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TITLE: RI Report for 200-LW-1 and 200-LW-2 OU

DOE/RL-2005-61
Draft A

Remedial Investigation Report for the 200-LW-1 (300 Area Chemical Laboratory Waste Group) and 200-LW-2 (200 Area Chemical Laboratory Waste Group) Operable Units

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

United States
Department of Energy
P.O. Box 550
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Draft A

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Date Published
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EXECUTIVE SUMMARY

The purpose of this remedial investigation (RI) report is to evaluate the data generated during the RI and other characterization activities at the 200-LW-1 and 200-LW-2 Chemical Laboratory Waste Group Operable Units (OU). This evaluation will (1) determine if sufficient data have been collected to support risk assessment and remedial decision making, (2) estimate risk at the representative sites based on existing data and data collected during the RI, (3) assess the accuracy of the conceptual exposure models and refinement of the contaminant distribution models, (4) determine the need to proceed with a feasibility study (FS), and (5) determine which constituents and site-specific considerations need to be addressed in the FS. This RI report also provides data to support the evaluation of remedial action alternatives in the FS with regard to meeting potential applicable-or-relevant-and-appropriate requirements (ARAR), risk reduction, and identifying potentially significant data gaps, if any. The FS ultimately will support a proposed plan, leading to a record of decision (ROD) for all of the waste sites within the 200-LW-1 and 200-LW-2 OUs.

The 200-LW-1 OU consists of six waste sites, and the 200-LW-2 OU consists of 14 waste sites, all which have been identified as *Resource Conservation and Recovery Act of 1976* past-practice sites. This RI report focuses on the characterization of one representative waste site, the 216-T-28 Crib, in the 200-LW-1 OU, and two representative waste sites in the 200-LW-2 OU, the 216-S-20 Crib and the 216-Z-7 Crib. One additional site, the 216-B-58 Trench, was identified as a representative site within the 200-LW-1 OU. However, in May 2004, this site was moved from the 200-LW-1 OU and consolidated into the 200-TW-1 OU. Additional information regarding the waste sites is provided in Chapter 1.0.

The RI field investigation was conducted from August 2004 to March 2005 at the three representative sites in accordance with the Work Plan (DOE/RL-2001-66, *Chemical Laboratory Waste Group Operable Units RI/FS Work Plan; Includes: 200-LW-1 and 200-LW-2 Operable Units*) (Work Plan). Data collected before and during the RI are discussed in this report. The field investigations at the three waste sites included drilling and sampling of one vadose zone borehole at each waste site and surface and subsurface soil sampling, followed by borehole geophysical surveys to help define the vertical extent of contamination within the area historically defined as the waste site boundary. Geophysical logging also was performed in existing boreholes near the 200-LW-1 and 200-LW-2 OU waste sites to help ascertain the lateral extent of contamination. Additional information regarding the RI field activities and results are provided in Chapter 3.0.

The primary objectives of the data quality objective process for the 200-LW-1 and 200-LW-2 OUs were to determine the environmental measurements necessary to refine the preliminary site conceptual model, support an evaluation of risk, and support an evaluation of remedial alternatives. The data quality objectives for the RI were met. All boreholes required by the Work Plan (DOE/RL-2001-66) were completed. All required samples were taken and analyzed for contaminants of potential concern at the 216-S-20 Crib and the 216-Z-7 Crib, and it has been determined that the data are of sufficient quantity and quality to support risk-assessment activities and to proceed to the FS to support evaluation of alternatives.

At the 216-T-28 Crib, incomplete soil recovery prevented samples from being collected and analyzed from the shallow zone (0 to 4.6 meters [0 to 15 feet]). However, it is anticipated that the major zones of contamination are below 4.6 meters (15 feet), because the bottom of the crib is located at 4.6 meters (15 feet). In addition, similarities in the 216-T-28 Crib, the 216-S-20 Crib, and the 216-Z-7 Crib construction and inventories suggest that the risk associated with the 216-T-28 Crib is similar to that of the 216-S-20 Crib and the 216-Z-7 Crib. Therefore, it has been determined that the data collected at the 216-T-28 Crib also are of sufficient quantity and quality to support risk-assessment activities and to proceed to the FS to support evaluation of alternatives.

The risk assessment data evaluation methodology used in this RI report considers applicable regulatory requirements, the data quality objective process conducted for the work plan, land-use uncertainties, risk assessment methodology, other OUs, and site-specific conditions. The data evaluation process consists of the following:

- Data screening for nondetected constituents and background constituents
- Human health risk assessment determinations for nonradiological contaminants
- Comparison to risk-based concentrations for nonradiological contaminants
- Qualitative evaluation of ecological risk based on site- and area-wide information

- Dose and risk evaluation for radiological contaminants
- Evaluation of impacts to groundwater.

Conceptual contaminant distribution models developed in the Work Plan (DOE/RL-2001-66) were refined based on the data in this report. The contaminant distribution models depict current contaminant distribution beneath the representative sites. These models will be used in the FS to apply the analogous site approach to the remaining waste sites (analogous sites). The analogous site approach streamlines the RI by applying the contaminant distribution models for sampled sites (representative sites) to the unsampled sites that are analogous to the representative sites. The 200 Areas Implementation Plan (DOE/RL-98-28, *200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program*) provides additional information on the analogous site approach.

A baseline risk assessment was performed using the RI data. The assessment was consistent with stated assumptions concerning land-use scenarios, cleanup goals, and potential receptors. A general summary of the risk assessment can be stated as follows.

- A fate and transport assessment for contaminants of potential concern was performed and is provided in Chapter 4.0. Soil concentrations of nonradiological contaminants were screened for groundwater protection based on the three-phase partition model in *Washington Administrative Code* (WAC) 173-340-747, "Deriving Soil Concentrations for Ground Water Protection." The RESidual RADioactivity (RESRAD) dose model (ANL 2002, *RESRAD for Windows*, Version 6.21) was used to evaluate radionuclide contaminants of potential concern for their impact on groundwater and associated risk. The model was used to predict potential doses from radionuclides potentially reaching groundwater; the doses then were converted to risk values.
- In addition to the primary fate and transport assessment described above, a qualitative assessment was performed on the nonradionuclide contaminants that exceeded criteria for groundwater protection based on WAC 173-340-747. The qualitative evaluation considered factors such as frequency of detections, depth of detections, whether a groundwater plume already exists for the contaminant, and quality assurance data associated with the contaminant. The purpose of the assessment was to determine if additional mathematical modeling was appropriate for these contaminants.

- A human health screening for direct soil contact was performed in accordance with risk assessment guidance from the U. S. Environmental Protection Agency (EPA/540/1-89/002, *Risk Assessment Guidance for Superfund (RAGS), Vol. I, Human Health Evaluation Manual (Part A), Interim Final*, OSWER Directive 9285.7-01A) and is provided in Chapter 5.0. This was performed for nonradionuclides using Hanford Site background levels and the defined risk-based concentrations in WAC 173-340-745, "Soil Cleanup Standards for Industrial Properties." For radionuclide contaminants of potential concern, it was performed using the RESRAD dose model. The RESRAD model was used to predict potential direct-contact doses from radionuclides; the doses then were converted to risk values.
- An ecological risk assessment was performed in accordance with ecological risk assessment guidelines from the U.S. Environmental Protection Agency (EPA/540/R-97/006, *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final*, and is included in Chapter 5.0 of this RI report. For nonradionuclides, preestablished screening levels for soil were obtained from WAC 173-340-900, "Tables," Table 749-3, "Ecological Indicator Soil Concentrations for Protection of Plants and Animals." For radionuclide contaminants, the ecological soil-screening levels developed by the U.S. Environmental Protection Agency for screening soils at contaminated sites were used for comparison to detected concentrations.

The results of the RI characterization confirmed the expected contaminants of potential concern and correlate well with contaminant distribution models in the Work Plan (DOE/RL-2001-66). Contaminants of concern and risk and dose rates were identified for each waste site and will be carried forward into the FS for evaluation of remedial alternatives. Further modeling is not deemed necessary for the RI process at these OUs.

Chapter 6.0 presents the conclusions, summarizes the results, and discusses the path forward for the 200-LW-1 and 200-LW-2 OUs. Table ES-1 summarizes the comparison of the risk and dose assessment to the industrial land-use criteria. Based on the results of the RI, remedial alternatives/closure strategies will be developed and evaluated against performance standards and evaluation criteria in the FS. The decision-making process for the 200-LW-1 and

200-LW-2 OUs will be based on the use of a proposed plan, a ROD, and modifications to WA7890008967, *Hanford Facility RCRA Permit*. The ROD for these OUs will cover all of the sites in the OUs, not just the representative sites characterized under the RI. After the ROD and the modification to the *Hanford Facility RCRA Permit* have been issued, a remedial design report and remedial action work plan will be prepared to detail the scope of the remedial action.

Table ES-1. Contaminants of Potential Concern Exceeding Risk Screening Levels. (2 Pages)

Risk	Dose Assessment	Representative Sites		
		200-LW-1 Operable Unit	200-LW-2 Operable Unit	
		216-T-28 Crib	216-S-20 Crib	216-Z-7 Crib
Human Health–Nonrad	Industrial – Total Excess Lifetime Cancer Risk from Contaminants of Concern $>1 \times 10^{-5}$ (WAC 173-340-745)	N[a]	N	N
Human Health – Rad	Industrial >15 mrem/yr; $>10^{-4}$ cancer risk	N[a]	N[b]	N
Groundwater Protection – Nonrad	> Soil Cleanup Levels for Groundwater Protection, WAC 173-340-747	Y Arsenic, Bismuth Fluoride, Ammonium Ion, Nitrate, Nitrogen as nitrite/nitrate, Butoxyethanol, 4-Chloro-3-methylphenol, Eicosene, Hexadecanoic, n-Hexanoic acid, Methylene chloride, Phenol, Oil & Grease, Uranium	Y Arsenic, Bismuth, Lead, Mercury, Uranium, Sulfide, Methylene chloride	Y Arsenic, Bismuth, Uranium, Nonadecane; 1,2,4-Trichloro-benzene
Groundwater Protection – Rad	> 4 mrem/yr	Y H-3 peaks at 4.5 yr at 41 mrem/yr	N	Y Tc-9 peaks at 500 yr, 8.5 mrem/yr;
Eco – Nonrad	Industrial > WAC 173-340-900, Table 749-3	Y Antimony, Arsenic, Barium, Beryllium, Bismuth, Boron, Cadmium, Chromium, Hexavalent Chromium, Copper, Lead, Mercury, Nickel, Selenium, Silver, Uranium, Chloride, Cyanide, Fluoride, Nitrate, Phosphate, Sulfate, Sulfide	N	N

Table ES-1. Contaminants of Potential Concern Exceeding Risk Screening Levels. (2 Pages)

Risk	Dose Assessment	Representative Sites		
		200-LW-1 Operable Unit	200-LW-2 Operable Unit	
		216-T-28 Crib	216-S-20 Crib	216-Z-7 Crib
Eco – Rad	Industrial > DOE-STD-1153-2002	Y Am-241, Sb-125, C-14, Cs-134, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Np-237, Ni-63, Pu-238, Pu-239/240, Ra-226, Ra-228, Tc-99, Th-228, Th-230, Th-232, Th-234, Sr-90, H-3, U-234, U-235, U-238	Y Np-237, K-40	Y Np-237

[a] No shallow zone (0 to 4.6 m [0 to 15 ft]) soils data available.

[b] The depth of the cover material is approximately 11 m (36 ft) below ground surface. Therefore, the depth of the contamination is deeper than 4.6 m (15 ft), and the industrial modeling does not apply. However, industrial modeling with "no cover" was conducted because radiological contaminants of potential concern were identified in low amounts in the samples of the cover.

DOE-STD-1153-2002, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota.*

WAC 173-340-745, "Soil Cleanup Standards for Industrial Properties."

WAC 173-340-747, "Deriving Soil Concentrations for Ground Water Protection."

WAC 173-340-900, "Tables."

N = no, does not exceed risk-screening level.

Y = yes, does exceed risk-screening level.

