated zone and to evaluate their response to remedial alternatives. Several studies focused on the released amount, current disposition, and projected movement of carbon tetrachloride in the 200-ZP-1 OU. Depth-discrete groundwater monitoring data were collected to show the vertical distribution of COCs within the aquifer and to monitor the movement of COCs in groundwater over time. This information will be used to support the screening of alternatives and baseline risk assessment in the FS. Pilot tests may be required in the future to determine the viability of various remedial alternatives in an FS.

7.1.1 Contaminant of Concern Evaluation

Sections 1.4.3 and 4.2, respectively, present the logic used to assess the COCs and the results of implementing the logic. The results from this evaluation are recommendations of analytes for future risk assessment as presented in Section 6.1.1. The logic was agreed upon by EPA, as documented in an attachment to the October 2005 200 Area Unit Managers' Meeting minutes (FH 2005a). The logic uses all of the groundwater data collected since 1988 for the analytes agreed upon as COCs in the 200-ZP-1 RI/FS work plan (DOE-RL 2004c) and shown in Table 1-5 of this document. This is more effort than originally agreed upon; however, it is a logical approach given the area covered by the OU and the need to evaluate constituents over time.

The COCs were divided into two groups: Group A and Group B. The Group A analytes are the analytes for which plumes have already been identified in the PNNL annual groundwater reports and are considered potential major risk drivers. The eight Group A COCs are total chromium, carbon tetrachloride, iodine-129, nitrate, technetium-99, TCE, tritium, and radioactive/total uranium. The Group B analytes are the analytes that are listed COCs in Table 1-5 that are not in Group A. This analyte list is too long to present here. Figures 1-3 and 1-4 present the logic used. The PRGs used for the COC screening are the "selected limit" in Table 1-5.

To better evaluate the risk for human and ecological receptors, data from more wells were added to the risk evaluation. The added wells include those with higher concentration wells within the plume for the Group A analytes. If these wells had not been added, the risk evaluation may have incorrectly indicated that known major risk drivers posed no/little risk.

The result of screening the Group A analytes is that all eight had at least one sample greater than two times the PRG. Thus, all of the analytes are recommended for further evaluation in the baseline risk assessment, which will be performed in the FS.

The results of screening the Group B COCs generated the following results. A large number of Group B COCs require no further action because either all are nondetects or all detected results are below the PRG (see Section 4.2).

The analytes detected above the PRG at less than 10% frequency were statistically evaluated and the results are shown in Table 7-1. These are recommended for additional risk evaluation and/or assessment.

The analytes detected above the PRG at more than 10% frequency were statistically evaluated and the results are shown in Table 7-1. The statistical evaluation was in addition to that originally agreed upon and presented in the logic in Figure 1-4. The statistical evaluation was the same approach used for the less frequently detected analytes and is based on MTCA statistical guidance (WAC 173-340).

A common laboratory contaminant routinely detected in samples is methylene chloride. While normally this would be removed as a common laboratory contaminant, the following observations resulted in retaining it as a COC:

- A significant number of detections occurred.
- Results ranged from nondetects to 4,100 μg/L.

- Under aerobic conditions, methylene chloride is a degradation product of carbon tetrachloride, which is a Group A analyte that will be evaluated in the baseline risk assessment.

7.2 CONTAMINANT DISTRIBUTION MODELS AND EXPOSURE MODELS

The conceptual contaminant distribution models and the conceptual exposure model developed in the DQO summary report (FH 2003c) were evaluated based on the data obtained during the RI and other data-collection activities. The contaminant distribution models generally can be described as follows.

- The contaminants migrate through the vadose zone in response to past disposal of waste liquids and/or natural recharge, reach groundwater, and flow along pathways of least resistance within the unconfined aquifer from higher to lower hydraulic head. General groundwater flow is currently east from the 200-ZP-1 OU toward the Columbia River.
  - The carbon tetrachloride model is still evolving. The conceptual model currently includes the following elements: the bulk of the remaining carbon tetrachloride mass in the subsurface resides in fine-grained layers within the vadose zone; soil gas data at the base of the vadose zone indicate that significant quantities of carbon tetrachloride are not currently migrating to the saturated zone; and significant dissolved-phase carbon tetrachloride concentrations exist in the unconfined aquifer, but it is uncertain whether carbon tetrachloride is present as a DNAPL.
  - The model for technetium-99 is undergoing additional evaluation. There are high concentrations of technetium-99 in recent wells proximal to the northeastern side of WMA-T, and the maximum technetium-99 concentrations appear deeper (below 9 m [30 ft]) in the unconfined aquifer than has been observed in previous older wells. This document has not discussed this, as the DQO process and a resulting sampling design are forth coming to address this area.

The exposure pathway model for the OU is presented in the DQO summary report (FH 2003c) and is summarized as follows.

- Humans may be exposed to groundwater (irrigation and/or drinking).
- Potential receptors are mainly current and future workers under the industrial land-use scenario (based on the current land-use assumptions) and terrestrial biota.
- Exposure pathways are ingestion, dermal contact, inhalation, and exposure to external radiation.
- Groundwater reaches the Columbia River and is blended with river water, thus contributing to the risk associated with the river.

The current contaminant distribution models are generally similar to those presented in the DQO summary report (FH 2003c); however, it is now understood that carbon tetrachloride is present deeper within the aquifer than previously estimated. Ongoing data acquisition efforts are directed at better defining the nature and extent of the COCs in the model.

The conceptual risk model contains the following media types: ingestion of groundwater (human for irrigation), inhaling contaminated soil particles (human and ecological receptors),

and inhalation of soil gas via fugitive emissions (human and ecological). Based on current land-use assumptions, potential receptors are current workers, future workers, and terrestrial biota.

7.3 CONTAMINANTS OF CONCERN AND HUMAN HEALTH SITE RISKS EVALUATION

A baseline risk assessment was not performed as part of this RI report, but rather will be performed as part of the FS. The risk evaluation for this RI consisted of comparing COCs to PRGs and evaluating some key COCs, as performed by PNNL. The comparison of the COCs for the Group A analytes indicated that these are potential major risk drivers and are recommended for added risk assessment in the FS. The Group B analytes that exceeded the PRGs are listed in Table 7-1 and are recommended for addition risk evaluation and potential risk assessment in the FS.

As documented in an attachment to the October 2005 200 Area Unit Managers' Meeting minutes (FH 2005a), it was agreed that four of the potential major risk drivers (i.e., carbon tetrachloride, technetium-99, iodine-129, and uranium) would be evaluated for risk as part of this RI report. This information is summarized in Section 6.1.2.

As expected, the largest risks are associated with ingestion of and exposure to groundwater containing carbon tetrachloride. This risk analysis shows that ingestion of and exposure to groundwater containing the highest levels of carbon tetrachloride in the upper portions of the unconfined aquifer would result in maximum estimated cancer risks of 2.2×10^{-4} and 1.1×10^{-3}, respectively, for the drinking water only and resident farmer exposure scenarios. Ingestion of and exposure to groundwater containing the highest levels of carbon tetrachloride in the upper portions of the unconfined aquifer resulted in calculated HQs of 171 and 815, respectively, for the same exposure scenarios. Ingestion and exposure to groundwater containing the highest levels of uranium in the uppermost aquifer yields HQs of 8.57 and 49.5, respectively, for these scenarios.

Significant radiological doses and associated incremental cancer risk are also associated with ingestion of and exposure to groundwater containing elevated levels of technetium-99, iodine-129, and uranium isotopes (uranium-234, uranium-235, and uranium-238). This risk analysis shows that ingestion of and exposure to groundwater containing the highest levels of technetium-99 in the upper portions of the unconfined aquifer would result in maximum estimated cancer risks of 2.3×10^{-5} and 2.9×10^{-4} for the drinking water only and residential farmer exposure scenarios, respectively. Maximum doses would be 38.5 and 490 mrem, respectively. For maximum concentration levels of iodine-129, maximum estimated cancer risks would be 2.2×10^{-6} and 1.3×10^{-4}, respectively, for these same exposure scenarios. Maximum doses from iodine-129 would be 3.6 and 220 mrem, respectively. For maximum concentration levels of uranium, estimated cancer risks would be 1.5×10^{-5} and 8.5×10^{-5} for these same exposure scenarios, respectively.

7.4 CONTAMINANTS OF CONCERN AND ECOLOGICAL SITE RISKS EVALUATION

There are no direct exposure pathways from Central Plateau groundwater to ecological receptors; the main concern regarding ecological exposure involves the Columbia River. To characterize ecological risks associated with contaminated 200-ZP-1 groundwater, a bounding analysis is

performed with three exposure scenarios. The three scenarios are (1) no dilution, (2) 50% dilution of groundwater with the Columbia River, and (3) a scenario that addresses a mass-balance dilution of groundwater in Columbia River water and assumes a mixing ratio of 1% of the analyte-specific maximum OU groundwater concentration and 99% Columbia River water (i.e., the 0.01 dilution scenario). Section 5.2 presents the ecological evaluation and details of the scenarios, the values used for risk screening and their technical origin and the results. Note that the values used for risk screening are based on the following:

- "Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A)
- *National Recommended Water Quality Criteria: 2002* (EPA 2002b)
- Additional well-recognized sources listed in Section 5.2 when analytes were not covered by the first two sources.

The results of risk evaluation/screening are summarized here. It must be noted that the dilution scenarios are based on maximum concentrations recorded in groundwater. As contaminants move from the 200-ZP-1 OU through the subsurface to the Columbia River, it is realistic to assume that isolated contaminant maxima in the 200-ZP-1 become mixed with the plume. This mixing within the contaminant plume represents an averaging of concentrations. As such, characteristics of the average concentration best represent contamination from the OU over the course of the plume traveling to the river. Based on the averaging, the three scenarios were re-evaluated.

The results of the risk evaluation using the average concentration and the dilution scenarios are as follows:

- **No dilution:** seven analytes exceed the HQ of 1
- **0.5 dilution factor:** four analytes exceed the HQ of 1
- **0.01 dilution factor:** no analytes exceed the HQ of 1.

Using groundwater concentrations representative of the average, there is no evidence for potential ecological risk for 200-ZP-1 OU contaminants in the Columbia River. However, there is an indication of the potential for adverse ecological effects in the hyporheic zone using representative groundwater concentrations; specifically, from hexavalent chromium, total uranium, carbon tetrachloride, and cyanide. Therefore, a more detailed ecological risk assessment is needed for these four analytes. Table 7-1 summarizes the COCs recommended for further ecological risk evaluation.

7.5 GENERAL CONCLUSIONS

The primary conclusions that may be derived from the 200-ZP-1 environmental investigations to date are listed below:

- Sufficient data currently exist to support a human health risk model.
- Sufficient human health risk exists from 14 of the COCs in Table 7-1 to require preparation of a baseline risk assessment and an FS.
- Sufficient ecological risk exists from four of the COCs in Table 7-1 to further evaluate an ecological assessment in the FS.

- Additional depth-discrete groundwater sampling data are needed to refine the three-dimensional model of COC distribution in the unconfined aquifer.
- Updated fate and transport modeling is required in the FS for the COCs to adequately evaluate their projected migration through the unconfined aquifer.
- Existing data do not confirm or reject the existence of free-phase carbon tetrachloride, TCE, or other DNAPL compounds in the unconfined aquifer.

7.6 PATH FORWARD

The following actions are suggested in addition to the FS and ecological assessment described in Sections 7.3.1 and 7.3.2:

- Evaluate existing and new data for the status of ongoing COC natural degradation processes, including: the association of specific COCs and their potential degradation products (e.g., for carbon tetrachloride, evaluate chloroform, methylene chloride, and chloromethane); abiotic degradation processes and rates, especially for a remediation by monitored natural attenuation; comparison of molar concentrations of carbon tetrachloride and chloroform in selected wells; and integration of vertical gradient data into conceptual models, especially for carbon tetrachloride.
- Develop detailed stratigraphic maps from available borehole logs for selected areas of the 200-ZP-1 OU.
- Perform treatability studies as needed to support the FS.
- Complete characterization of the downgradient extent of the carbon tetrachloride plume.
- Collect sediment samples for K_d calculations from as many as five new 200-ZP-1 wells (i.e., "AA," "BB," "CC," "DD," and "EE") that are planned in the vicinity of the Old Laundry Facility, and include this new data as an appendix to the 200-ZP-1 FS.
- Install new groundwater wells between the Old Laundry Facility and PFP, and between the Old Laundry Facility and T Plant, to better understand the three-dimensional distribution of carbon tetrachloride within the aquifer.
- Collect depth-discrete COC concentration and geochemical (e.g., DO) groundwater data from planned 200-ZP-1 wells "AA," "BB," "CC," "DD," and "EE," and include this new data as an appendix to the 200-ZP-1 FS.
- Ongoing monitoring data from 200-ZP-1 wells will be evaluated in the FS.

7.6.1 Feasibility Study

The FS will follow CERCLA guidance and the strategy in the 200 Areas Implementation Plan (DOE-RL 1999). The 200 Areas Implementation Plan focuses on the soil-contaminated sites; thus, the only applicable part of the plan is the integration between the vadose zone and groundwater. The risk assessment will be performed as part of the FS, as agreed upon between RL and EPA and as documented in an attachment to the October 2005 200 Area Unit Managers' Meeting minutes (FH 2005a). In addition, it is recommended that the FS include mapping of the COCs that are degradation products of the carbon tetrachloride by well. This will allow better

determination as to whether these COCs are truly degradation products. The degradation products include chloroform, methylene chloride, chloromethane, and methane.

The potential ARARs, preliminary RAOs, PRGs, general response actions, and the screening-level analysis of alternatives will be performed as part of the FS. The FS also will identify any applicable treatability studies.

The FS report will analyze remedial alternatives and response actions. General response actions that may be applicable to the 200-ZP-1 OU include the following:

- No action
- Institutional controls and monitored natural attenuation
- Pump and treat
- Permeable or impermeable containment
- Bioremediation
- Air sparging.

7.6.2 Further Ecological Evaluations

Ecological risk will be evaluated using the EPA's eight-step process, as outlined in *Ecological Evaluation of the Hanford 200 Area – Phase I: Compilation of Existing 200 Areas Ecological Data* (DOE-RL 2002a). The ecological evaluation in the document (DOE-RL 2002a) serves as the screening-level assessment for the Central Plateau.