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TERMS

ARAR	applicable or relevant and appropriate requirement
BCG	biota concentration guide
BDAC	Biota Dose Assessment Committee
bgs	below ground surface
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CLARC	cleanup levels and risk calculations
COC	contaminant of concern
COEC	contaminant of ecological concern
COPC	contaminant of potential concern
CTFN 2703-E	Chemical Tile Field North of 2703 Hazardous Waste Storage Area
CZ	contamination zone
DOE	U.S. Department of Energy
DQA	data quality assessment
DQO	data quality objective
Ecology	Washington State Department of Ecology
ECO-SSL	ecological soil-screening level
EPA	U.S. Environmental Protection Agency
EPC	exposure-point concentration
FS	feasibility study
GW	groundwater
GWP	groundwater protection
HAB	Hanford Advisory Board
H_{cc}	Henry's law constant
HEIS	*Hanford Environmental Information System* database
HHRA	human health risk assessment
HRLS	High-Rate Logging System
Implementation Plan	DOE/RL-98-28, *200 Areas Remedial Investigation/Feasibility Study Implementation Plan –Environmental Restoration Program*
IRIS	*Integrated Risk Information System*
K_d	distribution coefficient
K_{oc}	soil organic carbon-water partition coefficient
MB	mass balance
MCL	maximum contaminant level
MDA	minimum detectable activity
MDL	minimum detection level
N.A.	not applicable
N/A	not applicable
NA	not applicable / not available
ND	nondispersion
ND	not detected
NLA	no laboratory analysis
NS	not sampled
NMLS	Neutron-Moisture Logging System
NOAEL	no observed adverse-effect level

OU	operable unit
PCB	polychlorinated biphenyl
PUREX	Plutonium-Uranium Extraction (Plant or process)
QA	quality assurance
QC	quality control
RAO	remedial action objective
RBC	risk-based concentration
RCRA	*Resource Conservation and Recovery Act of 1976*
REDOX	Reduction-Oxidation (Plant or process)
RESRAD	RESidual RADioactivity
RI	remedial investigation
ROD	record of decision
SGLS	Spectral Gamma-Ray Logging System
SLERA	screening-level ecological risk assessment
SSL	soil screening level
STLRL	Severn Trent Laboratories, Inc., Richland, Washington
STLSL	Severn Trent Laboratories, Inc., St. Louis, Missouri
STOMP	Subsurface Transport Over Multiple Phases
SVOA	semivolatile organics analysis or analyte
SZ	saturated zone
TIC	tentatively identified compound
TPH	total petroleum hydrocarbon
Tri-Parties	Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
TRU	waste materials contaminated with 100 nCi/g of transuranic materials having half-lives longer than 20 years
TSD	treatment, storage, and/or disposal (unit)
UCL	upper confidence limit
VOA	volatile organics analysis or analyte
WAC	*Washington Administrative Code*
WIDS	*Waste Information Data System* database
Work Plan	DOE/RL-2001-66, *Chemical Laboratory Waste Group Operable Unit RI/FS Work Plan; Includes 200-LW-1 and 200-LW-2 Operable Units*
WSCF	Waste Sampling and Characterization Facility

METRIC CONVERSION CHART

Into Metric Units

If You Know	*Multiply By*	*To Get*
Length		
inches	25.4	Millimeters
inches	2.54	Centimeters
feet	0.305	Meters
yards	0.914	Meters
miles	1.609	Kilometers
Area		
sq. inches	6.452	sq. centimeters
sq. feet	0.093	sq. meters
sq. yards	0.0836	sq. meters
sq. miles	2.6	sq. kilometers
acres	0.405	Hectares
Mass (weight)		
ounces	28.35	Grams
pounds	0.454	Kilograms
ton	0.907	metric ton
Volume		
teaspoons	5	Milliliters
tablespoons	15	Milliliters
fluid ounces	30	Milliliters
cups	0.24	Liters
pints	0.47	Liters
quarts	0.95	Liters
gallons	3.8	Liters
cubic feet	0.028	cubic meters
cubic yards	0.765	cubic meters
Temperature		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius
Radioactivity		
picocuries	37	Millibecquerel

Out of Metric Units

If You Know	*Multiply By*	*To Get*
Length		
millimeters	0.039	inches
centimeters	0.394	inches
meters	3.281	feet
meters	1.094	yards
kilometers	0.621	miles
Area		
sq. centimeters	0.155	sq. inches
sq. meters	10.76	sq. feet
sq. meters	1.196	sq. yards
sq. kilometers	0.4	sq. miles
hectares	2.47	acres
Mass (weight)		
grams	0.035	ounces
kilograms	2.205	pounds
metric ton	1.102	ton
Volume		
milliliters	0.033	fluid ounces
liters	2.1	pints
liters	1.057	quarts
liters	0.264	gallons
cubic meters	35.315	cubic feet
cubic meters	1.308	cubic yards
Temperature		
Celsius	multiply by 9/5, then add 32	Fahrenheit
Radioactivity		
millibecquerel	0.027	picocuries

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1.0 INTRODUCTION

This remedial investigation (RI) report for the 200-LW-1 300 Area Chemical Laboratory Waste Group Operable Unit (OU) and the 200-LW-2 200 Area Chemical Laboratory Waste Group OU focuses on the characterization activities associated with the following representative waste sites:

- 216-T-28 Crib (200-LW-1 OU)
- 216-S-20 Crib (200-LW-2 OU)
- 216-Z-7 Crib (200-LW-2 OU).

The representative waste sites were identified in DOE/RL-98-28, *200 Areas Remedial Investigation/Feasibility Study Implementation Plan-Environmental Restoration Program* (Implementation Plan), and DOE/RL-2001-66, *Chemical Laboratory Waste Group Operable Units RI/FS Work Plan, Includes: 200-LW-1 and 200-LW-2 Operable Units*, Rev. 0 (Work Plan), for evaluation as part of the RI. The representative waste sites were evaluated by implementing the data quality objective (DQO) process. The DQO process was used to determine the data that should be collected to assess site conditions and support remedial decision making.

The 200-LW-1 OU waste sites received liquid wastes resulting from 300 Area process laboratory operations that supported radiochemistry and metallurgical experiments. The wastes were transferred from the 300 Area to the 200-LW-1 OU waste sites in the 200 Areas for disposal. The 200-LW-2 OU waste sites received liquid waste resulting mainly from 200 Areas laboratory operations that supported the major chemical processing facilities and equipment decontamination from T Plant. Some 200-LW-2 OU waste sites, however, also are known to have received waste from the 300 Area laboratories. The 200-LW-1 and 200-LW-2 OU representative waste sites were selected for characterization because waste stream inventories, effluent volumes received, and the current level of characterization suggest that contaminant inventories present in the subsurface beneath these receiving sites represent average or worst case conditions similar to those at the other waste sites in the respective OUs.

Modifications to the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al. 1989) M-013 series milestones for past-practice waste site investigations approved in April 2002 (Change Request M-013-02-01) describes the approach to investigate one or more OUs in a single RI/feasibility study (FS) process. This modification reduces the number of work plans, RI reports, and FSs needed for the 200 Areas waste sites. The revised approach allows the collection in more than one OU at a time of data needed to adequately characterize the waste sites and to evaluate effective remedial alternatives for groups of OUs in a single activity.

The original 200-LW-1 OU 300 Area Chemical Laboratory Waste Group OU Work Plan was prepared and issued to the Washington State Department of Ecology (Ecology) on December 31, 2001, in fulfillment of Tri-Party Agreement milestone M-13-00L. However, in accordance with the revised approach, waste sites in the 200-LW-2 200 Area Chemical Laboratory Waste Group OU were consolidated into the original 200-LW-1 OU Work Plan (Tri-Party Agreement Change Number M-15-01-03). The OUs were consolidated because they received similar waste streams and because the contaminant distribution beneath these waste sites is expected to be analogous for use, waste-site type, inventory, and effluent volume discharge. The revised Work Plan, consolidating the OUs, was issued as DOE/RL-2001-66, *Chemical Laboratory Waste Group Operable Units RI/FS Work Plan, Includes: 200-LW-1 and 200-LW-2 Operable Units*, Rev. 1, in June 2002.

The characterization and remediation of waste sites at the Hanford Site are addressed in the Tri-Party Agreement (Ecology et al. 1989). This agreement addresses the integration of cleanup programs under the *Comprehensive Environmental Response, Compensation and Liability Act of 1980* (CERCLA) and the *Resource Conservation and Recovery Act of 1976* (RCRA) to provide a standard approach to directing cleanup activities and to ensure that applicable regulatory requirements are met. Details of this integration for the 200 Areas are presented in the Implementation Plan (DOE/RL-98-28) and in the 200-LW-1 and 200-LW-2 Work Plan (DOE/RL-2001-66).

The 200-LW-1 and 200-LW-2 OUs are located near the center of the Hanford Site in south-central Washington State (Figure 1-1). As originally defined in the Implementation Plan (DOE/RL-98-28), the 200-LW-1 OU consisted of eight RCRA past-practice waste sites, and the 200-LW-2 OU consisted of 17 RCRA past-practice waste sites. Subsequent to the issuance of the Implementation Plan, two additional sites (200-W-21 Pump Station and 200-W-82 Product Piping) were added to the 200-LW-1 OU, increasing the total to 10 waste sites. In the fall of 2001, an evaluation was initiated of the waste sites identified in the 200-LW-1 and 200-LW-2 OUs following the waste-site reclassification process described in the *Tri-Party Agreement Handbook Management Procedures,* Guideline Number TPA-MP-14, "Maintenance of the Waste Information Data System (WIDS)" (RL-TPA-90-0001). As a result of that process, no waste sites were reclassified. In April 2004, three 200-LW-2 OU waste sites (216-U-4 Reverse Well, 216-U-4A French Drain, and 216-U-4B French Drain) were moved into the newly designated 200-UW-1 OU and four 200-LW-1 OU waste sites (216-B-53A, 216-B-53B, 216-B-54, and 216-B-58 Trenches) were moved into the 200-TW-1 OU. Currently, six sites remain in the 200-LW-1 OU, and 14 sites remain in the 200-LW-2 OU. These waste sites are shown in Figures 1-2 through 1-5 and listed in Table 1-1.

The RI field work was conducted from August 2004 to March 2005 in accordance with the Work Plan (DOE/RL-2001-66). Data were collected to characterize the nature and vertical extent of chemical and radiological contamination and the physical conditions in the vadose zone underlying the historical boundaries of the 216-T-28 Crib in the 200-LW-1 OU, and the historical boundaries of the 216-S-20 Crib and 216-Z-7 Crib in the 200-LW-2 OU. Borehole drilling and sampling, direct-push sampling, and surface and borehole geophysical surveys were conducted during the field activities. These activities are summarized in D&D-25461, *200-LW-1 and 200-LW-2 Operable Units - Borehole Summary Report for Boreholes in the 216-S-20, 216-T-28, and 216-Z-7 Cribs*. The data from the activities conducted at the representative waste sites will support the evaluation of remedial alternatives for these two OUs in the FS.

This RI Report is prepared in fulfillment of Tri-Party Agreement Milestone M-015-46A.

1.1 PURPOSE

This RI report focuses on the characterization of three representative waste sites, the 216-T-28 Crib, the 216-S-20 Crib, and the 216-Z-7 Crib. Data from these three representative waste sites were collected from August 2004 to March 2005. Existing boreholes near these three waste sites were geophysically logged to provide additional data, and direct-push holes at the 216-Z-7 Crib were geophysically logged to help locate the borehole. These data are evaluated as part of this RI.

This RI report evaluates data generated during the RI to determine if sufficient data have been collected to support risk assessment and remedial decision making, to estimate risks at the representative waste sites based on the data collected during the RI and on existing data, to determine if any treatability investigations are required to support the decision to proceed with an FS, and to determine those contaminants of concern (COC) and site-specific considerations that need to be addressed in the FS.

This report also provides data to support the evaluation of alternatives in the FS with regard to meeting potential applicable or relevant and appropriate requirements (ARAR), applying risk reduction, and identifying significant data gaps, if any. An evaluation of the baseline risk using characterization data generated during the RI and significant data from other investigations also is included in this report. Risk is evaluated for nonradiological contaminants using U.S. Environmental Protection Agency (EPA) risk assessment guidance. Risk from radiological contaminants is evaluated through the RESidual RADioactivity (RESRAD) computer dose model (ANL 2002, *RESRAD for Windows*, Version 6.21).

1.2 SUPPORTING DOCUMENTS AND REMEDIAL INVESTIGATION BASIS

Supporting documents that provided the basis for the RI Report are as follows.

- **DOE/RL-96-81, *Waste Site Grouping for 200 Areas Soil Investigations*.** This document presents the final prioritized waste site groups, identifies representative waste sites, and provides preliminary conceptual contaminant distribution models for the waste groups.

- **DOE/RL-98-28, *200 Areas Remedial Investigation/Feasibility Study Implementation Plan - Environmental Restoration Program*.** This plan outlines a strategy to streamline the characterization and remediation of waste sites in the 200 Areas, including CERCLA past-practice sites, RCRA past-practice sites, and RCRA treatment, storage and/or disposal (TSD) units. It outlines the framework for implementing assessment activities and evaluating remedial alternatives in the 200 Areas to ensure consistency in documentation, level of characterization, and decision making; establishes a regulatory framework to integrate the requirements of RCRA and CERCLA into one standard approach for cleanup activities in the 200 Areas; lists potential ARARs; identifies preliminary remediation goals and preliminary remedial action objectives (RAO); introduces conceptual exposure models for establishing preliminary remediation goals and RAOs; introduces an approach to risk assessment that is applicable to the 200 Areas; and discusses potentially feasible remedial technologies that may be used in the 200 Areas.

- **DOE/RL-2001-66,** ***Chemical Laboratory Waste Group Operable Units RI/FS Work Plan; Includes 200-LW-1 and 200-LW-2 Operable Units.*** This work plan describes the path forward for the characterization of the 200-LW-1 and 200-LW-2 OUs. It describes the planned characterization of representative waste sites 216-T-28 Crib, 216-S-20 Crib, and 216-7 Crib.

- **D&D-25461,** ***200-LW-1 and 200-LW-2 Operable Units - Borehole Summary Report for Boreholes in the 216-S-20, 216-T-28, and 216-Z-7 Cribs.*** This report describes the characterization activities performed at the 200-LW-1 and 200-LW-2 OU representative waste sites in fiscal years 2004 and 2005.

- **BHI-01589,** ***Remedial Investigation DQO Summary Report for the 200-LW-1 300 Area Laboratory Waste Group Operable Unit.*** This report describes the DQO process that was followed for the 200-LW-1 OU, which confirmed the waste sites to be investigated and the contaminants of concern to be analyzed.

- **WMP-18098,** ***Data Quality Objectives Summary Report for the Designation of the 200-LW-1 and 200-LW-2 Investigation-Derived Waste.*** This report describes the DQO process that was followed to identify additional data collection needs to support waste designation and disposal of investigation-derived waste generated during RI activities.

1.3 DATA EVALUATION METHODOLOGY

The data evaluation methodology used in this RI report considers applicable regulatory requirements, DQO processes (BHI-01589 and WMP-18098) conducted for the Work Plan (DOE/RL-2001-66), land-use uncertainties, risk assessment methodology, other OUs, and site-specific conditions. This evaluation process ultimately supports use of the data in the FS. The purpose of this RI report is to evaluate the data generated during the RI and determine if the data are sufficient to support the FS development, evaluation of remedial alternatives, and selection of a preferred remedy or remedies.

The data evaluation process was preceded by collection and validation of the data. Also, a data quality assessment (DQA) was performed. The data were collected under the Work Plan (DOE/RL-2001-66) based on the DQOs established for these OUs (BHI-01589 and WMP-18098). In accordance with the quality assurance/quality control (QA/QC) procedures specified in the sampling and analysis plan (SAP) in Appendix A of the Work Plan (DOE/RL-2001-66), at least 5 percent of all data were validated. A summary of the data validation is presented in Appendix B. Summary tables providing information such as frequency of detection, minimum and maximum detected values, etc., are provided in Appendix A of this RI.

The data evaluation process consists of the following:

- Data screening for undetected contaminants
- Data screening of maximum detected contaminants against established Hanford Site background values
- Human health risk assessment determinations for nonradiological contaminants
- Evaluation of ecological risk using indicator concentrations
- Human health dose and risk evaluation for radiological contaminants
- Comparison to WAC 173-340-745, "Soil Cleanup Standards for Industrial Properties"
- Evaluation of impacts to groundwater.

Details of this evaluation are provided in Chapters 4.0 and 5.0. A flowchart of the data evaluation process is provided as Figure 1-6.

1.3.1 Identification of Contaminants of Concern

Initially the entire data set was screened, and undetected contaminants were eliminated from further consideration. Because of the limited number of samples, 95 percent upper confidence limits (UCL) were not calculated; maximum concentrations for specific horizons were used for comparisons and evaluation.

Laboratory sample sizes for the 200-LW-1 and 200-LW-2 OU sites varied from one to three samples for different analytes at each depth. One boring was performed per site. Borings were located in a biased manner (e.g., most likely location for contamination). Based on EPA guidance (EPA 2002, *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites,* OSWER 9285.6-10), these sample sizes are insufficient to generate a valid upper one-sided 95 percent UCL on the true mean soil concentration using Land's method, as specified in WAC 173-340-740(7)(d)(i)(A), "Unrestricted Land Use Soil Cleanup Standards," "Compliance Monitoring." Use of the maximum concentration ensures that less than 10 percent of the samples exceed the soil cleanup value and that no single sample concentration exceeds two times the soil cleanup level as specified in WAC 173-340-740(7)(e)(i) and (ii). In addition, sampling at the 200-LW-1 and 200-LW-2 OU sites was designed to sample areas at which suspected soil contamination had a probability of occurrence based on knowledge about the sites, and therefore the samples meet the criteria for direct comparison of soil sample concentrations with cleanup levels under WAC 173-340-740(7)(d)(iii).

The data were compared to the 90th percentile of the background concentrations from DOE/RL-92-24, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*; DOE/RL-96-12, *Hanford Site Background: Part 2, Soil Background for Radionuclides*; and Ecology 94-115, *Natural Background Soil Metals Concentrations in Washington State.* If the maximum detected value was less than the 90th percentile background value, the contaminant was eliminated as a contaminant of potential concern (COPC). If background data were not available for a contaminant, it was retained for further evaluation, as described in Sections 1.3.2 and 1.3.3.

1.3.2 Human Health Risk Evaluation

The risk evaluation for the representative waste sites is based on EPA risk assessment guidance. Radiological contaminants are addressed through a dose and risk evaluation. Human health risks are evaluated for an industrial exposure scenario using site-specific data and exposure assumptions obtained from state and Federal guidance documents. The land surrounding the 200 East and 200 West Areas was designated as industrial-exclusive in DOE/EIS-0222-F, *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*. All of the 200-LW-1 OU waste sites are located within the 200 Areas Core Zone and also within the industrial-exclusive land-use boundary. Two 200-LW-2 OU waste sites (the 216-S-19 Pond and the 216-S-26 Crib) are located outside of the 200 Areas industrial-exclusive land-use boundary but within the 200 Areas Core Zone. The remaining 200-LW-2 OU sites are located within the 200 Areas Core Zone and also the industrial-exclusive land-use boundary.

The Tri-Parties (Ecology, EPA, and the U.S. Department of Energy [DOE]) undertook the task of developing a risk framework to support risk assessments in the Central Plateau. This included a series of workshops completed in 2002 with representatives from DOE, EPA, Ecology, the Hanford Advisory Board (HAB), the Tribal Nations, the State of Oregon, and other interested stakeholders. The workshops focused on the different programs involved in activities in the Central Plateau and the need for a consistent application of risk assessment assumptions and goals. The results of the risk framework are documented in letter HAB 132, "Exposure Scenarios Task Force on the 200 Area," in the Tri-Parties' response to "Consensus Advice #132: Exposure Scenarios Task Force on the 200 Area" (Klein et al. 2002), and in *Report of the Exposure Scenarios Task Force* (HAB 2002). The following items summarize the risk framework description from the Tri-Parties' response to the HAB. Clarifications have been added to the original response language.

- The Core Zone (200 Areas including B Pond [main pond] and S Ponds) will have an industrial scenario for the foreseeable future.

- The Core Zone will be remediated and closed, allowing for "other uses" consistent with an industrial scenario (environmental industries) that will maintain an active human presence in this area, which in turn will enhance the ability to maintain the institutional knowledge of waste left in place for future generations. Exposure scenarios used for this zone should include a reasonable maximum exposure to a worker/day user, to possible Native American users, and to intruders.

- The DOE will follow the required regulatory processes for groundwater remediation (including public participation) to establish the points of compliance and RAOs. It is anticipated that groundwater contamination under the Core Zone will preclude beneficial use for the foreseeable future, which is at least the period of waste management and institutional controls (150 years). It is assumed that the tritium and I-129 plumes beyond the Core Zone boundary will exceed the drinking water standards for the next 150 to

300 years (less for the tritium plume). It is expected that other groundwater contaminants will remain below, or will be restored to, drinking water levels outside the Core Zone.

- No drilling for water use or otherwise will be allowed in the Core Zone. An intruder scenario will be calculated for in assessing the risk to human health and environment.
- An industrial land-use scenario will set cleanup levels on the Central Plateau. Waste sites outside the Core Zone but within the Central Plateau (200 N Area, Gable Mountain Pond, BC Controlled Area) will be remediated and closed based on an evaluation of multiple land-use scenarios to optimize institutional-control cost and long-term stewardship.
- Other land-use scenarios (e.g., residential, recreational) may be used for comparison purposes to support decision making, especially for the following:
  - The post-institutional controls period (>150 years)
  - Sites near the Core Zone perimeter to analyze opportunities to "shrink the site"
  - Early (precedent-setting) closure/remediation decisions
- This framework does not consider the tank waste retrieval decision.

Because all of the 200-LW-1 and 200-LW-2 OU waste sites are located in the 200 Areas Core Zone, this description serves as the basis for the risk assessment activities. The risk assessment is presented for an industrial-exclusive land-use scenario in Chapter 5.0. The risk assessment will follow the risk guidelines identified through the risk framework workshops as documented in the Tri-Parties' response to HAB Advice #132 (Klein et al. 2002). Risk evaluations for possible Native American users and intruder scenarios may be considered in the FS for informational purposes.

The risk evaluation for the 200-LW-1 and 200-W-2 OUs is based on these guidelines, as well as on EPA and Ecology risk assessment guidance. Radiological contaminants are addressed through a dose evaluation, described in Section 1.3.3, which then is converted to a risk value. Hypothetical human health risks are calculated for industrial-exposure scenarios using inputs developed from other Hanford Site OUs, site-specific data, and guidance documents.

The DOE worked for several years with cooperating agencies and stakeholders to define land-use goals for the Hanford Site and develop future land-use plans (Drummond 1992, *The Future for Hanford: Uses and Cleanup, The Final Report of the Hanford Future Site Uses Working Group*). The cooperating agencies and stakeholders included the National Park Service; Tribal Nations; States of Washington and Oregon; local, county, and city governments; economic and business development interests; environmental groups; and agricultural interests. These activities initially were reported by Drummond (1992) and culminated in DOE/EIS-0222-F and the associated 64 FR 61615, "Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS)," which were issued in 1999.

Drummond (1992) identified the following nine general recommendations:

- Protect the Columbia River
- Deal realistically and forcefully with groundwater contamination
- Use the Central Plateau wisely for waste management
- Do no harm during cleanup or with new development
- Cleanup of areas of high future use value is important
- Clean up to the level necessary to enable the future-use option to occur
- Transport waste safely and be prepared
- Capture economic development opportunities locally
- Involve the public in future decisions about the Hanford Site.

Specific to the Central Plateau, the findings and recommendations from the Future Site Uses Working Group are as follows.

- The Central Plateau is unique.

- Some type of government presence or oversight should be assumed for the foreseeable future.

- Waste from other Hanford Site locations should be concentrated in the 200 Areas.

- Waste management, storage, and disposal activities should be concentrated within the 200 Areas whenever feasible to minimize the amount of land devoted to these activities, and adverse impacts to clean areas also should be minimized.

- Wastes generated in or coming to the 200 Areas from the rest of the Site will not necessarily be permanently disposed of in the 200 Areas. Offsite shipments are occurring and may continue. New technologies may be applied to waste in the future.

- Waste and contaminants within the 200 Areas should be treated and managed to prevent migration from the 200 Areas to other areas or off the Hanford Site.

- Access to the "exclusive" areas, including "exclusive buffers," will be restricted to personnel who are properly trained and monitored.

The working group identified a single cleanup scenario for the Central Plateau. This scenario assumes that future uses of the surface, subsurface, and groundwater in and immediately surrounding the 200 East and 200 West Areas will be industrial-exclusive.

All of the 200-LW-1 and 200-LW-2 OU waste sites are located in the Core Zone. All three representative waste sites are located in the Core Zone. The industrial exposure scenario is used to evaluate each representative waste site.