The Phase I ecological evaluation report (DOE-RL 2002a) is a foundation for the Central Plateau ecological evaluation. The 200-ZP-1 OU ecological risk assessment must consider information obtained from four different sampling events. Two of three sampling and analysis events have been implemented for terrestrial ecological sampling on the Central Plateau (i.e., *Central Plateau Terrestrial Ecological Sampling and Analysis Plan – Phase I* [DOE-RL 2004a] and *Central Plateau Terrestrial Ecological Sampling and Analysis Plan – Phase II* [DOE-RL 2005b]). A third SAP will be prepared and implemented in FY06. A fourth ecological SAP is being generated for the 100 and 300 Areas to include the hyporheic zone of the Columbia River. The 200-ZP-1 FS will integrate any ecological risk assessments with results from these ecological sampling and analysis results both on the Central Plateau and at the 100 Area along the Columbia River.

Any ecological risk assessment results from the FS will be used to provide the portion of risk attributable to the 200-ZP-1 OU that reached the Columbia River. This information will ultimately be used in the Columbia River risk assessment.

7.7 POST-RECORD OF DECISION ACTIVITIES

After the FS, a ROD will be written for the 200-ZP-1 OU. After the ROD has been issued, a remedial design report/remedial action work plan (RDR/RAWP) will be prepared to detail the scope of the remedial action. As part of this activity, the DQO process will be conducted and SAPs will be prepared to direct confirmatory and/or remedial design and verification sampling and analysis efforts. Before starting remediation, additional confirmation and/or remedial design sampling and testing may be required. During the remedial action, sampling and analyses will be performed routinely to ensure that the remedy is working. Verification sampling will be

performed after the remedial action is complete to determine if ROD requirements have been met and if the remedy was protective of human health and the environment.

The RDR/RAWP will include an integrated schedule of remediation activities specified in the ROD. The available options for remedy implementation throughout the 200 Areas will be explored during the course of the RI/FS process and may be reflected in the remedial action work plan. Following the completion of the remediation effort, closeout activities will be performed.

Table 7-1. Contaminants of Concern for Risk Evaluation in the Feasibility Study.

Human Health COCs			Ecological COCs
Group A (Potential Major Risk Driver) Analytes	Group B Analytes With <10% of Results > PRG and 95% UCL of Results > PRG	Group B Analytes With >10% of Results > PRG and 95% UCL of Results > PRG	HQ >1, Average Concentration and 0.5 DF as Discussed in Section 7.4
Carbon tetrachloride[a]	Antimony	Hexavalent chromium	Carbon tetrachloride
Chromium (total)	1,2-dichloroethane	Iron	Cyanide
I-129	Tetrachloroethylene (PCE)	Chloroform	Hexavalent chromium
Nitrate			Uranium (total)
Tc-99			
Trichloroethylene (TCE)			
Tritium			
Uranium (total and radioactive)			

[a] Retain methylene chloride for additional evaluation because it is a potential degradation product of carbon tetrachloride.

COC = contaminant of concern
DF = dilution factor
HQ = hazard quotient
PRG = preliminary remediation goal
UCL = upper confidence limit

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APPENDIX A

PLATE MAP OF 200-UP-1 AND 200-ZP-1 MONITORING NETWORK

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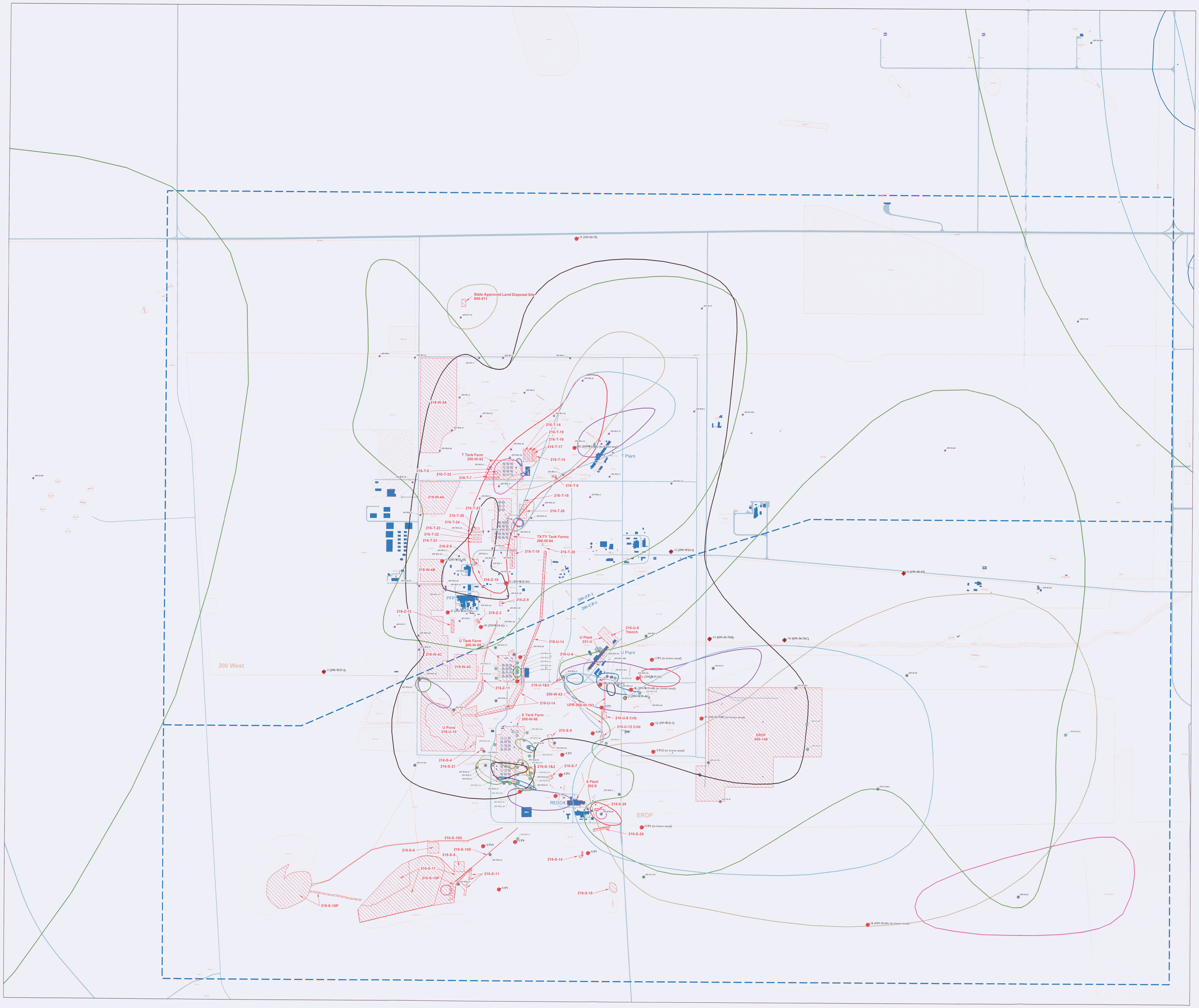
Proposed 200-UP-1 and 200-ZP-1 Monitoring Network

- Existing Monitoring Well
- Proposed Monitoring Well
- Proposed Monitoring Well At Known Coordinates
- RCRA Monitoring Well
- Operable Unit Boundary
- Associated Waste Site
- Other Waste Site

2003 Sample Data

- Chromium Concentrations 100 ug/L
- Carbon Tetrachloride Concentrations 5 and 2000 ug/L
- Iodine-129 Concentrations 1 pCi/L
- Nitrate Concentrations 20 mg/L
- Strontium 90 Concentrations 8 pCi/L
- Technetium-99 Concentrations 900 pCi/L
- Trichloroethylene Concentrations 5 ug/L
- Tritium Concentrations 20,000 pCi/L
- Uranium Concentrations 30 pCi/L



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N W E S

Meters: 0 250 500 1,000

Feet: 0 500 1,000 2,000 3,000

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APPENDIX B

PLATE MAP OF HANFORD SITE 200 AREA WASTE SITES

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GROUNDWATER REMEDIATION PROJECT

HANFORD SITE
200 WEST Waste Sites

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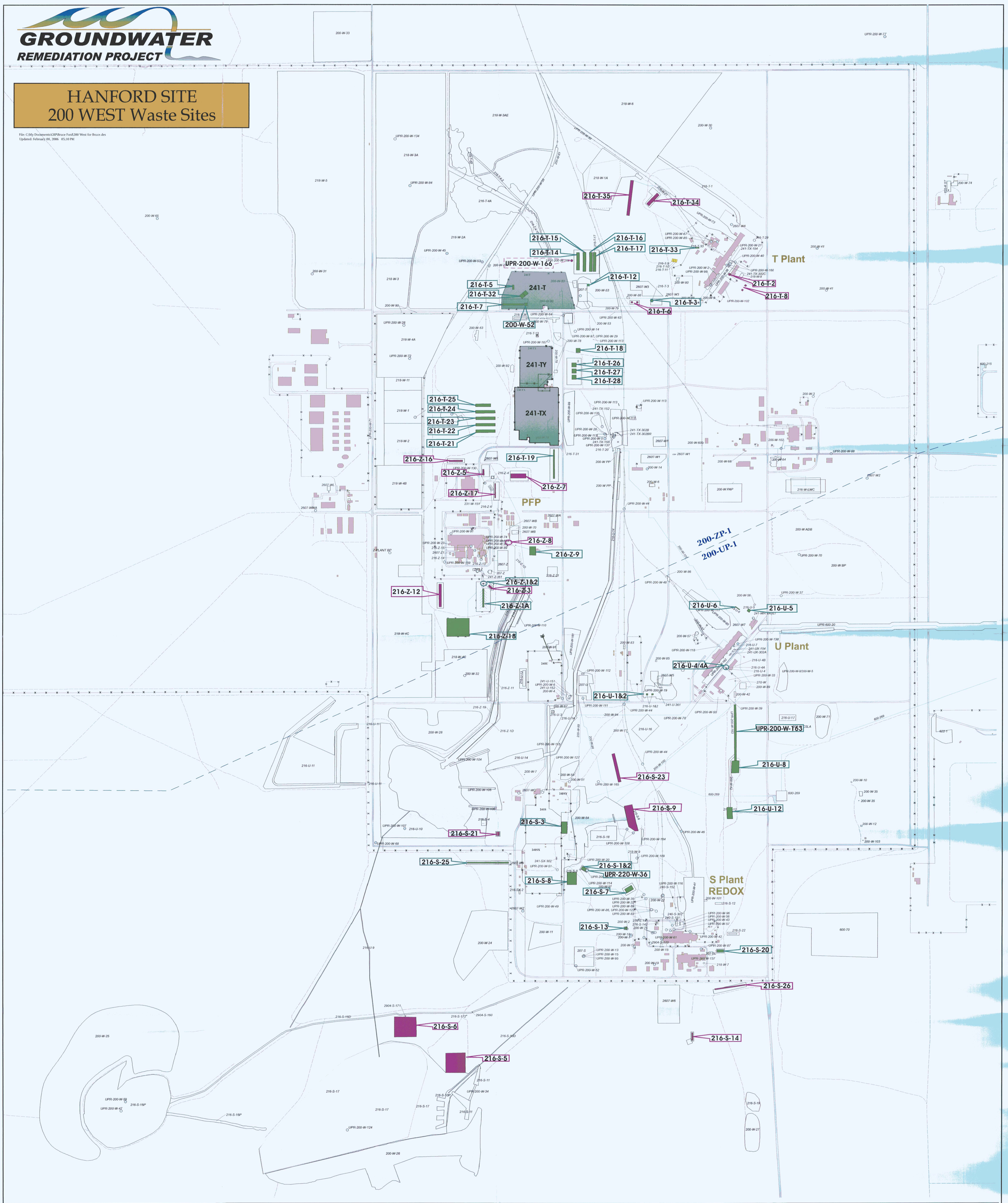

Buildings and Mobiles
Tank Farms
Definite
Tank Farm
Possible

Major Roads
Service Roads
Railroads
Perimeter Fences
Security Fences
Hazardous Fences

GROUNDWATER REMEDIATION PROJECT

APPENDIX C

PLATE MAP OF CARBON DEPTH-DISCRETE GROUNDWATER DATA FOR THE 200 WEST AREA

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APPENDIX C – EXPLANATION

Depth-discrete groundwater samples were collected from 39 wells during work performed for this 200-ZP-1 remedial investigation report and for *Carbon Tetrachloride DNAPL Source-Term Characterization* (DOE/RL-2006-58 [in publication]). The three carbon tetrachloride iso-concentration maps provided in this appendix and the associated vertical plots are based on analyses of groundwater samples collected from the unconfined aquifer from 2002 through 2006. The depth-discrete data were grouped into three depth intervals: shallow (water table to 18.3 m [60 ft] below the water table), middle (18.3 to 36.6 m [60 to 120 ft] below the water table), and deep (36.6 m [120 ft] below the water table to the aquifer base). The carbon tetrachloride data and associated wells for each depth interval are shown on the shallow aquifer, middle aquifer, and deep aquifer maps. Wells with data from more than one depth interval are shown on each of the relevant maps.

The carbon tetrachloride data were then contoured using computer software (Surfer 8™). Contouring was based on a kriging algorithm and a 1.5–m (5-ft) grid spacing. The "gridding file" generated by Surfer 8 was then imported to ArcGIS® computer mapping software to display the contours on a map of the Hanford Site. A minimal degree of professional hydrogeologic judgment was then used to refine the resulting isopleths based on geologic and groundwater flow characteristics of the unconfined aquifer. Dashed isopleths represent areas with limited data where the isopleth location is uncertain.

The most recent carbon tetrachloride isopleths (i.e., fiscal year 2005 [FY05]) generated by Pacific Northwest National Laboratory (PNNL) are shown as black lines for concentrations of 5 µg/L and 2,000 µg/L. The PNNL isopleths are based on a larger data set than the depth-discrete samples and represent the estimated carbon tetrachloride plume in the shallow aquifer. The PNNL groundwater data are averaged and generally include samples collected from FY03 through FY05.