Nonradiological contaminants from the shallow zone soil 0 to 4.6 m (0 to 15 ft) below ground surface (bgs) are screened to industrial soil risk-based concentrations (RBC) and industrial air RBCs for direct contact and inhalation of ambient air, respectively. Nonradiological contaminants from the deep-zone soil (0 m to water table) are compared with the soil RBCs for the protection of groundwater. For the purposes of this RI report, contaminant concentrations were compared to RBCs developed under CERCLA guidance (EPA/540/R-92/003, *Risk Assessment Guidance for Superfund: Volume I -- Human Health Evaluation Manual (Part B. Development of Risk-Based Preliminary Remediation Goals), Interim*, Publication 9285.7-01B) using the excess lifetime cancer risk range of 10^{-4} to 10^{-6} and a hazard quotient of 1.0 using an industrial land-use scenario for nonradiological contaminants. Because the waste sites in these OUs are within the Core Zone, RBCs used for screening correspond to a 10^{-5} risk level.

1.3.3 Modeling Approach

Risk and dose estimates were modeled for radiological constituents identified as COPCs using RESRAD Version 6 (ANL 2002). Dose and risk estimates were modeled for shallow-zone soil 0 m to 4.6 m (0 to 15 ft) bgs on the basis of direct exposure to soils for an industrial-exposure scenario. Dose estimates then were compared to direct exposure standards for the public and workers. Risk estimates also were provided for comparison to Washington State and EPA target risk ranges. Input parameters were developed on the basis of previous Hanford Site RESRAD modeling activities, 200 Areas-specific geologic and hydrogeologic information sources, and data collected for this RI report.

Groundwater was evaluated for nonradiological contaminants based on existing standards for protection of groundwater WAC 173-340-720(4), "Ground Water Cleanup Standards," "Method B Cleanup Levels for Potable Ground Water," equations 720-1 and 720-2, and 40 CFR 141, "National Primary Drinking Water Regulations." The fate and transport evaluation included evaluating the frequency of detection, the location of the contaminant within the soil column, the distribution coefficient, whether the contaminant has already reached groundwater, and whether modeling would provide additional information beyond that already known. Additional information is provided in Chapters 4.0 and 5.0 of this RI report.

1.3.4 Ecological Risk Evaluation Methodology

DOE/RL-2001-54, *Central Plateau Ecological Evaluation*, has been prepared to support ecological evaluations under the RI/FS process for Central Plateau waste sites. DOE/RL-2001-54 completes a screening-level ecological risk assessment (SLERA) for the Central Plateau in accordance with the eight-step EPA ecological risk assessment process presented in EPA/540/R-97/006, *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final* (see Figure 1-1 in DOE/RL-2001-54).

The document contains a compilation and evaluation of ecological sampling data that have been collected over many years from undisturbed and disturbed habitats in the Central Plateau. The document describes the habitats on the Central Plateau, including sensitive habitats and the plants and animals that inhabit them. It identifies potential species of concern, including threatened and endangered species and new-to-science species. A detailed survey of the Central Plateau performed in 2000 and 2001 is incorporated into the ecological evaluation document and provides a current, detailed description of the ecological setting of the Central Plateau, and augments the ecological information presented in this RI report.

DOE/RL-2001-54 helps answer questions about Central Plateau ecological resources that it is important to preserve and protect. The document also identifies ecological data needs that can be addressed in future ecological sampling activities on the Central Plateau.

The SLERA in DOE/RL-2001-54 is meant to be a conservative evaluation of risk to the ecological receptors that are unique to the Central Plateau from stressors—in this case, introduction of contaminants and habitat elimination. The SLERA identifies pathways for ecological receptors to be exposed to the contamination and evaluates potential risk from those exposures.

Chapter 2.0 of DOE/RL-2001-54 describes the physical and ecological setting of the Central Plateau and identifies important aspects of the ecology and the condition of the waste sites to consider during the ecological risk assessment. For instance, while most waste sites are in a disturbed habitat with little vegetation to support wildlife, the nearby shrub-steppe offers a more hospitable habitat for wildlife. This region needs protection, because similar habitat is being encroached on and eliminated in other parts of eastern Washington. Individual species whose populations are limited and are designated as sensitive species also must be protected.

Recent surveys of the biological diversity on the Hanford Site have identified a number of new-to-science species whose protection status has not yet been determined. The U.S. Fish and Wildlife Service and Washington State may gather additional information from the scientific community at the Hanford Site to help them determine the protection status of the new species. Most of the waste in the waste sites has been stabilized, thereby limiting ecological access. The decisions to stabilize and remediate waste sites must be balanced with the potential disruption to the ecosystem both at and adjacent to the waste sites, as well as from distant locations (e.g., borrow-source sites).

The conceptual site model in DOE/RL-2001-54, Chapter 3.0, explains the ecological resources and the ways that receptors may be exposed. It shows where chemicals and radionuclides from the waste sites are likely to come into contact with receptors in the environment. The exposure pathways that are expected to be complete at most waste sites are as follows:

- Direct contact with or ingestion of soil by invertebrates (e.g., beetles, ants) and burrowing mammals
- Uptake of contaminants in soil by vegetation
- Bioaccumulation through ingestion of food items (e.g., food-chain effects) consumed by wildlife that may forage at the waste sites.

Chapter 4.0 of DOE/RL-2001-54 discusses the toxicity values available for contaminants believed to be present in the Central Plateau. Contaminants were identified from preliminary sampling data available from a subset of waste sites. These contaminants were screened, primarily for the likelihood of their presence in the environment (i.e., half-life and persistence). A literature search for bird and mammalian toxicity values was performed. Toxicity values are not available for some contaminants. A risk management decision will be needed to determine how contaminants without toxicity values will be handled during the risk assessment for each OU.

Chapter 5.0 of DOE/RL-2001-54 presents the exposure parameters used for estimating the exposure in a quantitative manner. In a SLERA, most exposure parameters are set conservatively at 100 percent. The only organism-specific factor necessary is body weight, and this variable is available in the literature. This chapter further evaluated the exposure pathways and constructed a food chain exposure model for wildlife specific to the Central Plateau. The wildlife are shown in the food chain and habitat model in DOE/RL-2001-54.

DOE/RL-2001-54, Chapter 6.0, is the screening-level risk calculation for the Central Plateau. Washington State and DOE provide contaminant-specific numerical values (WAC 173-340-900, "Tables") and biota concentration guides (BCG) (DOE-STD-1153-2002, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*) to potential risks. These are conservative numbers designed to address all possibilities while considering potential risks. Data are available for a subset of the Central Plateau waste sites. These maximum concentrations of contaminants detected at the waste sites were compared with the state and DOE screening-level values. For chemicals, 12 metals, pentachlorophenol, and 4-dinitrophenol were detected at a maximum concentration above the screening level. The high number of metals presenting a risk requires closer examination. Site-specific bioavailability data would be helpful for understanding whether this is a reflection of the conservative nature of the screening assessment or an actual risk to the ecosystems at the waste sites. Concentrations of four radionuclides, Cs-137, Ra-226, Ra-228, and Sr-90, were above acceptable limits in the soil samples. It is important to recognize the limitations and uncertainty associated with risks identified by screening-level assessments. The risk calculations are useful for determining relative risks between waste sites, not site-specific risks. The information should be considered carefully along with actual biological evidence from the waste site area to determine if a hazard exists. Data are available for hundreds of wastes sites in the Central Plateau (DOE/RL-2001-54, Appendix C). These data include soil from the waste site, vegetation, and soil invertebrates.

The SLERA in DOE/RL-2001-54 leads to the problem formulation stage of a baseline ecological risk assessment. During problem formulation, the risk managers and others consider the toxicity evaluation, conceptual model exposure pathways, and assessment endpoints to support cleanup decisions. As a result, they are able to better define the initial risks and to determine direction for the DQO process, if needed. The DQO process then will complete the following:

- Establish the level of effort needed to assess ecological risk at a particular site or OU
- Identify relevant and available data
- Design a conceptual model of the ecological threats at a site and the measures to assess those threats
- Select methods and models to be used in the various components of the risk assessment
- Develop assumptions to fill data gaps for toxicity and exposure assessments, based on logic and scientific principles.

Data collected during the RI directly support the ecological evaluation. Contaminant data from the soil sampling conducted in the RI are compared against WAC 173-340-900, Table 749-3, "Ecological Soil Indicator Concentrations," as the beginning step of the OU-specific screening-level evaluation of ecological risk from nonradiological contaminants. For radiological contaminants, no promulgated screening or cleanup levels are available. The BCGs from DOE/STD-1153-2002 are used in this evaluation of radiological contaminants. Additional details are provided in Chapter 5.0.

1.3.5 Analogous Site Approach

The concept and rationale for using analogous sites to reduce the amount of site characterization is discussed in the 200 Areas Implementation Plan (DOE/RL-98-28). The use of this approach relies on, first, grouping sites with similar location, geology, waste site history, and contaminants, and then choosing one or more representative waste sites for comprehensive field investigations, including sampling. Findings from site investigations at representative waste sites are extended to apply to other sites in the waste group that were not characterized. Sites for which field data have not been collected are assumed to have chemical characteristics similar to those of the sites that were characterized. Confirmatory investigations of limited scope, rather than full characterization efforts, can be performed at the sites not selected as representative waste sites. The regulatory pathway and documentation requirements are streamlined, and less characterization is performed for remedial decision making. In addition, the time and cost required to characterize nonrepresentative waste sites is greatly reduced.

Data from representative waste sites are used to evaluate remedial alternatives and to select one or more alternatives to apply for the entire waste group. Although a degree of uncertainty exists in employing the analogous-site concept, substantial benefit is realized in the early selection of a remedy that allows early cleanup action to be performed.

Selection of representative waste sites is fundamental to the implementation of the analogous site approach. These sites often are indicative of worst case and typical conditions in an OU and in some cases have been characterized extensively. The representative waste sites evaluated in this RI report were identified as being representative of sites within their respective OUs in the 200 Areas Implementation Plan (DOE/RL-98-28); therefore, data collected from these sites and the resulting contaminant distribution models are anticipated to be representative of the remaining (or analogous) waste sites in the OUs.

This analogous approach was enhanced in June 2002 with Tri-Party Agreement change packages M-013-02-01 and M-015-01-03, which consolidated the 200-LW-1 and 200-LW-2 OUs into one work plan (DOE/RL-2001-66).

Existing data on each waste site have been assembled and evaluated to develop a conceptual understanding of the waste sites. The approach that was used to further investigate, characterize, and evaluate the sites is presented in the Work Plan (DOE/RL-2001-66). Preliminary remedial action alternatives that are likely to be considered for these OUs are identified in the Work Plan. These preliminary remedial action alternatives are to be further developed and agreed to in the FS/closure plans and in the eventual record of decision (ROD) for these OUs. A DQO process was conducted for the 200-LW-1 and 200-LW-2 OUs (BHI-01589 and WMP-18098) to define the radiological and nonradiological COPCs to be characterized and to specify the number, type, and location of samples to be collected at the representative waste sites. The results of the DQO process formed the basis for the Work Plan (DOE/RL-2001-66).

A proposed plan and ROD will be written to identify the proposed remedy (or remedies) for all waste sites in the OUs. The ROD will include criteria for any post-ROD confirmatory sampling and analysis needed to verify that all remaining (or analogous) sites in the OU meet the conceptual model for the waste group. If a waste site is significantly different from, and fails to meet, the contaminant distribution model, and the selected remedy is not appropriate, the site will be reevaluated based on historical and any new information. The reevaluation could result in a decision to use a contaminant distribution model established for a different OU. The reevaluation also could result in a decision to do additional confirmatory sampling. Changes to the preferred alternative would be evaluated as needed, based on confirmatory data. The analogous site approach focuses on the typical and worst case sites as representative waste sites; therefore, data from the representative waste sites should bound the analogous sites within the OUs. Also, the ability to use data and information from representative waste sites outside the OUs helps reduce the potential to reassign waste sites between OUs. A separate DQO process will be conducted to identify data needs and quality requirements to support the confirmatory sampling design. A permit modification also will be prepared to reference these activities and satisfy the requirements of the *Hanford Facility RCRA Permit* (WA7890008967).

1.4 WASTE SITE DESCRIPTION AND HISTORY

As defined in the 200 Areas Implementation Plan (DOE/RL-98-28), two representative waste sites were identified for the 200-LW-1 OU and two representative waste sites were identified for the 200-LW-2 OU. One of the 200-LW-1 OU sites, the 216-B-58 Trench, was moved into the 200-TW-1 OU, in accordance with Tri-Party Agreement Change Control Form C-03-02. The remaining waste sites, the 216-T-28 Crib, the 216-S-20 Crib, and the 216-Z-7 Crib, are evaluated in this RI report.

The 216-T-28 Crib was chosen as the worst case site in the 200-LW-1 OU because of its radiological and nonradiological inventory, effluent volume received, and extent of vadose zone contamination. The 216-Z-7 Crib was selected as a worst case site in the 200-LW-2 OU, based on high inventories of plutonium, cesium, and strontium. The 216-S-20 Crib site was selected as a typical case site, because it was used for the longest duration and contains significant inventories of radionuclides (plutonium, cesium, and strontium) and known inorganic waste.

Most of the waste discharged to the soil column in the 200-LW-1 and 200-LW-2 OUs was generated between 1953 and 1968 (DOE/RL-2001-66). In general, the waste sites received liquid wastes discharged from 300 Area laboratory operations, 200 Areas laboratory operations, and 200 Areas decontamination and equipment refurbishment activities.

Data from the representative waste sites were collected in fiscal years 2004 and 2005. Table 1-2 briefly describes representative waste sites in the 200-LW-1 and 200-LW-2 OUs. The following sections describe the sites in detail. Information was obtained from the Work Plan (DOE/RL-2001-66).

1.4.1 216-T-28 Crib

The 216-T-28 Crib is the southernmost of the 216-T-26, 216-T-27, and 216-T-28 Crib series (Figure 1-2). The unit is a 200-LW-1 OU waste site and consists of a 36 cm (14-in.) steel inlet pipe reducing to a 25.4 cm (10-in.) steel pipe, 2.4 m (8 ft) below grade. The pipe branches to four 20.3 cm (8-in.) steel pipes, each one extending to a 1.2 m (4-ft)-long by 1.2 m (4-ft)-diameter, open-end, vertically-oriented, concrete sewer pipe (Figure 1-7). This structure rests in an excavation that is 4.6 m (15 ft) deep by 9 by 9 m (30 by 30 ft). The excavation is filled with 2.4 m (8 ft) of gravel and 2.1 m (7 ft) of earth. The crib is enclosed within a light chain barricade and is marked with underground contamination warning signs (DOE/RL-91-61, *T Plant Source Aggregate Area Management Study Report*).

The 216-T-28 Crib was active from February 1960 to February 1966. During that time, it received 4,230,000 L (1,117,450 gal) of liquid mixed waste containing 387 kg (850 lb) of uranium, 70 g (0.15 lb) of plutonium, 193 Ci of Cs-137, 106 Ci of Sr-90, and 10,000 kg (22,050 lb) of nitrates (DOE/RL-96-81). The waste included steam condensate decontamination waste, miscellaneous effluent from the 221-T Canyon Building, decontamination waste from the 2706-T Decontamination Facility, and 300 Area laboratory waste from the 340 Waste Neutralization Facility (DOE/RL-96-81).

An underground pipeline to the T Tank Farm was used to transfer waste from T Plant (221-T Canyon Building) (after it cascaded through Tanks 241-T-110, 241-T-111 and 241-T-112) to the 216-T-26, 216-T-27, and 216-T-28 Cribs. The tanks contained steam condensate and process decontamination waste from T Plant, along with 2706-T Facility equipment decontamination waste (DOE/RL-91-61).

In 1964, 300 Area waste was added to the 216-T-28 and 216-T-27 Cribs from tanker trucks via a vent riser. Waste site 200-W-82 Product Piping is a liquid waste truck station for 300 Area liquid wastes disposal to the 216-T-28 Crib. T Plant waste that was discharged to the 216-T-27 and 216-T-28 Cribs was routed from the T Tank Farm. Effluent temporarily was diverted to the 216-T-27 Crib in November 1965. The crib was deactivated in December 1966, when the prescribed radionuclide disposal limit was reached. Deactivation consisted of blanking the pipeline from the tank farms to the 216-T-26 through 216-T-28 Crib series and the 216-T-28 vent riser (*Waste Information Data System* database [WIDS]).

From 1969 to 1979, a few contaminated Russian thistles were found growing on the surface of this area. Most of the thistles were removed as they were found, but some had deteriorated, causing contamination of the ground surface. A radiation survey performed in May 1975 identified spotty surface contamination to a maximum of 30,000 c/min. Remedial action in June and July 1975 included removing 15 cm (6 in.) of soil from affected areas and disposing of it in the 200 West Area Dry Burial Ground. The site then was covered with clean fill to its original level (WIDS).

1.4.2 216-S-20 Crib

The 216-S-20 Crib is located 93 m (305 ft) southeast of the 202-S Plant Canyon Building and 91 m (300 ft) north of 10th Street (Figure 1-3). The unit has a side slope of 1H:1V (horizontal:vertical) and contains two 3.7 by 3.7 by 2.7 m (12- by 12- by 9-ft) (L x W x H) wooden structures, 15 m (50 ft) apart, with the crib top of each located 5.5 m (18 ft) below grade (Figure 1-8). The bottom of each wooden structure is suspended in a gravel fill that is 1.2 m (4 ft) above the bottom of the unit (DOE/RL-91-60, *S Plant Source Aggregate Area Management Study Report*). The outer area of the crib is barricaded with a light chain with surface contamination warning signs and a concrete post marker. The surface is sand and gravel with a slight depression around the riser vents. Within the outer barricade are two inner barricades around each of the metal riser vents. The inner chains are posted with underground radioactive material and cave-in potential signs at each corner (DOE/RL-91-52, *U Plant Source Aggregate Area Management Study Report*).

The 216-S-20 Crib began operating in January 1952 and was retired in May 1973. The unit received 135,000,000 L (35,663,200 gal) of waste containing 38.7 kg (85 lb) of uranium, 171 g (0.4 lb) of plutonium, 56.5 Ci of Cs-137, 22.7 Ci of Sr-90, and 20,000 kg (44,000 lb) of nitrates (DOE/RL-96-81). Until July 1953, the crib received miscellaneous waste from laboratory hoods and decontamination sinks from the 202-S Plant Canyon Building via the 207-SL Retention Basin and the 219-S Retention Building. From July 1953 to September 1963, the crib received the above effluent via pipelines from the 207-SL Retention Basin, 219-S Retention Building, and 300 Area laboratories via a tanker truck that disposed of waste through a manhole located south of the crib. From September 1963 to January 1969, the crib received miscellaneous waste from laboratory hoods and decontamination sinks in the 222-S Laboratory via the 219-S Retention Building. After January 1969, 300 Area laboratory wastes were sent to the 216-T-28 Crib. From January 1969 to November 1972, the 216-S-20 Crib was inactive because of surface subsidence. The 219-S Retention Building and 207-SL Retention Basin pipelines were valved out from the site. The 222-S Laboratory effluent was rerouted to 202-S Building concentrators for boildown and discharge to underground storage (DOE/RL-91-52 and HW-18700-DEL, *REDOX Technical Manual*).

The 216-S-20 Crib has had a history of subsidence. Since the completion of stabilization in December 1974, sink holes have been filled on three different occasions. No cavities are likely to remain below the ground surface (RHO-CD-673, *Handbook 200 Area Waste Sites*). It is estimated that the 216-S-20 Crib has received a total covering of 0.3 m (1 ft) of stabilization soil. Thus, 9.8 m (32 ft) is the total depth of the unit from the surface. No known unplanned releases are associated with this crib.

1.4.3 216-Z-7 Crib

The 216-Z-7 Crib is an inactive waste site located approximately 153 m (500 ft) east of the 231-Z Plutonium Isolation Plant and about 137 m (450 ft) north of 19th Street (Figure 1-2). The 216-Z-7 Crib consists of two parallel wooden structures 45.7 m (150 ft) long by 1.5 m (5 ft) wide by 0.6 m (2 ft) high, placed in a 1.5 m (5-ft)-deep excavation (Figure 1-9). However, the entire area surrounding the 216-Z-7 Crib was excavated to approximately 3 m (10 ft). Surface stabilization of 0.6 m (2 ft) is assumed for this site. Thus, the total depth from the current 216-Z-7 Crib surface to the bottom of the structure is approximately 3.6 m (12 ft). Each wooden structure was constructed of three overlapping tiers. A 45.8 m (150-ft)-long 7.5 or 10 cm (3- or 4-in.)-diameter perforated distribution pipe ran above the second tier. Each of the two trenches was covered by 503 m (1,650 ft) of 5 cm (2 in.) of planking topped with tar paper. The excavation was backfilled with gravel (DOE/RL-91-58, *Z Plant Source Aggregate Area Management Study Report*).

The 216-Z-7 Crib received process waste from the 231-Z Plutonium Isolation Plant via the 231-W-151 Sump from 1947 to 1967. A riser on the west side of the crib received 300 Area liquid waste from the 340 Waste Neutralization Facility via tanker trucks. In total, the site received an estimated 79,900,000 L (21,100,000 gal) of liquid waste containing 4.46 kg (10 lb) of uranium, 2,000 g (4 lb) of plutonium, 200 Ci of Cs-137, 200 Ci of Sr-90, and 20,000 kg (44,000 lb) of nitrates (DOE/RL-96-81).

When the facility was retired in 1967, deactivation was accomplished by blanking the pipeline west of the 231-W-151 Sump and the distribution piping. No unplanned releases were associated with this crib.

Figure 1-1. Location of the Hanford Site and the 200-LW-1 and 200-LW-2 Operable Unit Waste Sites.

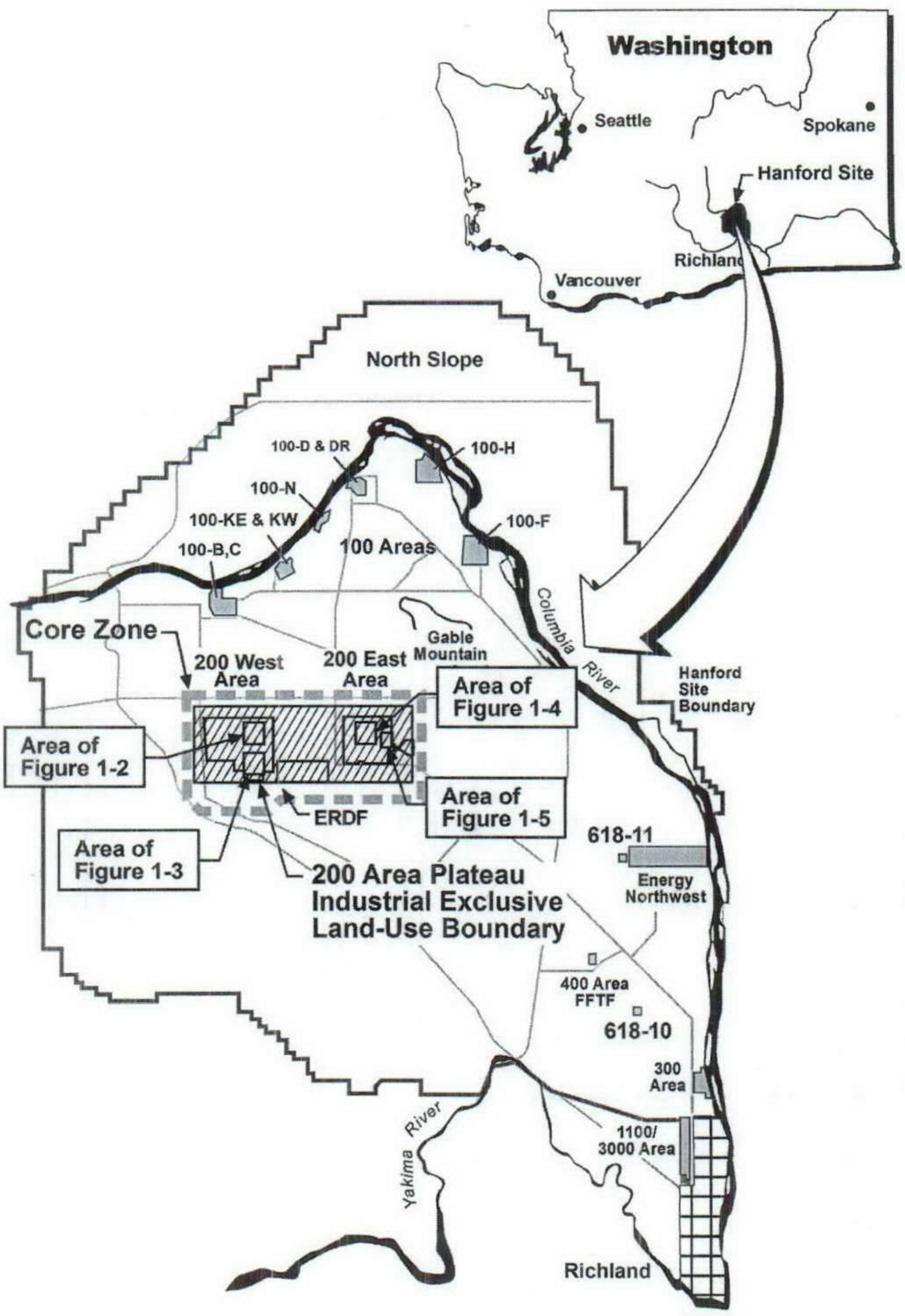

Figure 1-2. Location of 200-LW-1 and 200-LW-2 Operable Unit Representative Waste Sites and Other 200-LW-1 Waste Sites Located Near T Plant and the Z Plant Complex in the 200 West Area.