Issues and Observations

The depth-discrete 5 µg/L and 100 µg/L isopleths are generally estimated due to the lack of data near the edges of the plume.

Two "hot spots" (i.e., 4,000 µg/L) are shown on the shallow map. A data gap exists between these two areas. It is uncertain whether the two hot spots are actually one larger hot spot.

It appears that the northern and eastern extent in the middle and deep intervals may be more aerially extensive than in the shallow interval (which may be due to the smaller data set for the middle and deep intervals).

Additional shallow groundwater data is available than was used in this data set.

A significant data gap is present east of the 216-Z-9 laundry waste crib (located near well 299-13-1).

Surfer 8™ is a trademark of SSG-Surfer.com, a division of Scientific Software Group, Sandy, Utah.
ARCGis® is a registered trademark of ESRI, Redlands, California.

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Carbon Tetrachloride and Degradation Compounds in 200 West Area Groundwater - Shallow Aquifer (Water Table to 60 ft Below Water Table)

- Existing Monitoring Well
- Existing Extraction Well
- New Monitoring Well
- New Monitoring Well At Exact Coordinates
- RCRA Monitoring Well
- Key Wells Used for Detailed Geochemical and Geotechnicoil Evaluation and Aquifer Testing
- Additional Wells Used to Support Risk Evaluation
- Additional Support Wells
- Primary Known Carbon Tetrachloride Waste Disposal Site
- Associated Waste Site
- Other Waste Site
- Operable Unit Boundary
- FY05 Carbon Tetrachloride Concentrations

BLACK isopleths are based on average annual groundwater concentrations (primarily in 2005, but excluding 2004 or 2003 when 2005 data are unavailable for a specific well). The black isopleths include both groundwater monitoring and depth-discrete data for the shallow portion of the unconfined aquifer.

PURPLE isopleths are based on maximum groundwater concentrations for depth-discrete samples collected from 2003 through 2005 (routine groundwater monitoring data are excluded). The depth-discrete data are divided into the following three depth intervals:

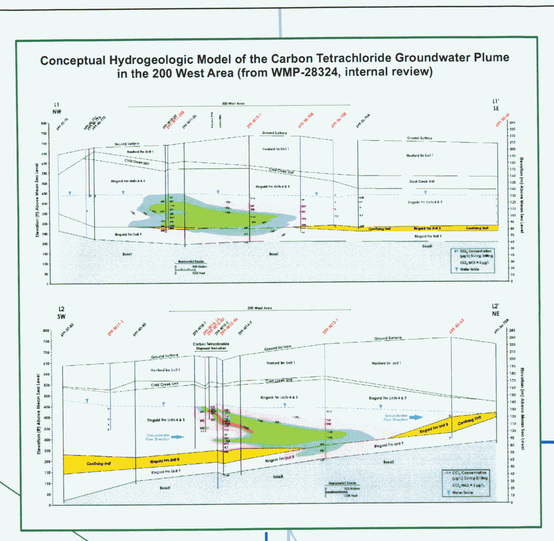
Shallow Aquifer from the water table to 60 ft below the water table,
Middle Aquifer from 60 ft to 120 ft below the water table, and
Deep Aquifer from 120 ft below the water table to the aquifer base.

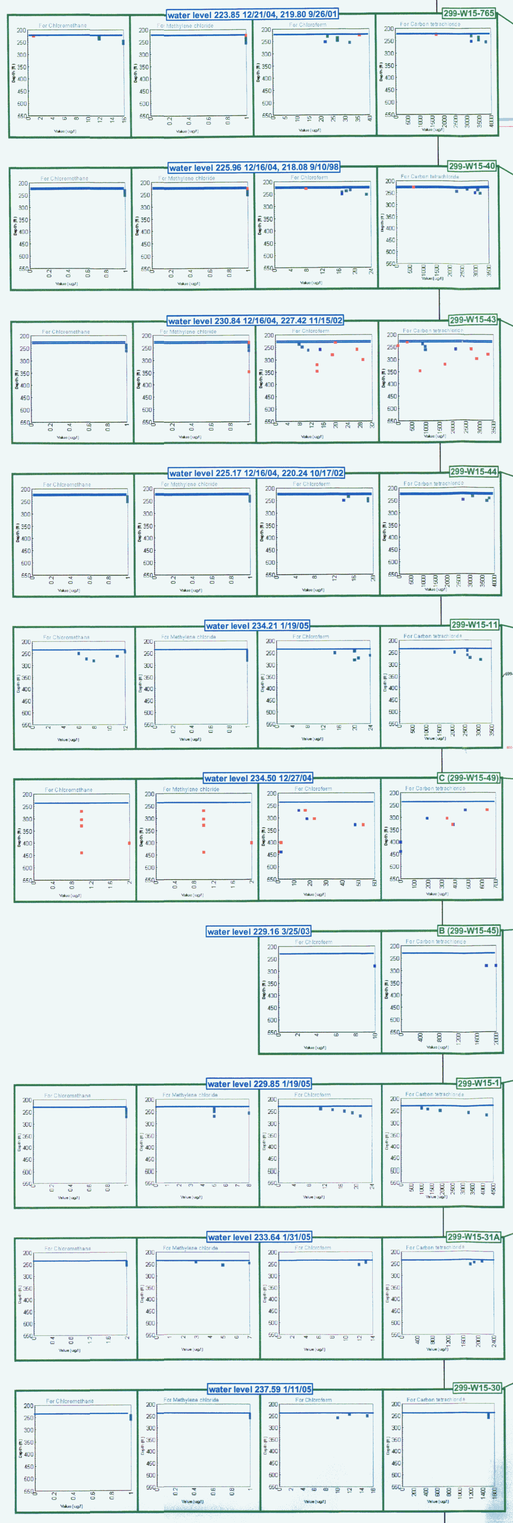
The **PURPLE** isopleths were determined by a computer-contouring program, and then modified according to professional judgment.

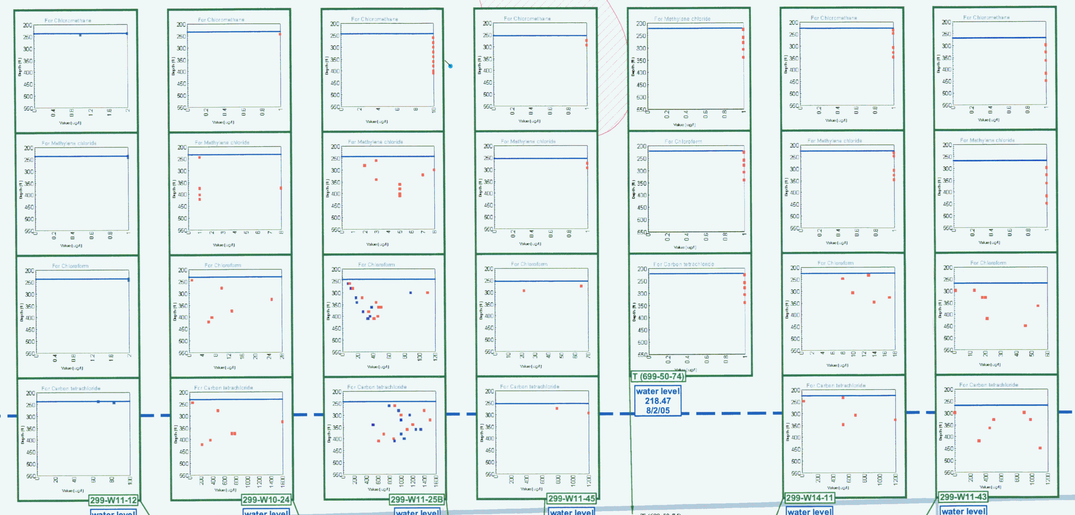
Solid PURPLE-colored lines indicate the estimated lateral extent for the given concentration.

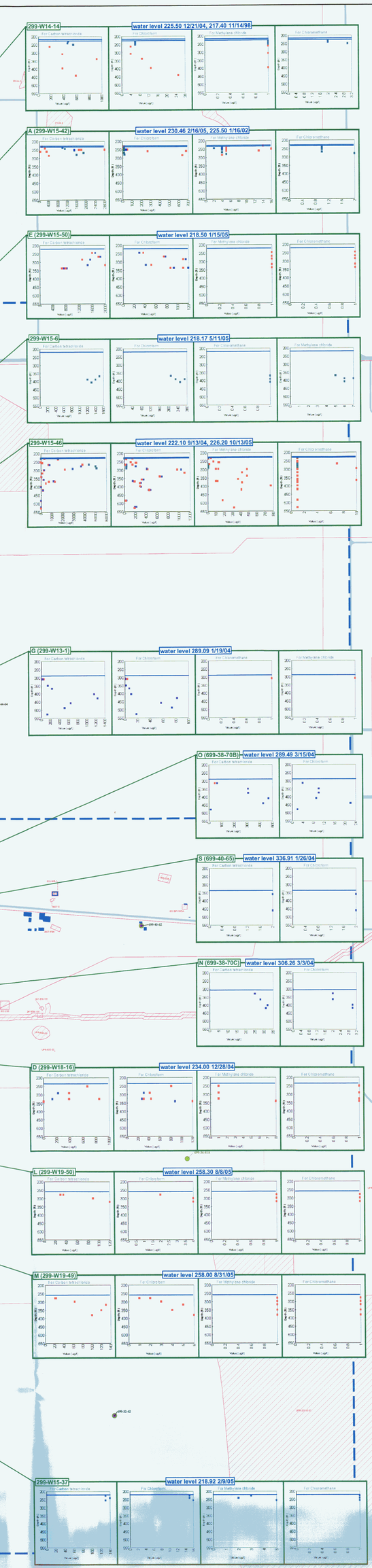
Dashed PURPLE-colored lines indicate areas where the estimated lateral extent is less certain due to insufficient data for the depth interval.

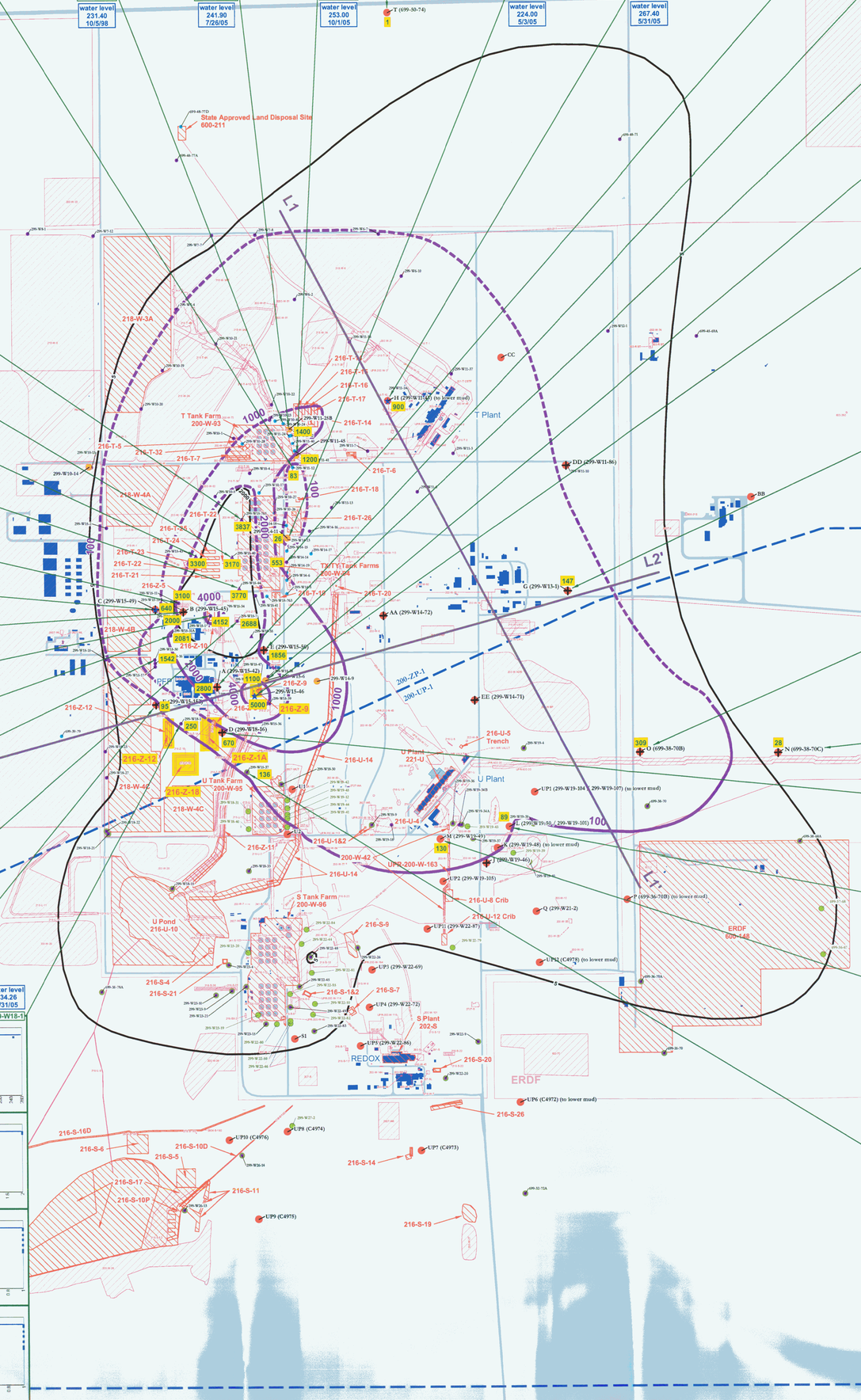
Marker Code:
Blue: Field Data
Red: Lab Data
Teal: VET Data

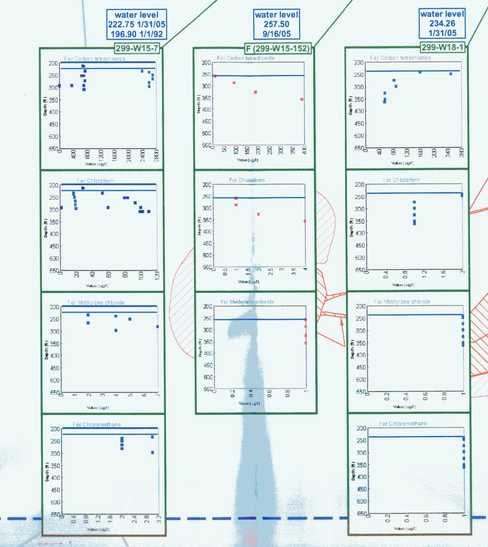












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Carbon Tetrachloride and Degradation Compounds in 200 West Area Groundwater - Middle Aquifer (60 ft to 120 ft Below Water Table)

- Existing Monitoring Well
- Existing Extraction Well
- New Monitoring Well
- New Monitoring Well At Exact Coordinates
- RCRA Monitoring Well
- Key Wells Used for Detailed Geochemical and Geotechnical Evaluation and Aquifer Testing
- Additional Wells Used to Support Risk Evaluation
- Additional Support Wells
- Primary Known Carbon Tetrachloride Waste Disposal Sites
- Associated Waste Site
- Other Waste Site
- Operable Unit Boundary
- FY05 Carbon Tetrachloride Concentrations

BLACK isopleths are based on average annual groundwater concentrations (primarily in 2005, but including 2004 or 2003 when 2005 data are unavailable for a specific well). The black isopleths include both groundwater monitoring and depth-discrete data for the shallow portion of the unconfined aquifer.