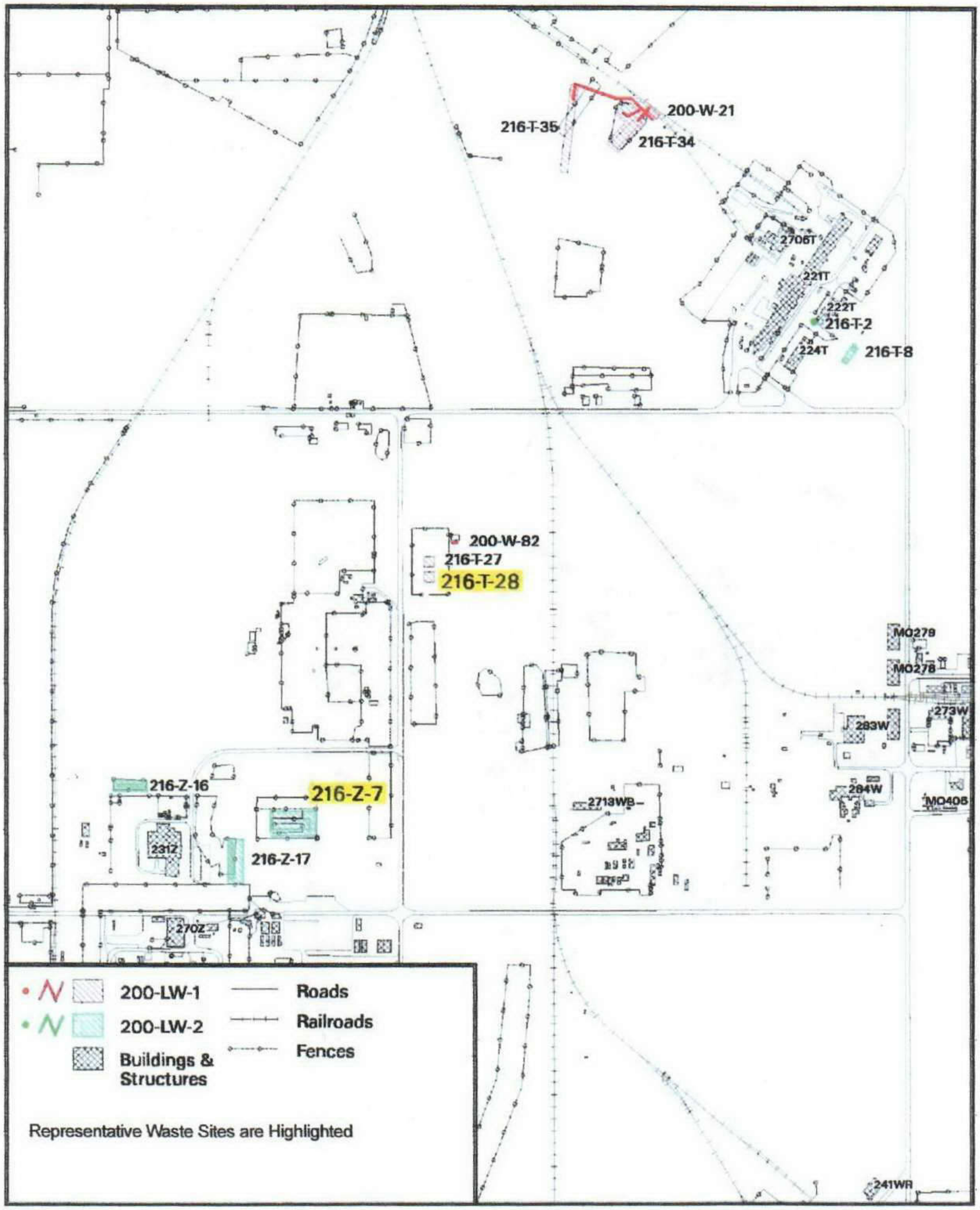

Figure 1-3. Location of the 216-S-20 Crib Representative Waste Site and Other 200-LW-2 Waste Sites Located Near the Reduction-Oxidation Plant in the 200 West Area.

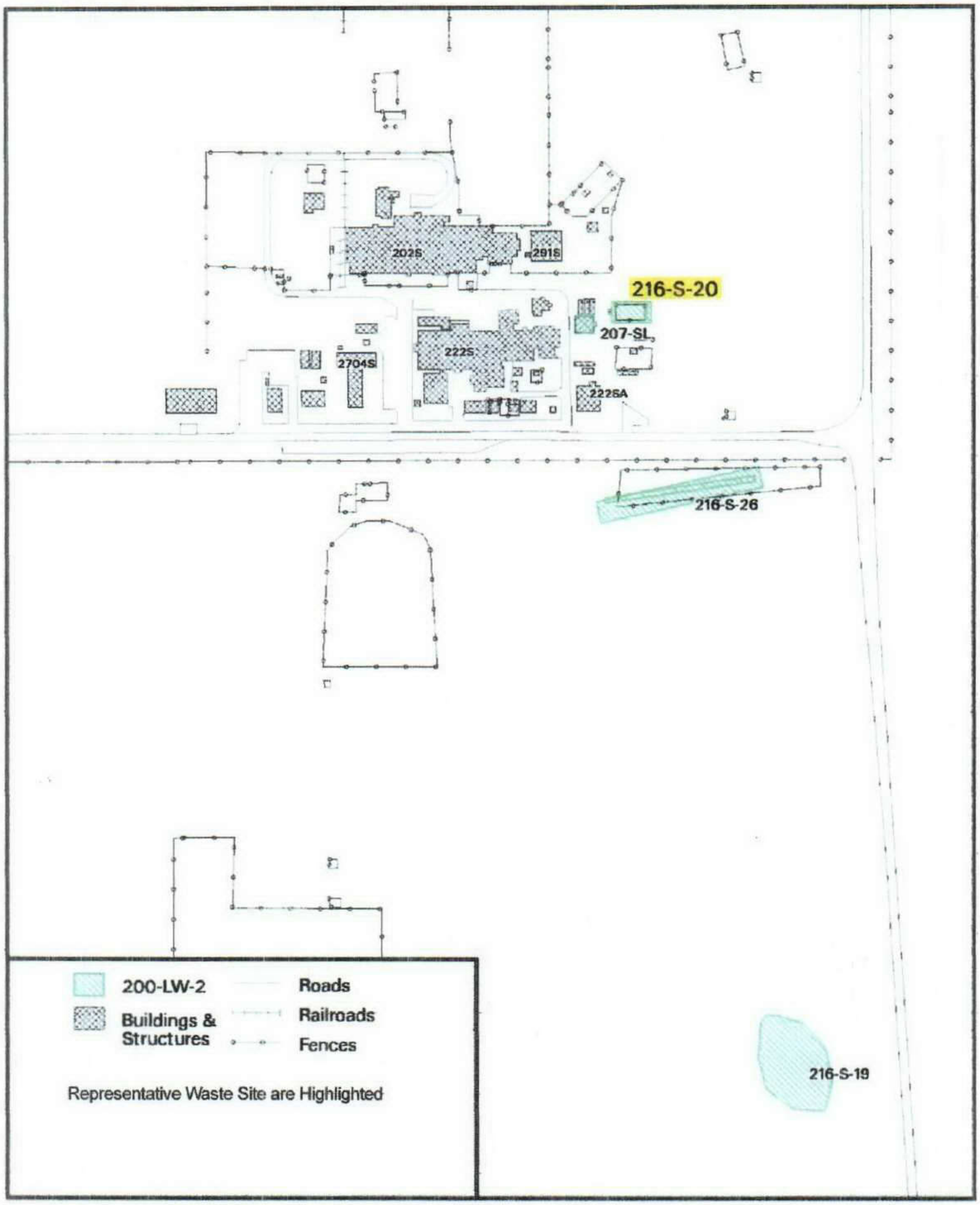

Figure 1-4. Location of the 200-LW-2 Operable Unit Waste Sites Adjacent to B Plant in the 200 East Area.

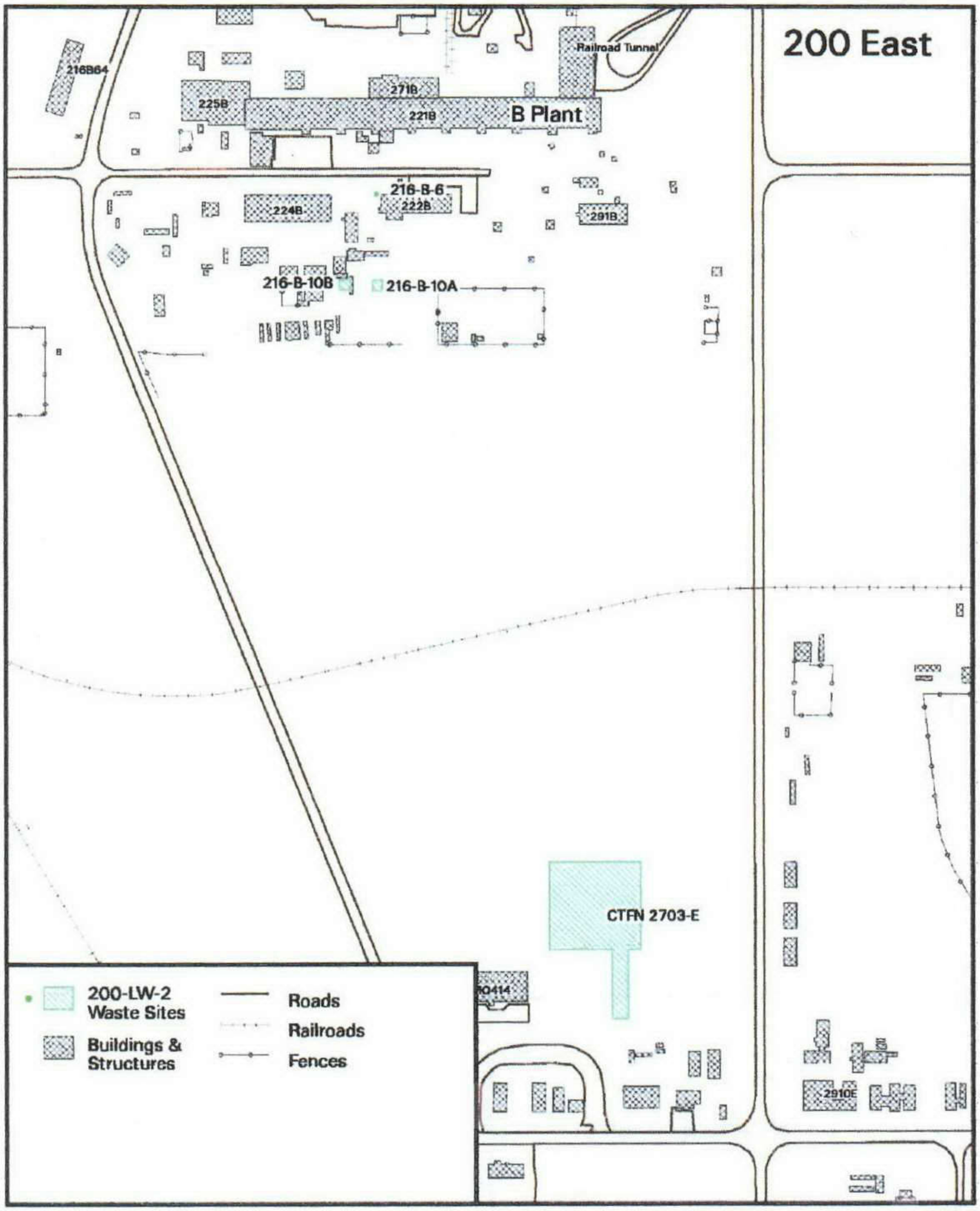

Figure 1-5. Location of 200-LW-2 Operable Unit Waste Sites Located Near the Plutonium-Uranium Extraction Plant in the 200 East Area.