PURPLE isopleths are based on maximum groundwater concentrations for depth-discrete samples collected from 2003 through 2005 (routine groundwater monitoring data are excluded). The depth-discrete data are divided into the following three depth intervals:

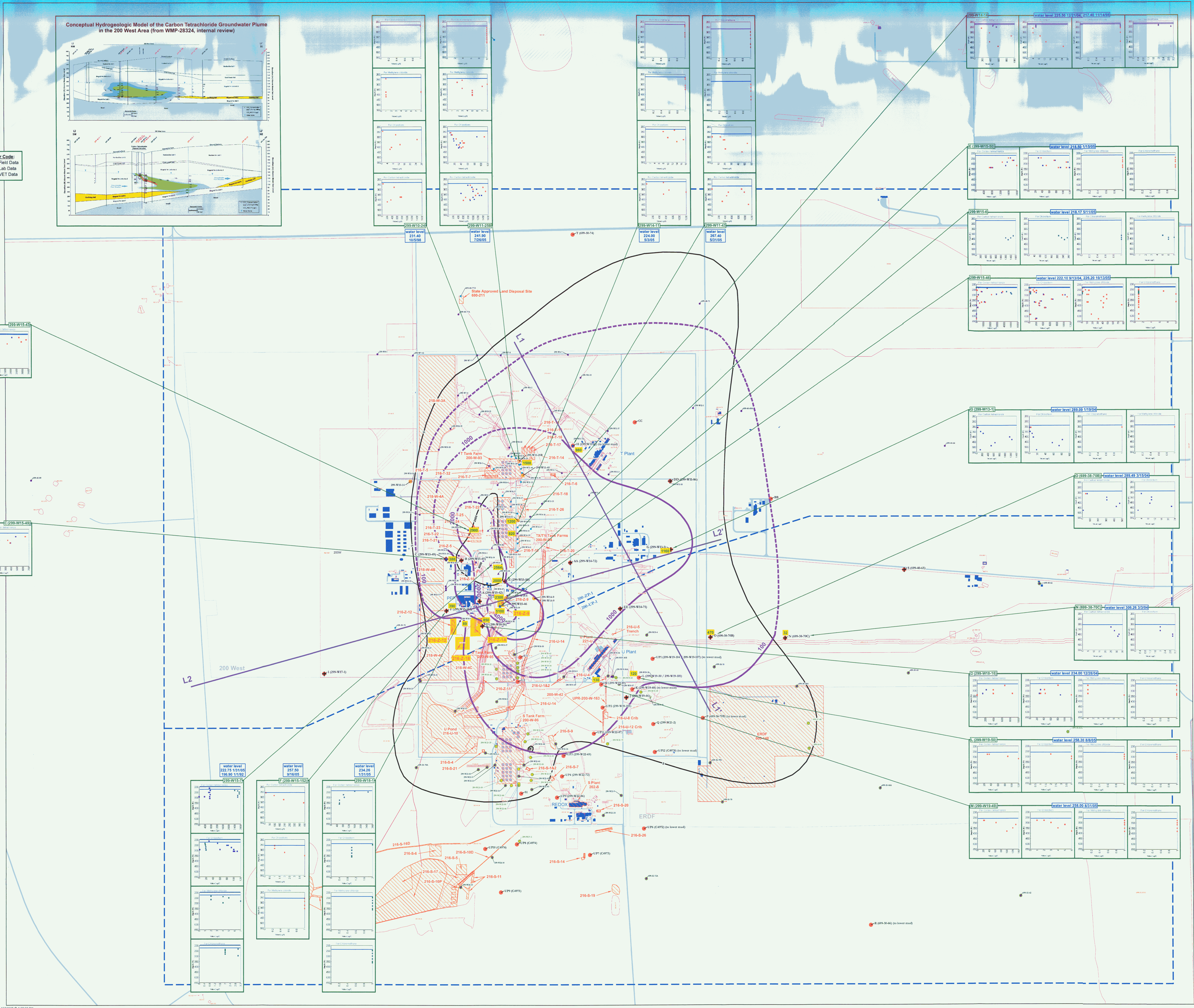
Shallow Aquifer from the water table to 60 ft below the water table,
Middle Aquifer from 60 ft to 120 ft below the water table, and
Deep Aquifer from 120 ft below the water table to the aquifer base.

The **PURPLE** isopleths were determined by a computer-contouring program, and then modified according to professional judgment.

Solid PURPLE-colored lines indicate the estimated lateral extent for the given concentration.

Dashed PURPLE-colored lines indicate areas where the estimated lateral extent is less certain due to insufficient data for the depth interval.

Marker Code:
Blue: Field Data
Red: Lab Data
Teal: VET Data



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Carbon Tetrachloride and Degradation Compounds in 200 West Area Groundwater - Deep Aquifer (120 ft to Base of Aquifer)

- Existing Monitoring Well
- Existing Extraction Well
- New Monitoring Well
- New Monitoring Well At Exact Coordinates
- RCRA Monitoring Well
- Key Wells Used for Detailed Geochemical and Geotechnical Evaluation and Aquifer Testing
- Additional Wells Used to Support Risk Evaluation
- Additional Support Wells

- Primary Known Carbon Tetrachloride Waste Disposal Site
- Associated Waste Site
- Other Waste Site
- Operable Unit Boundary FY05
- Carbon Tetrachloride Concentrations

BLACK isopleths are based on average annual groundwater concentrations (primarily in 2005, but including 2004 or 2003 when 2005 data are unavailable for a specific well). The black isopleths include both groundwater monitoring and depth-discrete data for the shallow portion of the unconfined aquifer.

PURPLE isopleths are based on maximum groundwater concentrations for depth-discrete samples collected from 2003 through 2005 (routine groundwater monitoring data are excluded). The depth-discrete data are divided into the following three depth intervals:

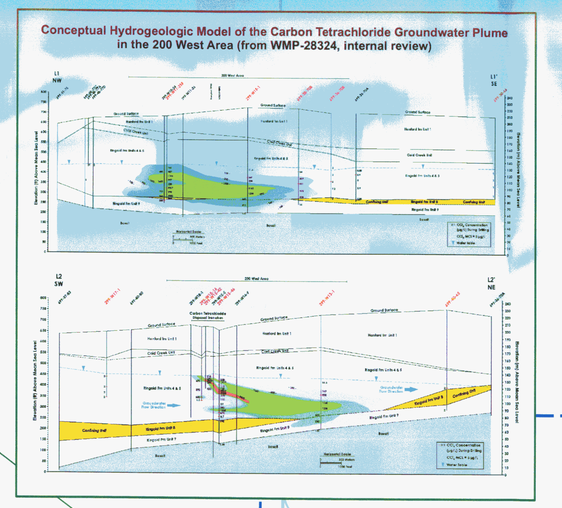
Shallow Aquifer from the water table to 60 ft below the water table,
Middle Aquifer from 60 ft to 120 ft below the water table, and
Deep Aquifer from 120 ft below the water table to the aquifer base.

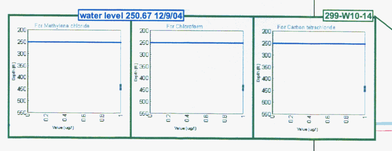
The **PURPLE** isopleths were determined by a computer-contouring program, and then modified according to professional judgment.

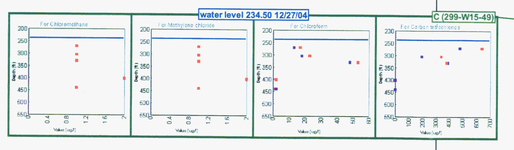
Solid PURPLE-colored lines indicate the estimated lateral extent for the given concentration.

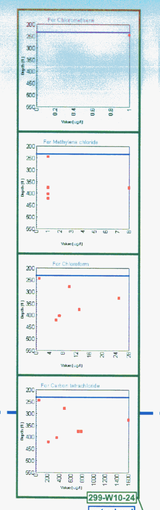
Dashed PURPLE-colored lines indicate areas where the estimated lateral extent is less certain due to insufficient data for the depth interval.

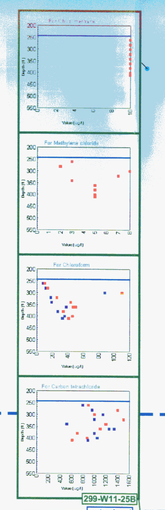
Marker Code:
Blue: Field Data
Red: Lab Data
Teal: VET Data