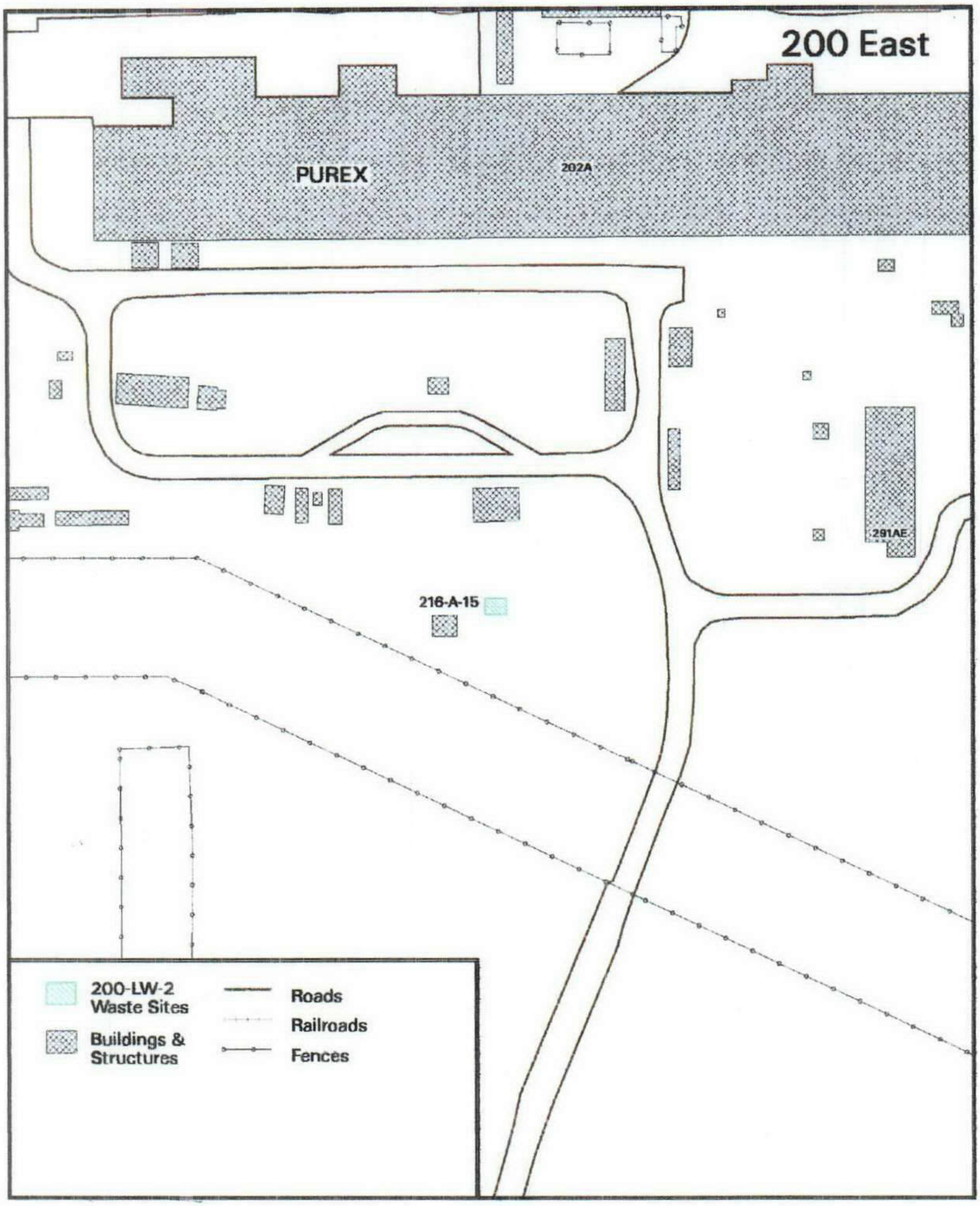

Figure 1-6. Data Evaluation Process.

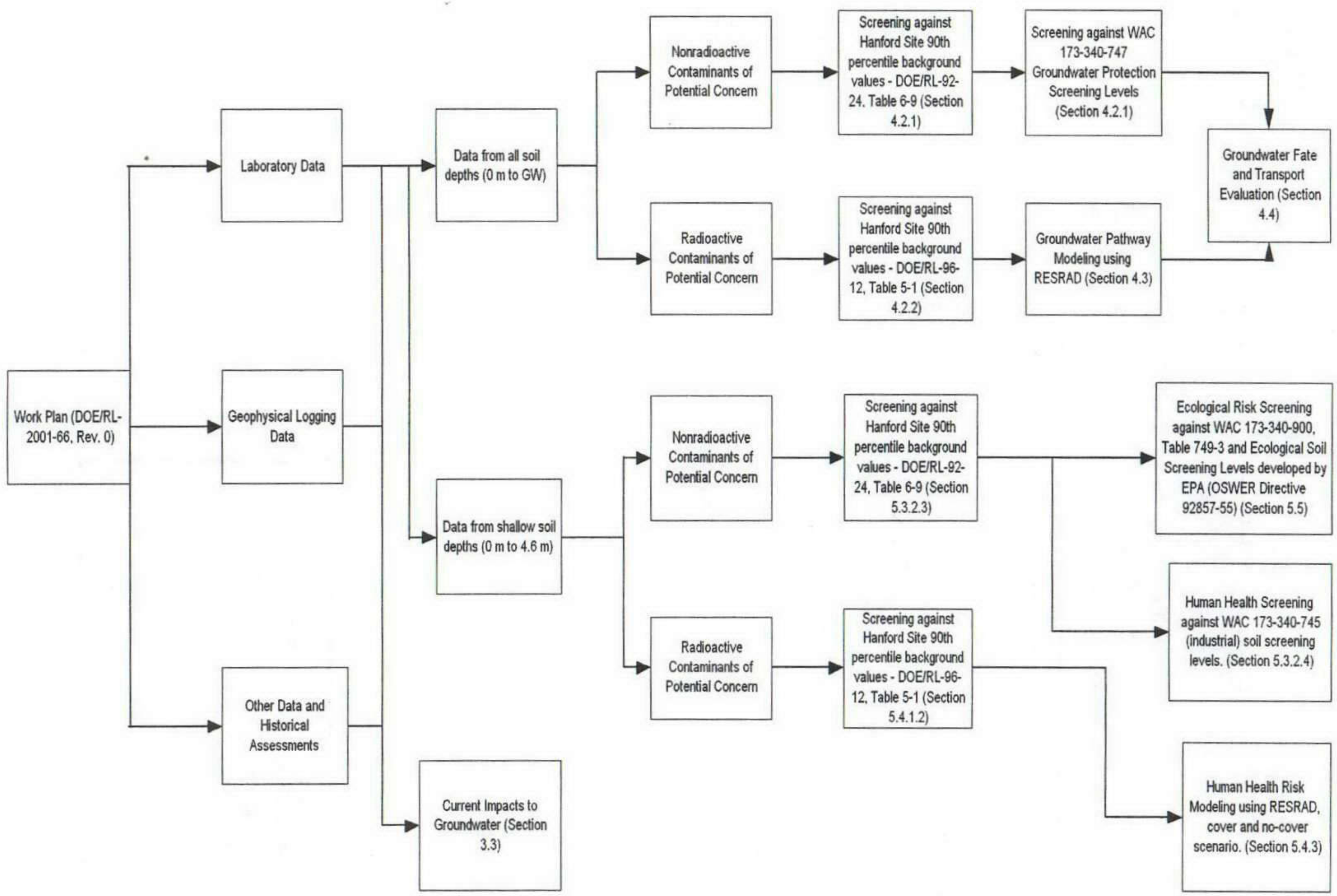

Figure 1-7. 216-T-28 Crib Construction Diagram.

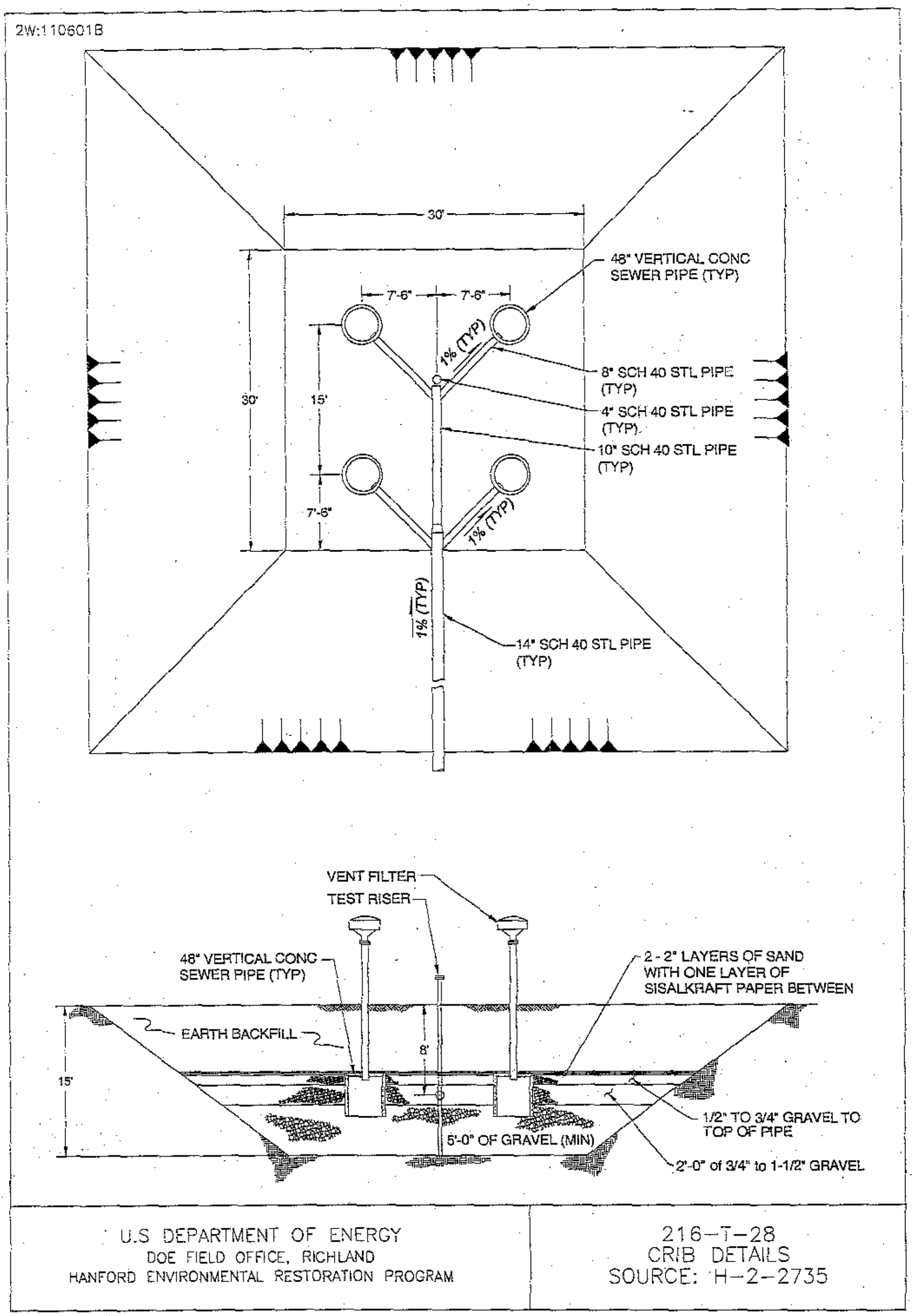

Figure 1-8. 216-S-20 Crib Construction Diagram.