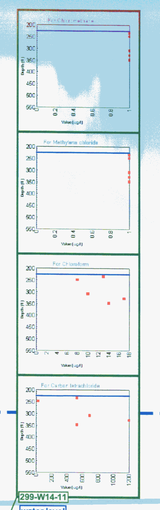


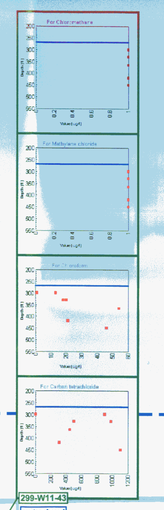


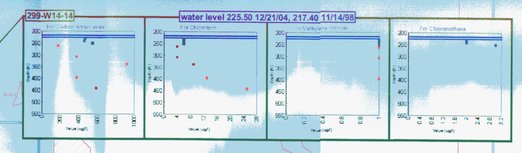


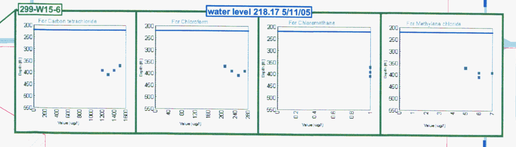


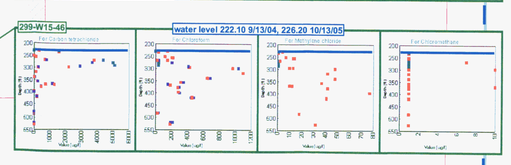


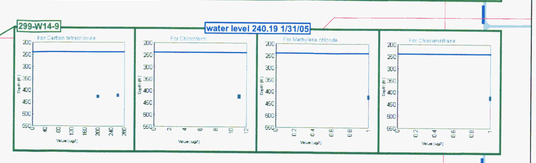


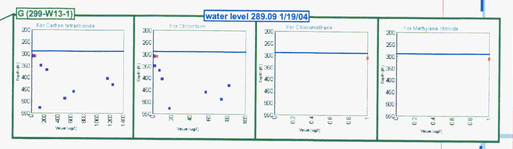


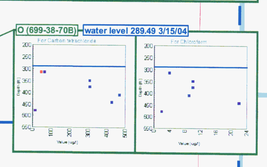


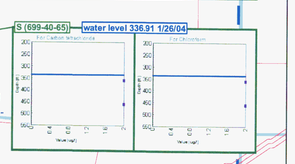


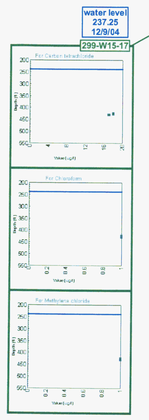


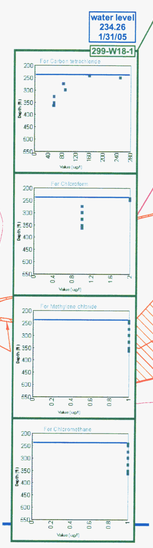


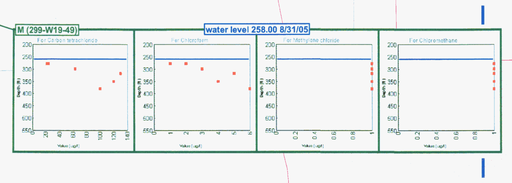


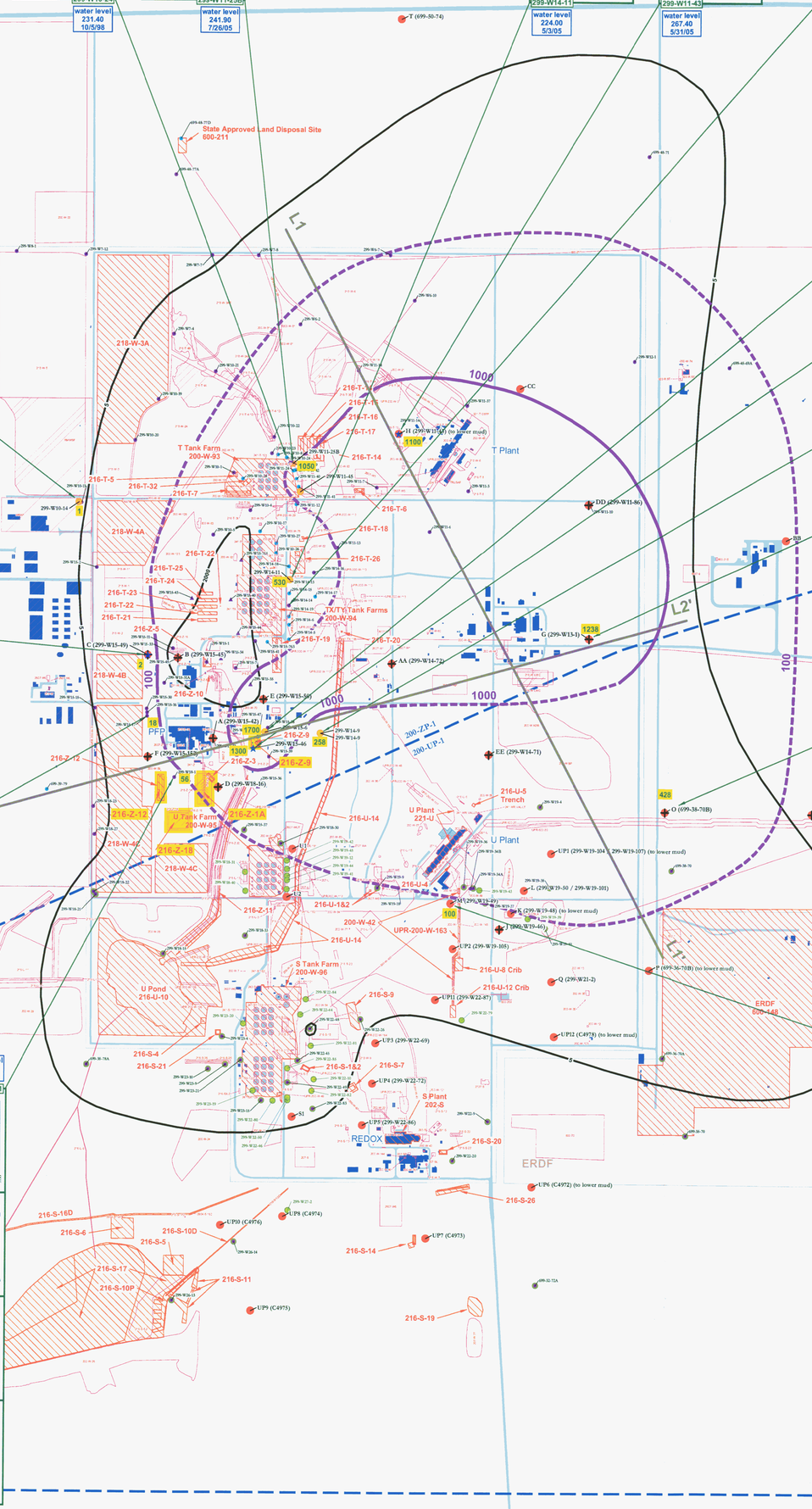












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US DEPARTMENT OF ENERGY
RICHLAND OPERATIONS OFFICE

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APPENDIX D

200 AREA MAPS OF LIQUID RELEASE INVENTORY DATA

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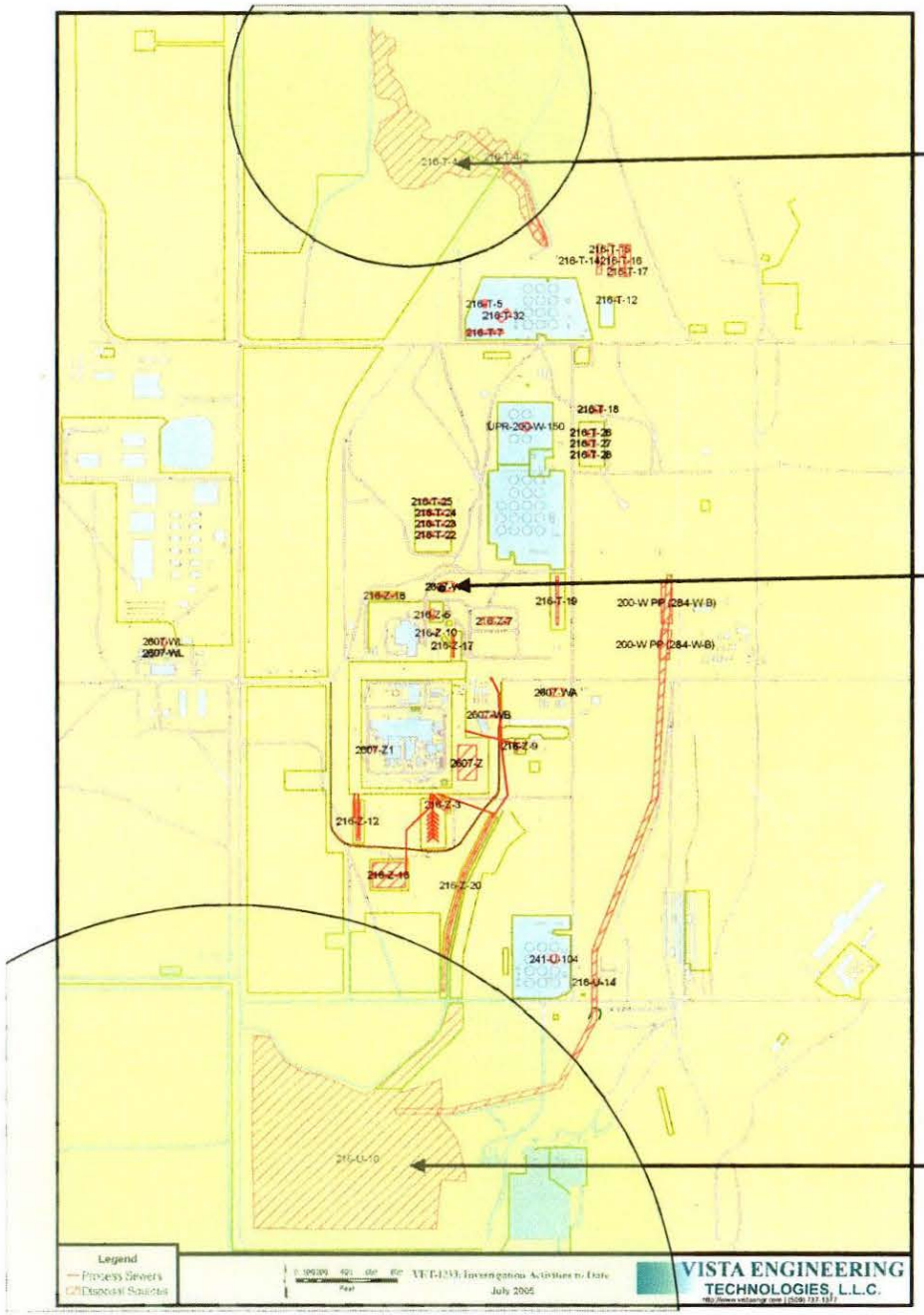
1944 Liquid Release Data

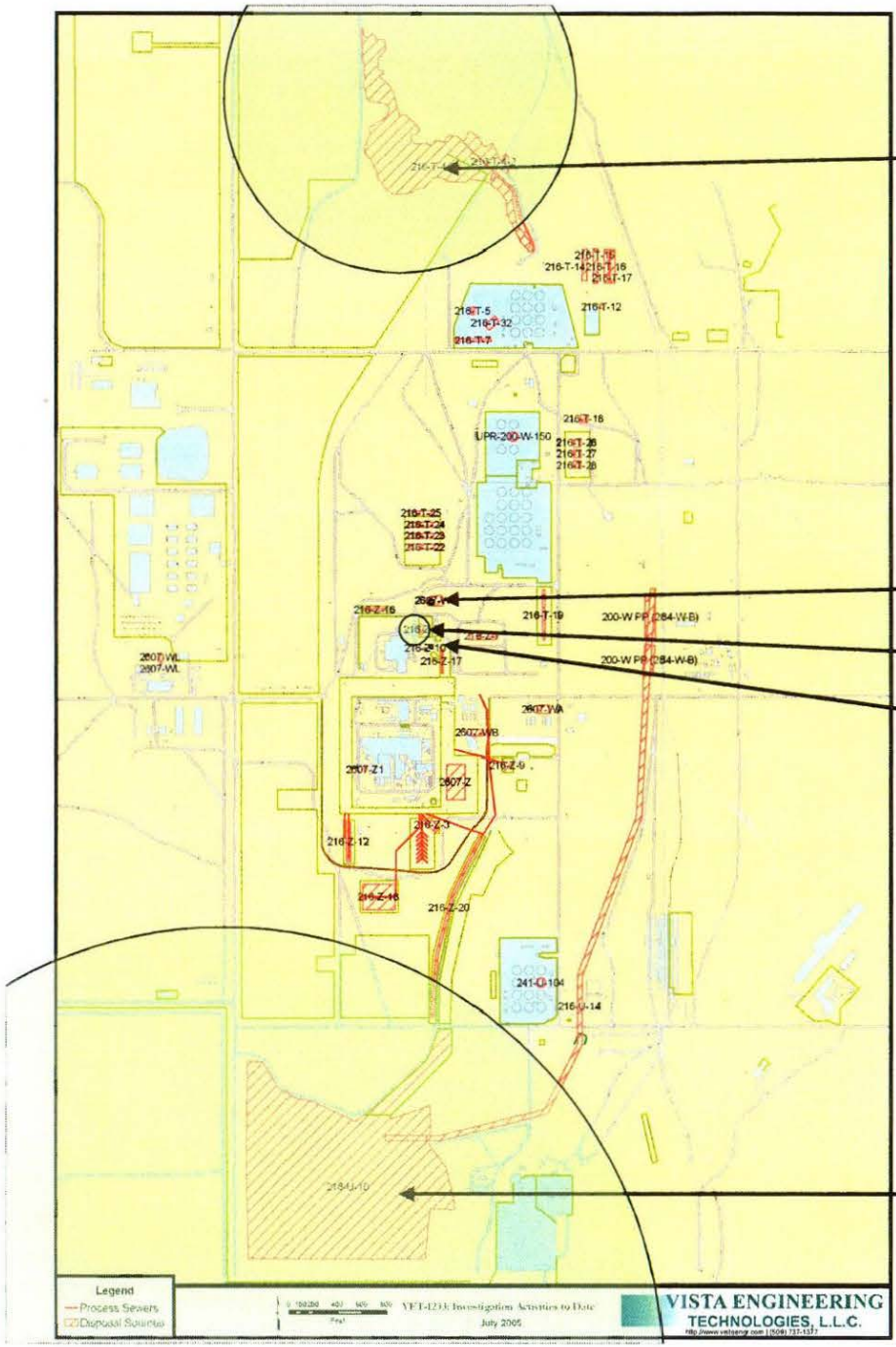


216-T-4, 1944-1978; 1,215,046,857 L/yr

2607-W8, 1944-1998; 1,825,000 L/yr

216-U-10, 1944-1996; 3,072,509,434 L/yr

1945 Liquid Release Data



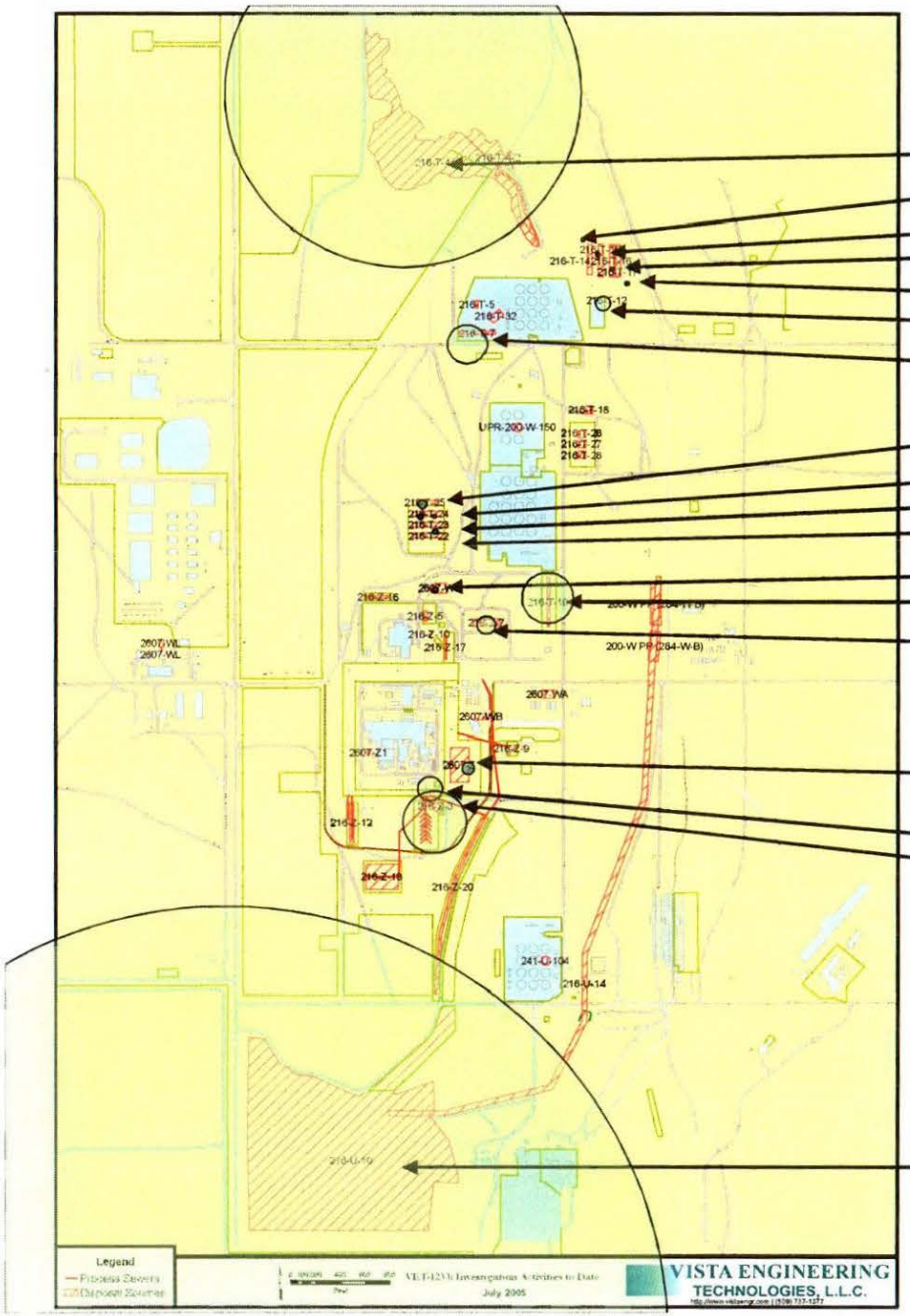
216-T-4, 1944-1978; 1,215,046,857 L/yr

2607-W8, 1944-1998; 1,825,000 L/yr

216-Z-5, 1945-1947; 10,350,000 L/yr

216-Z-10, 1945; 1,000,000 L/yr

216-U-10, 1944-1996; 3,072,509,434 L/yr



1954 Liquid Release Data

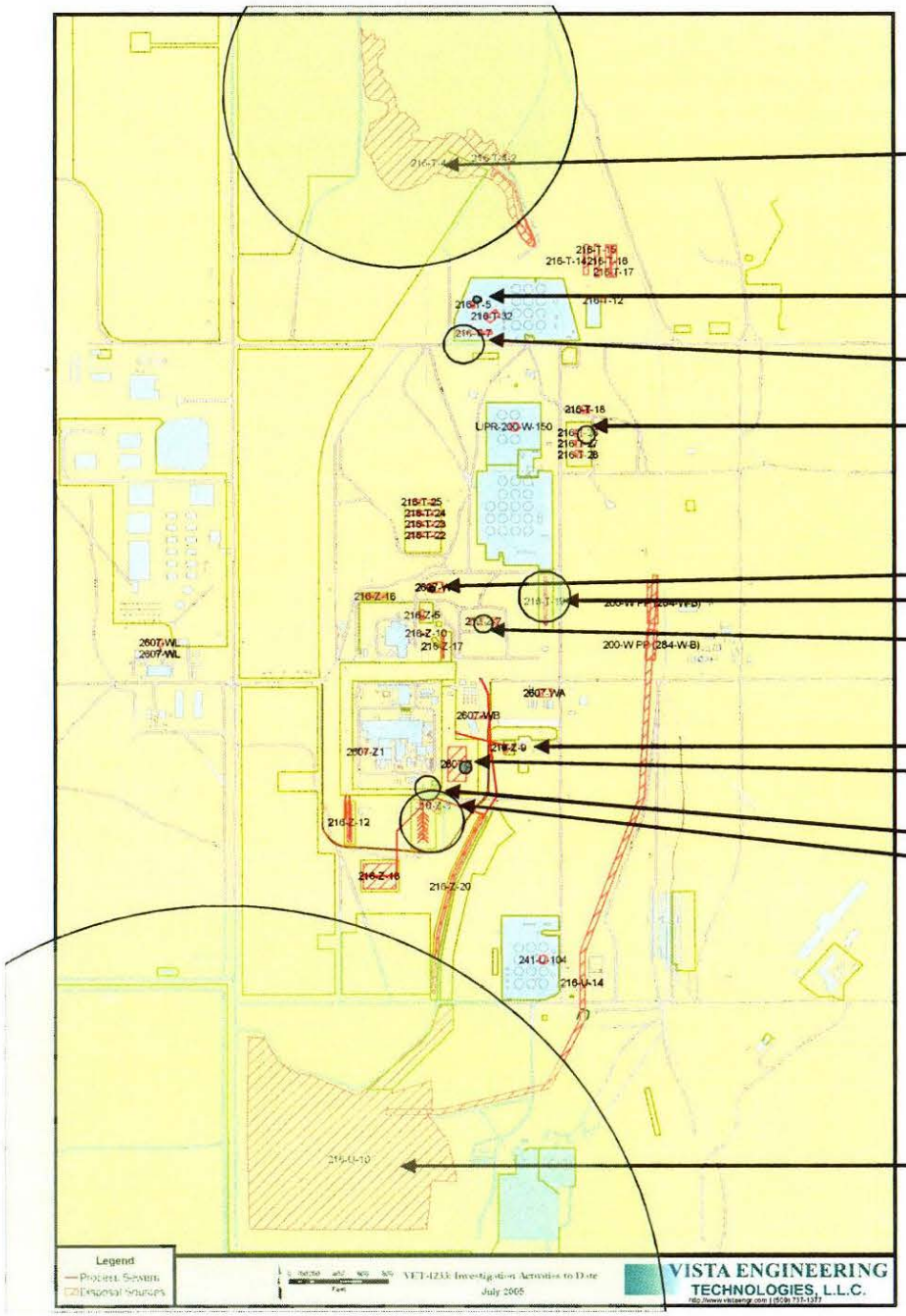
216-T-4, 1944-1978; 1,215,046,857 L/yr
216-T-14, 1954; 1,000,000 L/yr
216-T-15, 1954; 1,000,000 L/yr
216-T-16, 1954; 1,000,000 L/yr
216-T-17, 1954; 785,000 L/yr
216-T-12, 1954; 5,000,000 L/yr
216-T-7, 1948-1955; 13,756,625 L/yr

216-T-25, 1954; 3,000,000 L/yr
216-T-24, 1954; 1,530,000 L/yr
216-T-23, 1954; 1,480,000 L/yr
216-T-22, 1954; 1,530,000 L/yr
2607-W8, 1944-1998; 1,825,000 L/yr
216-T-19, 1951-1976; 17,510,231 L/yr
216-Z-7, 1947-1966; 6,144,695 L/yr

2607-Z, 1949-1998; 8,288,000 L/yr

216-Z-1:2, 1949-1969; 4,212,625 L/yr
216-Z-3, 1952-1959; 22,316,250 L/yr

216-U-10, 1944-1996; 3,072,509,434 L/yr



1955 Liquid Release Data

216-T-4, 1944-1978; 1,215,046,857 L/yr

216-T-5, 1955; 2,600,000 L/yr

216-T-7, 1948-1955; 13,756,625 L/yr

216-T-26, 1955-1956; 6,002,000 L/yr

2607-W8, 1944-1998; 1,825,000 L/yr

216-T-19, 1951-1976; 17,510,231 L/yr

216-Z-7, 1947-1966; 6,144,695 L/yr

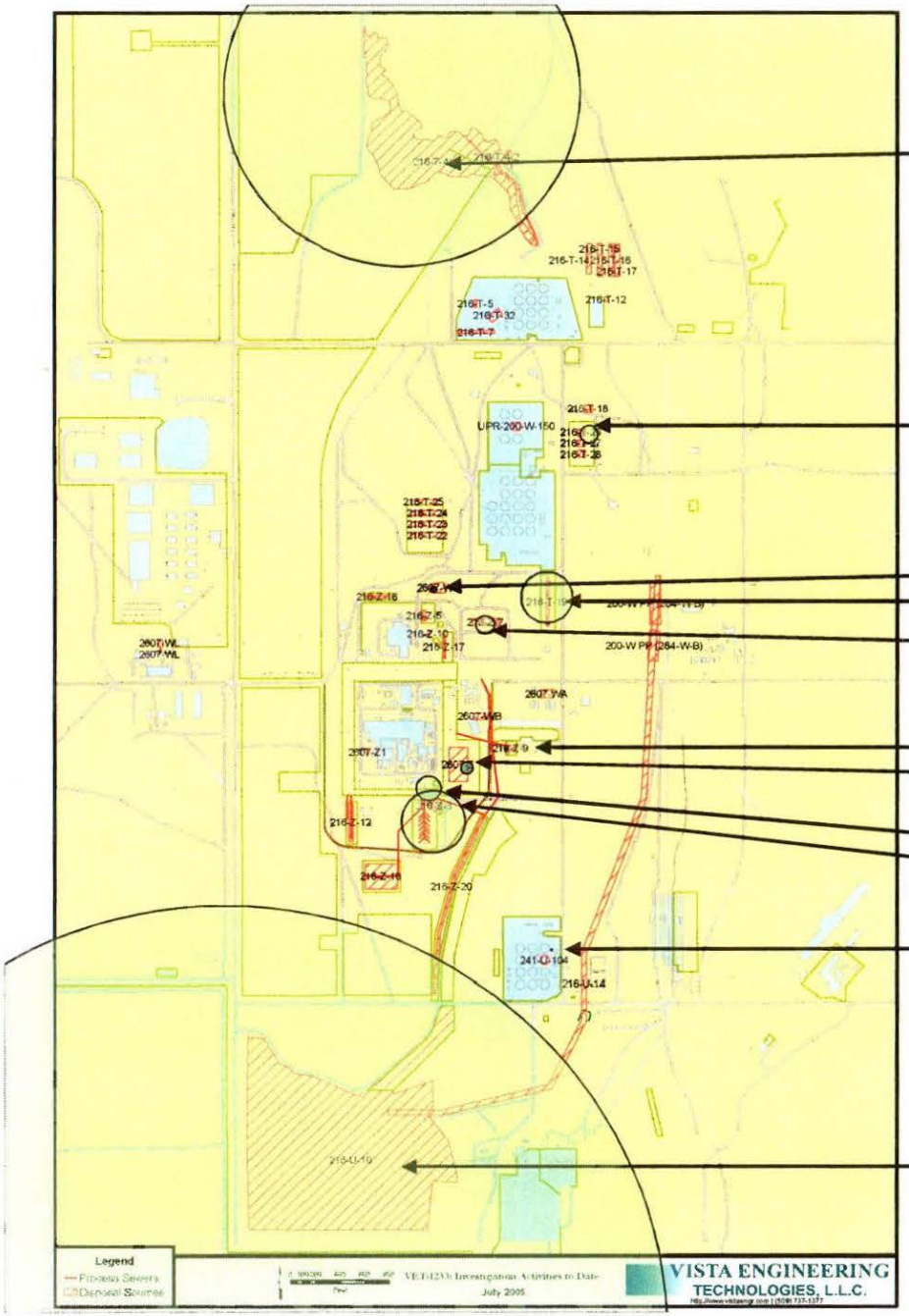
216-Z-9, 1955-1962; 511,275 L/yr

2607-Z, 1949-1998; 8,288,000 L/yr

216-Z-1:2, 1949-1969; 4,212,625 L/yr

216-Z-3, 1952-1959; 22,316,250 L/yr

216-U-10, 1944-1996; 3,072,509,434 L/yr



1956 Liquid Release Data

216-T-4, 1944-1978; 1,215,046,857 L/yr

216-T-26, 1955-1956; 6,002,000 L/yr

2607-W8, 1944-1998; 1,825,000 L/yr

216-T-19, 1951-1976; 17,510,231 L/yr

216-Z-7, 1947-1966; 6,144,695 L/yr

216-Z-9, 1955-1962; 511,275 L/yr

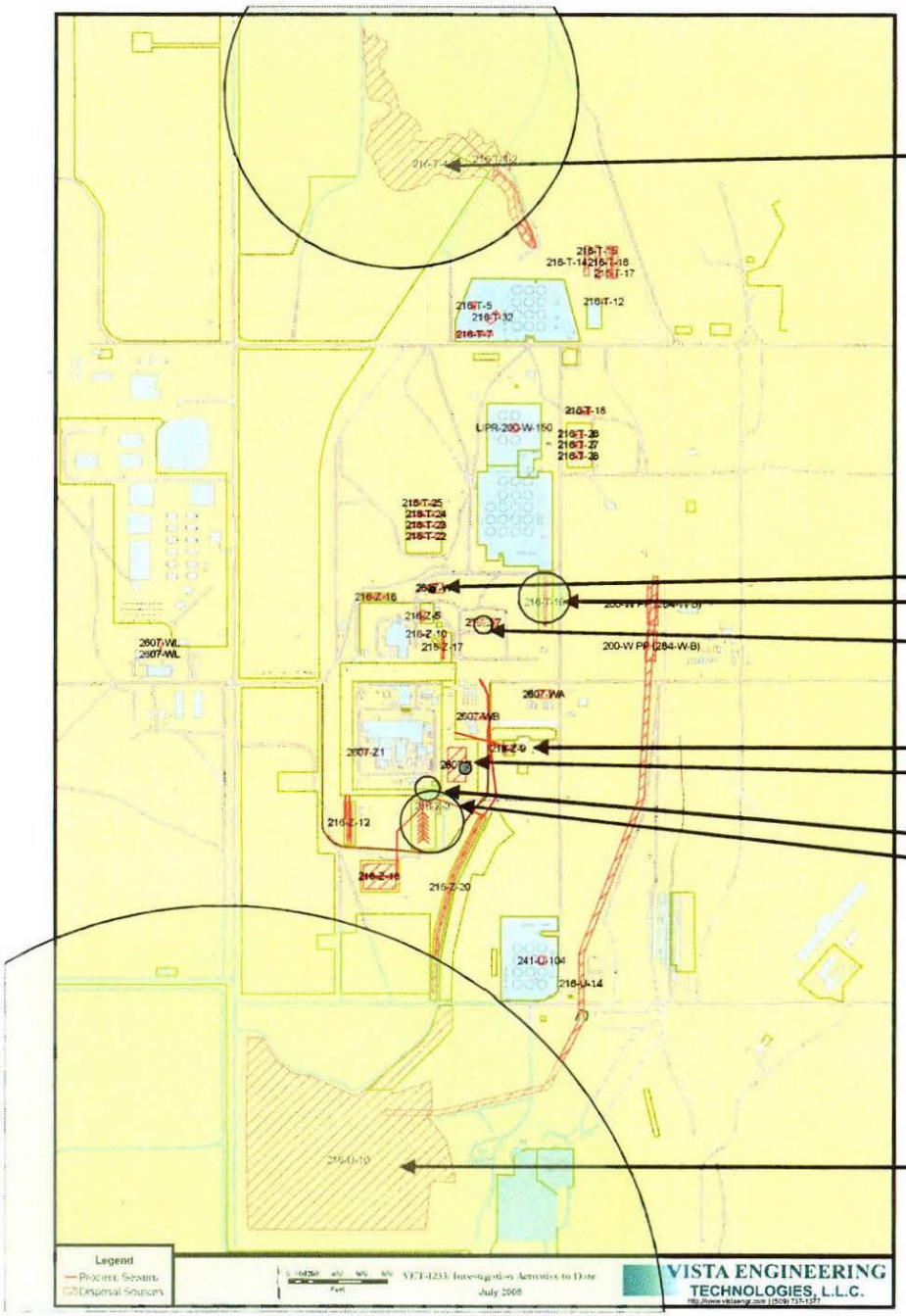
2607-Z, 1949-1998; 8,288,000 L/yr

216-Z-1:2, 1949-1969; 4,212,625 L/yr

216-Z-3, 1952-1959; 22,316,250 L/yr

216-U-104, 1956; 500,400 L/yr

216-U-10, 1944-1996; 3,072,509,434 L/yr



1957 Liquid Release Data

Nothing New

216-T-4, 1944-1978; 1,215,046,857 L/yr

2607-W8, 1944-1998; 1,825,000 L/yr

216-T-19, 1951-1976; 17,510,231 L/yr

216-Z-7, 1947-1966; 6,144,695 L/yr

216-Z-9, 1955-1962; 511,275 L/yr

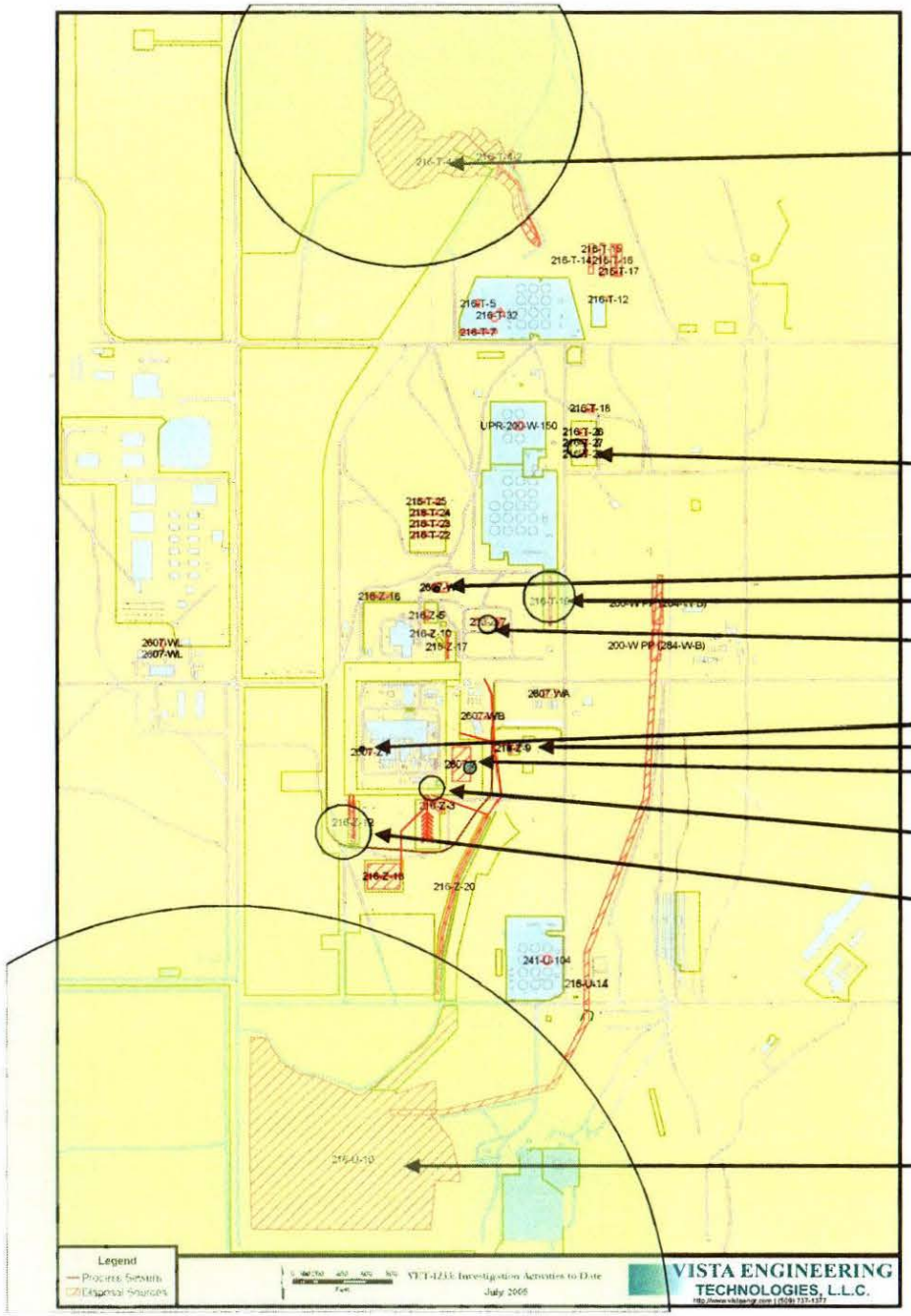
2607-Z, 1949-1998; 8,288,000 L/yr

216-Z-1:2, 1949-1969; 4,212,625 L/yr

216-Z-3, 1952-1959; 22,316,250 L/yr

216-U-10, 1944-1996; 3,072,509,434 L/yr

1960-61 Liquid Release Data



216-T-4, 1944-1978; 1,215,046,857 L/yr

216-T-28, 1960-1966; 6,048,200 L/yr

2607-W8, 1944-1998; 1,825,000 L/yr

216-T-19, 1951-1976; 17,510,231 L/yr

216-Z-7, 1947-1966; 6,144,695 L/yr

2607-Z1, 1958-1998; 949,000 L/yr

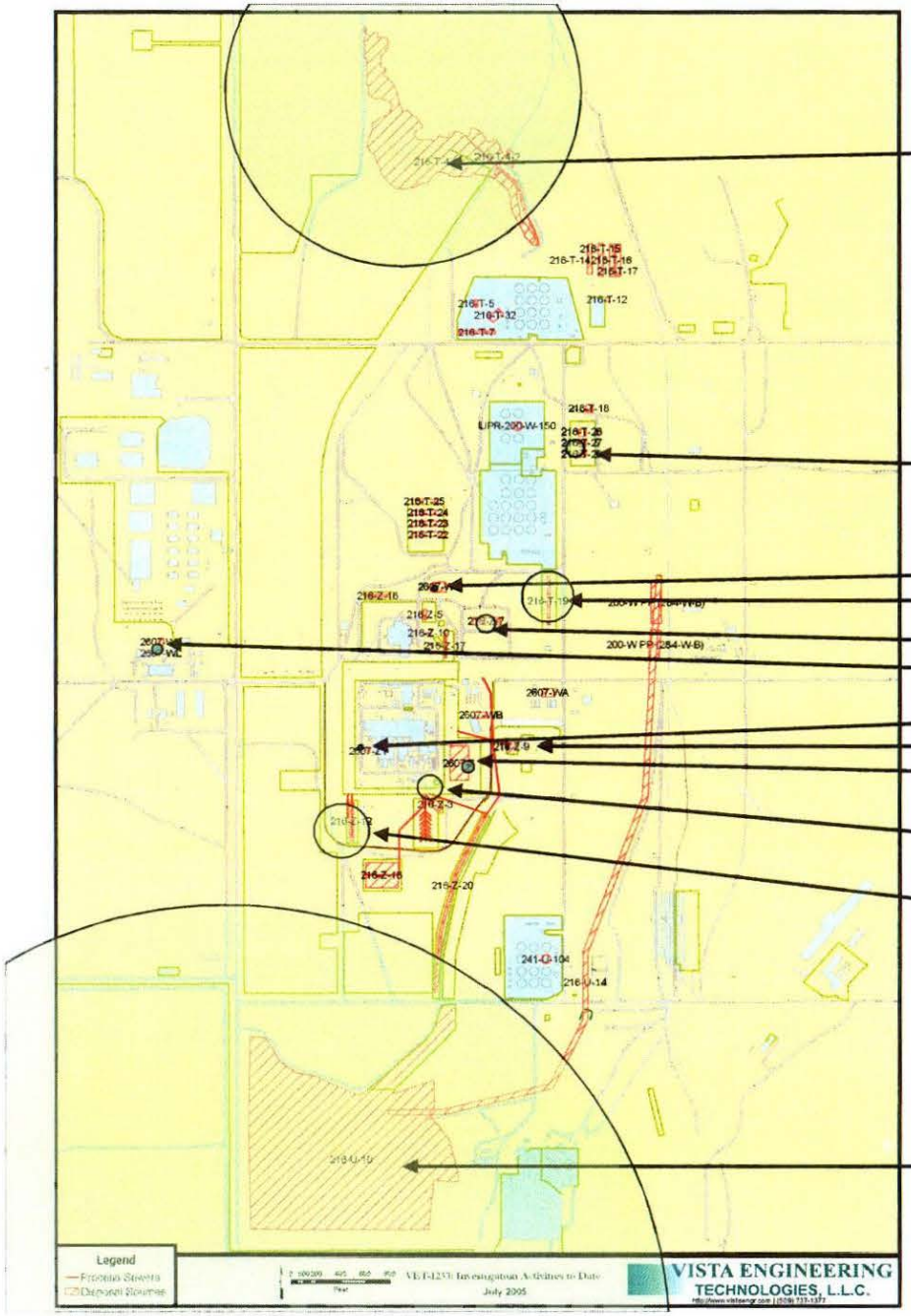
216-Z-9, 1955-1962; 511,275 L/yr

2607-Z, 1949-1998; 8,288,000 L/yr

216-Z-1:2, 1949-1969; 4,212,625 L/yr

216-Z-12, 1959-1973; 18,756,267 L/yr

216-U-10, 1944-1996; 3,072,509,434 L/yr



1962 Liquid Release Data

216-T-4, 1944-1978; 1,215,046,857 L/yr

216-T-28, 1960-1966; 6,048,200 L/yr

2607-W8, 1944-1998; 1,825,000 L/yr

216-T-19, 1951-1976; 17,510,231 L/yr

216-Z-7, 1947-1966; 6,144,695 L/yr

2607-WL, 1962-1998; 3,813,000 L/yr

2607-Z1, 1958-1998; 949,000 L/yr

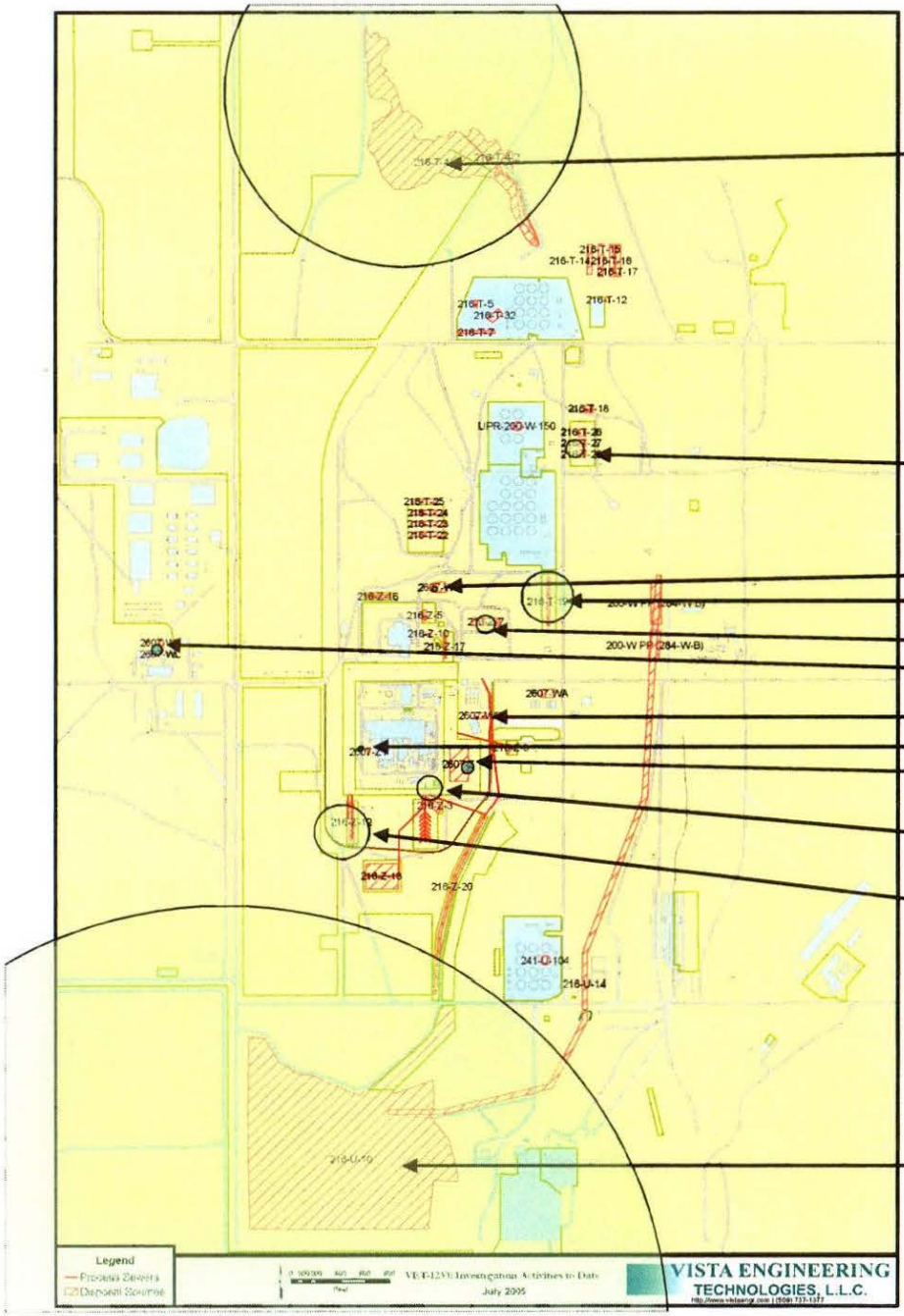
216-Z-9, 1955-1962; 511,275 L/yr

2607-Z, 1949-1998; 8,288,000 L/yr

216-Z-1:2, 1949-1969; 4,212,625 L/yr

216-Z-12, 1959-1973; 18,756,267 L/yr

216-U-10, 1944-1996; 3,072,509,434 L/yr



1963 Liquid Release Data

216-T-4, 1944-1978; 1,215,046,857 L/yr

216-T-28, 1960-1966; 6,048,200 L/yr

2607-W8, 1944-1998; 1,825,000 L/yr

216-T-19, 1951-1976; 17,510,231 L/yr

216-Z-7, 1947-1966; 6,144,695 L/yr

2607-WL, 1962-1998; 3,813,000 L/yr

2607-WB, 1963-1998; 870,100 L/yr

2607-Z1, 1958-1998; 949,000 L/yr

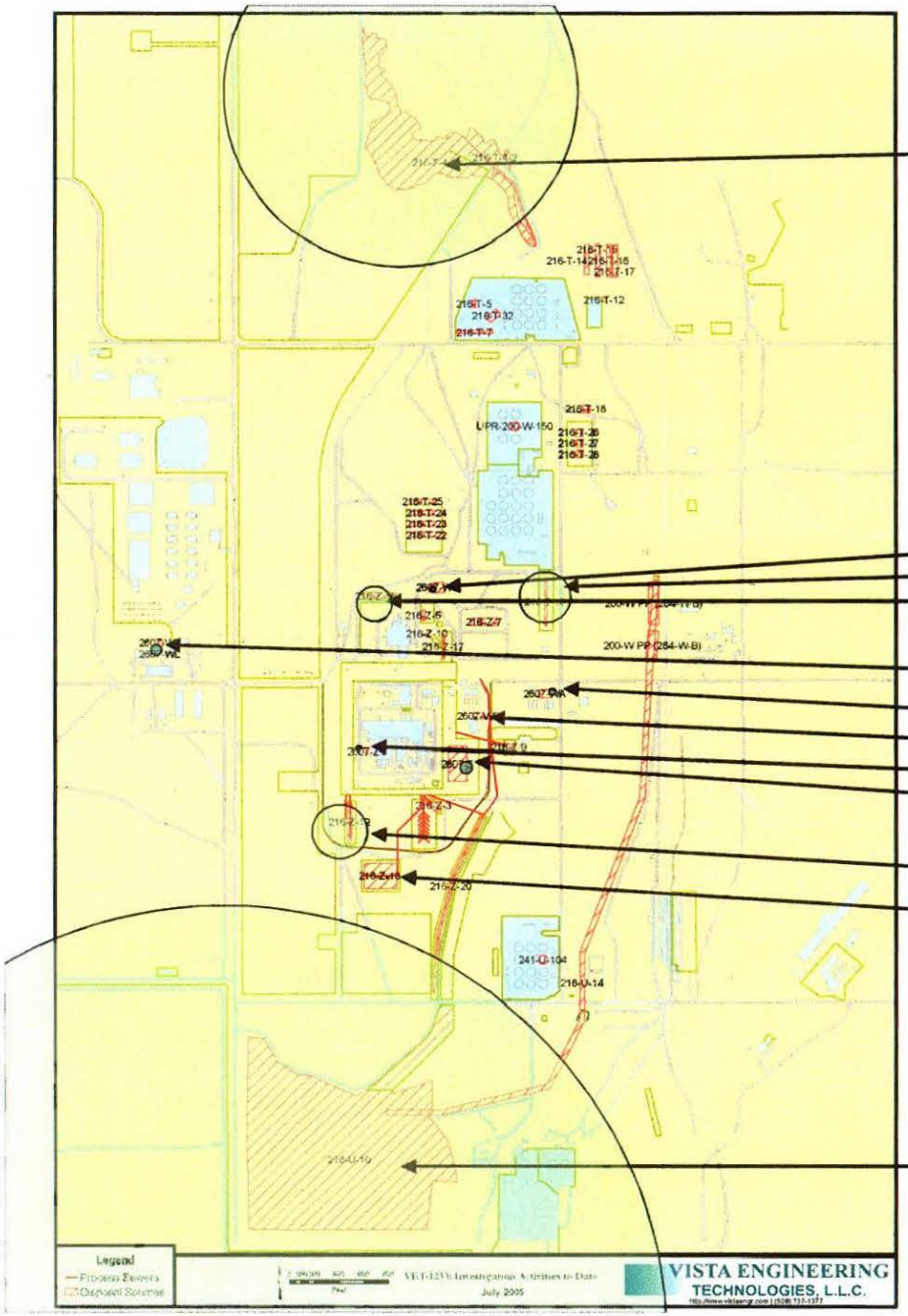
2607-Z, 1949-1998; 8,288,000 L/yr

216-Z-1:2, 1949-1969; 4,212,625 L/yr

216-Z-12, 1959-1973; 18,756,267 L/yr

216-U-10, 1944-1996; 3,072,509,434 L/yr

1970-71 Liquid Release Data



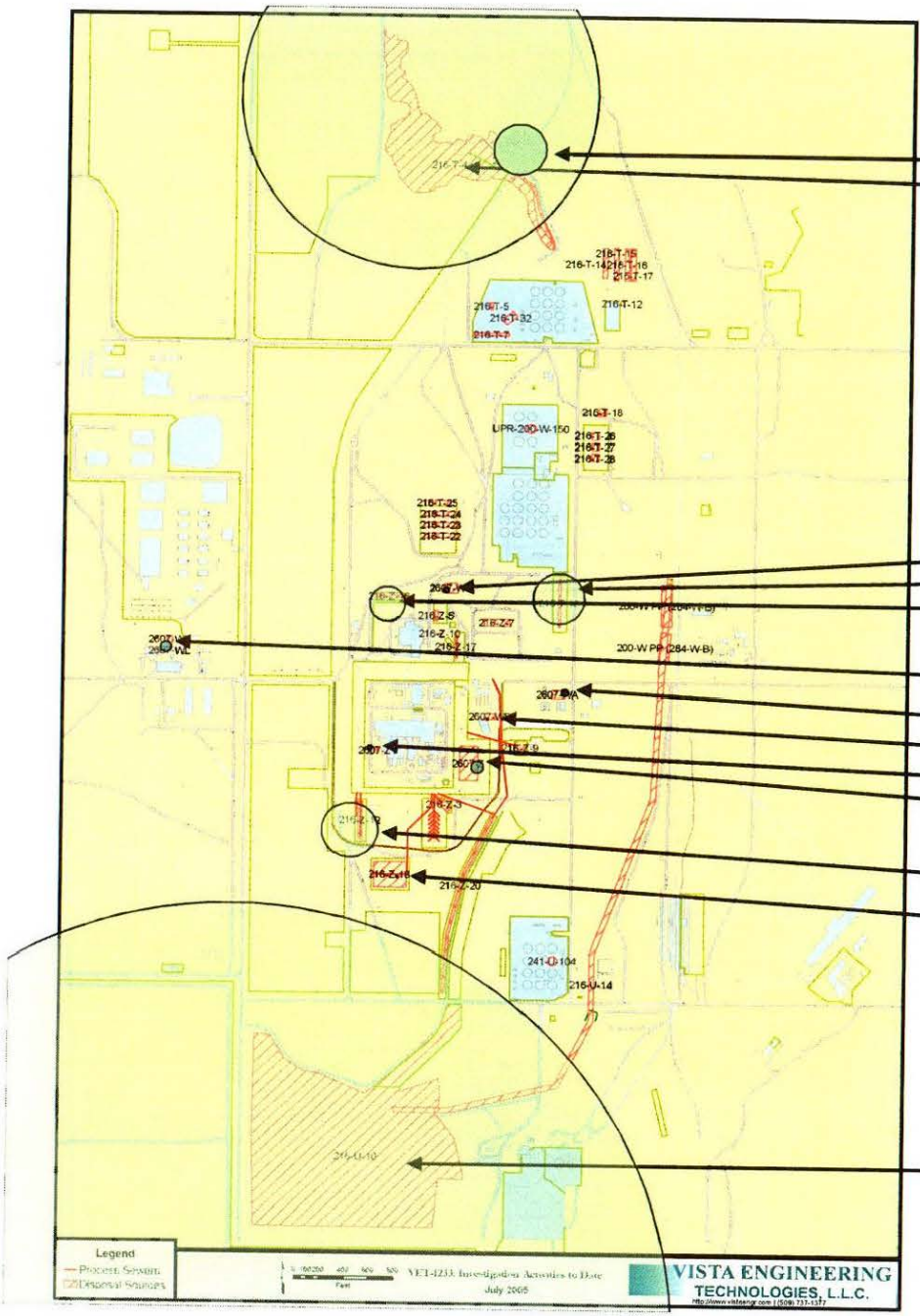
216-T-4, 1944-1978; 1,215,046,857 L/yr

2607-W8, 1944-1998; 1,825,000 L/yr
216-T-19, 1951-1976; 17,510,231 L/yr
216-Z-16, 1968-1977; 10,196,610 L/yr

2607-WL, 1962-1998; 3,813,000 L/yr
2607-WA, 1968-2000; 2,130,000 L/yr
2607-WB, 1963-1998; 870,100 L/yr
2607-Z1, 1958-1998; 949,000 L/yr
2607-Z, 1949-1998; 8,288,000 L/yr

216-Z-12, 1959-1973; 18,756,267 L/yr
216-Z-18, 1969-1973; 771,600 L/yr

216-U-10, 1944-1996; 3,072,509,434 L/yr



1972 Liquid Release Data

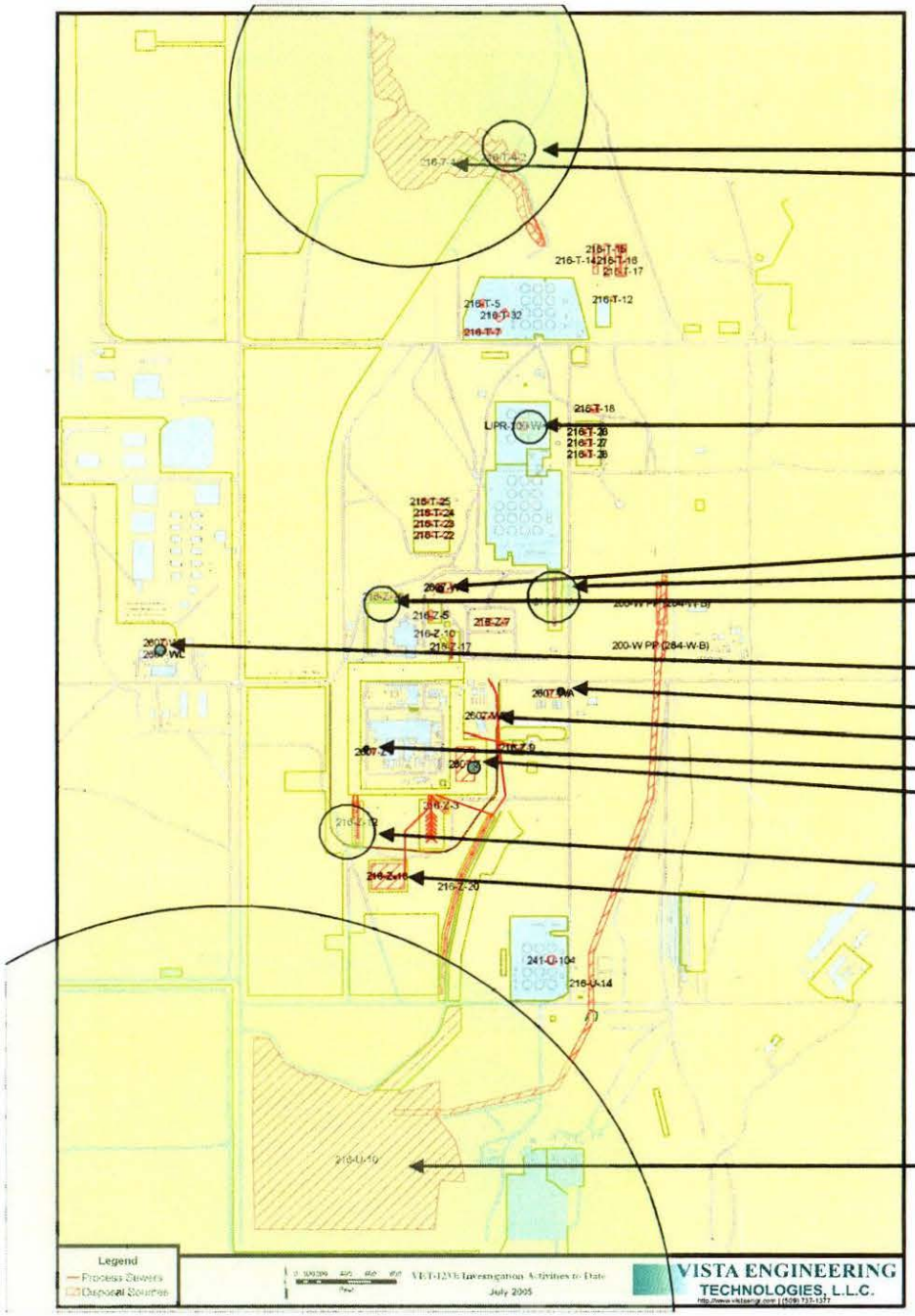
216-T-4-2, 1972-1996; 17,953,040 L/yr
216-T-4, 1944-1978; 1,215,046,857 L/yr

2607-W8, 1944-1998; 1,825,000 L/yr
216-T-19, 1951-1976; 17,510,231 L/yr
216-Z-16, 1968-1977; 10,196,610 L/yr

2607-WL, 1962-1998; 3,813,000 L/yr
2607-WA, 1968-2000; 2,130,000 L/yr
2607-WB, 1963-1998; 870,100 L/yr
2607-Z1, 1958-1998; 949,000 L/yr
2607-Z, 1949-1998; 8,288,000 L/yr

216-Z-12, 1959-1973; 18,756,267 L/yr
216-Z-18, 1969-1973; 771,600 L/yr

216-U-10, 1944-1996; 3,072,509,434 L/yr



1973 Liquid Release Data

216-T-4-2, 1972-1996; 17,953,040 L/yr
216-T-4, 1944-1978; 1,215,046,857 L/yr

UPR-200-W-150, 1973; 11,400,000 L/yr

2607-W8, 1944-1998; 1,825,000 L/yr
216-T-19, 1951-1976; 17,510,231 L/yr
216-Z-16, 1968-1977; 10,196,610 L/yr

2607-WL, 1962-1998; 3,813,000 L/yr
2607-WA, 1968-2000; 2,130,000 L/yr
2607-WB, 1963-1998; 870,100 L/yr
2607-Z1, 1958-1998; 949,000 L/yr
2607-Z, 1949-1998; 8,288,000 L/yr

216-Z-12, 1959-1973; 18,756,267 L/yr
216-Z-18, 1969-1973; 771,600 L/yr

216-U-10, 1944-1996; 3,072,509,434 L/yr

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