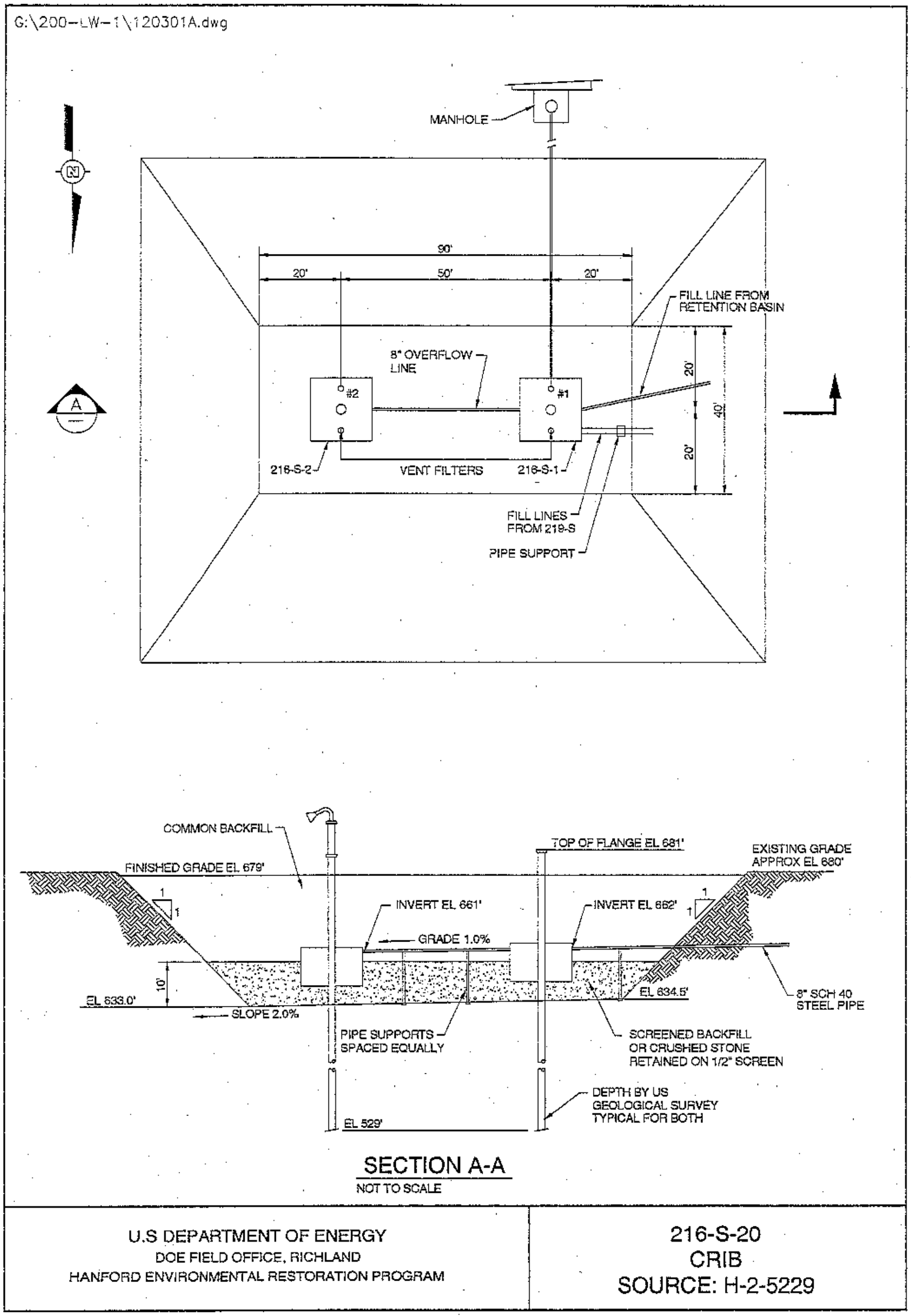

Figure 1-9. 216-Z-7 Crib Construction Diagram.

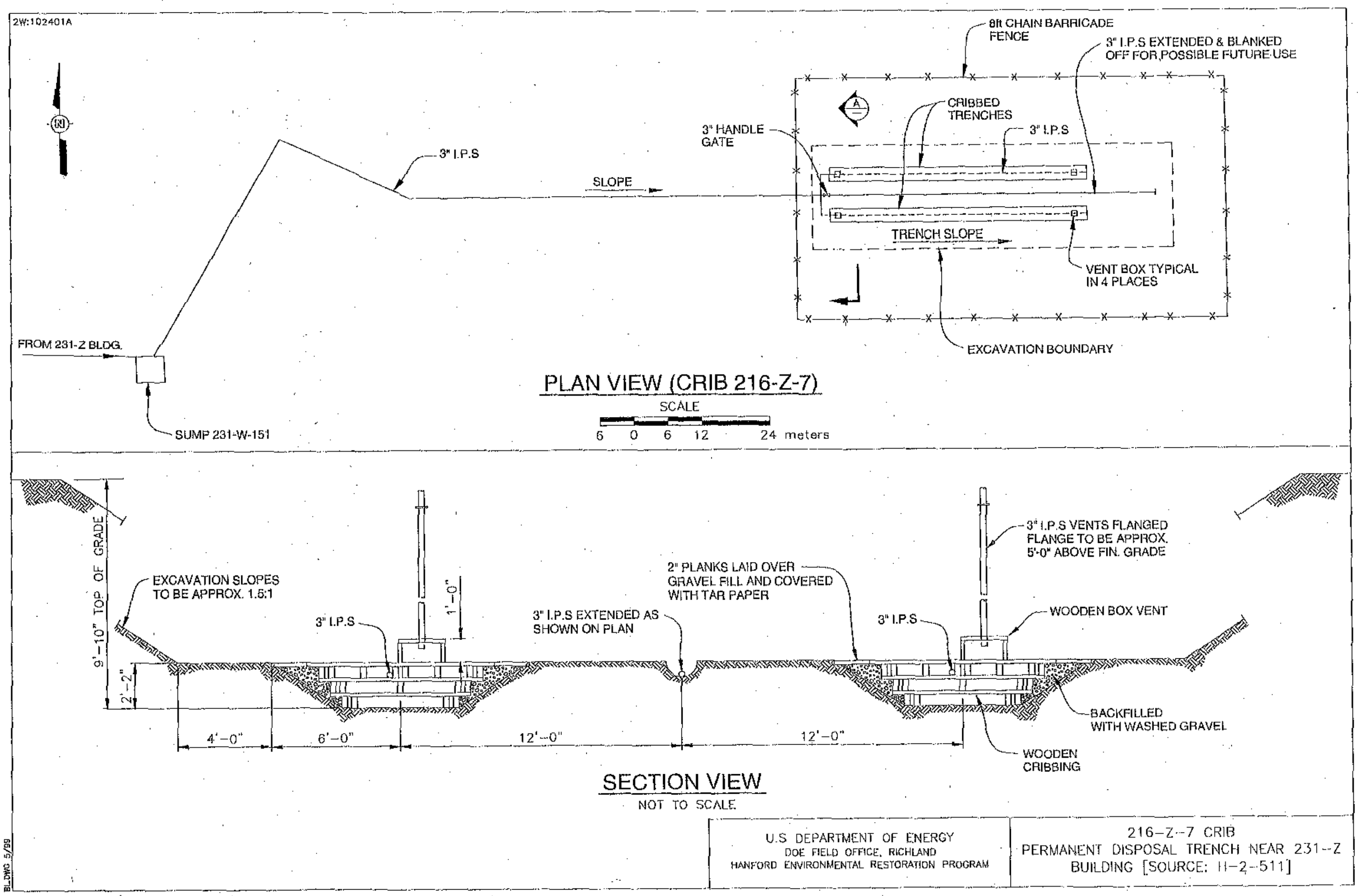

Table 1-1. List of 200-LW-1 and 200-LW-2 Operable Unit Waste Sites (data from DOE/RL-2001-66).

Operable Unit	Site Code	Site Type
200-LW-1	200-W-21	Pump Station
200-LW-1	200-W-82	Product Piping
200-LW-1	216-T-27	Crib
200-LW-1	216-T-28	Crib
200-LW-1	216-T-34	Crib
200-LW-1	216-T-35	Crib
200-LW-2	207-SL	Retention Basin
200-LW-2	216-A-15	French Drain
200-LW-2	216-B-6	Injection/Reverse Well
200-LW-2	216-B-10A	Crib
200-LW-2	216-B-10B	Crib
200-LW-2	216-S-19	Pond
200-LW-2	216-S-20	Crib
200-LW-2	216-S-26	Crib
200-LW-2	216-T-2	Injection/Reverse Well
200-LW-2	216-T-8	Crib
200-LW-2	216-Z-7	Crib
200-LW-2	216-Z-16	Crib
200-LW-2	216-Z-17	Trench
200-LW-2	CTFN 2703-E	Drain/Tile Field

CTFN 2703-E = Chemical Tile Field North of 2703 Hazardous Waste Storage Area.

Table 1-2. Description of Representative Waste Sites in the 200-LW-1 and 200-LW-2 Operable Units. (2 Pages)
(From DOE/RL-2001-66)

Site Code	Site Name	Location	Dates of Operation	Source Facility	Contaminant/ Volume Released	Depth	Waste Site Dimensions	General Description
216-T-28 Crib	216-T-28 Crib, 216-TY-3 Cavern, 216-TY-3 Crib, 216-TX-3 Cavern, 216-TX-3 Crib	Inside the 200 West Area, south of 23rd Street and east of Camden Avenue	1960 to 1966	221-T Plant Canyon Building steam condensate and process decontamination, 2607-T equipment decontamination waste from T Plant after it cascaded through tanks 241-T-110, 241-T-111, and 241-T-112 and the 300 Area laboratory facilities from the 340 Waste Neutralization Facility Complex.	4,230,000 L with 387 kg U; 70 g Pu; 193 Ci Cs-137; 106 Ci Sr-90, 10,000 kg NO_3	4.6 m (15 ft)	9 x 9 m (30 x 30 ft)	The unit consists of a 36 cm (14-in.) steel inlet pipe reducing to a 25.4 cm (10-in.) steel pipe, 2.4 m (8 ft) below grade. The pipe branches to four 20.3 cm (8-in.) steel pipes, each one extending to a 1.2 m (4-ft)-long by 1.2 m (4-ft)-diameter, open-end concrete sewer pipe. This structure rests in an excavation that is 4.6 m (15 ft) deep by 9 x 9 m (30 x 30 ft). The excavation is filled with 2.4 m (8 ft) of gravel and 2.1 m (7 ft) of earth. An underground pipeline was used to transfer waste from T Plant to the 216-T-27 and 216-T-28 Cribs. In 1964, 300 Area waste was combined with the T Plant waste that was discharged to the 216-T-27 and 216-T-28 Cribs. Effluent was temporarily diverted to the 216-T-27 Crib in November 1965. Remedial action in June and July 1975 included removing 15 cm (6 in.) of soil from affected areas and disposing of it in the 200 West Area Dry Waste Burial Grounds. The ground surface was covered with clean fill dirt to its original level. The 216-T-26, 216-T-27, and 216-T-28 Cribs all were surface stabilized in May 1990. They are enclosed within a common steel post and chain barricade that is posted "Underground Radioactive Material."

Table 1-2. Description of Representative Waste Sites in the 200-LW-1 and 200-LW-2 Operable Units. (2 Pages) (From DOE/RL-2001-66)

Site Code	Site Name	Location	Dates of Operation	Source Facility	Contaminant/ Volume Released	Depth	Waste Site Dimensions	General Description
216-S-20 Crib	216-S-20 Crib, 216-SL-1&2 Crib, 216-SL-2 Crib	Southeast of the 202-S (Reduction-Oxidation Plant) Facility	1952 to 1972	Liquid waste from 222-S Laboratory hoods. Also received 300 Area laboratory waste via manhole/piping located on the south side of crib.	135,000,000 L with 38.7 kg U; 171 g Pu; 56.5 Ci Cs-137; 22.7 Ci Sr-90; 20,000 kg NO_3	8.5 m (27.9 ft) Depth to the bottom of the crib	3.7 x 3.7 x 2.7 m (12 x 12 x 9 ft) Each crib	The unit contains two 3.7 x 3.7 x 2.7 m (12 x 12 x 9-ft) (LxWxH) wooden structures that are 15 m (49 ft) apart. The bottom of each wooden crib box is filled with 1.2 m (4 ft) of gravel. Each wooden crib box has two risers extending from the top of the box to above ground. The crib boxes are connected in series, with one box overflowing into another via a pipe. From January 1969 to November 1972, the site was inactive because of surface subsidence. The site was deactivated in December 1974. The unit has a history of subsidence. Sink holes have been filled in on three different occasions with several cubic yards of fill dirt. Two areas inside the Underground Radioactive Material Area are marked with post and chain and "cave-in potential" signs.
216-Z-7 Crib	216-Z-7 Crib, 231-W Crib, 231-W Trench, 216-Z-6 Crib	East of the 231-Z Plutonium Isolation Plant Building and north of 19th Street	1947 to 1967	Process waste from the 231-Z Plutonium Isolation Plant via the 231-Z-151 Sump; and 231-Z Plutonium Isolation Plant laboratory waste via the 231-W-151 Sump. It also received 300 Area laboratory waste from the 340 Waste Neutralization Facility.	79,900,000 L with 4.46 kg U; 2000 g Pu; 200 Ci Cs-137; 200 Ci Sr-90; 20,000 kg NO_3	0.6 m (2 ft) Surface stabilization 3 m (10 ft) Excavation	51 x 15 m (167 x 49 ft) Excavation	The crib was built to replace the 216-Z-5 Crib. The site consists of two parallel wooden structures 45.7 m (150 ft) long by 1.5 m (5 ft) wide by 0.6 m (2 ft) high, placed in a 1.5 m (5-ft)-deep excavation. Each wooden structure was constructed of three overlapping tiers. A 45.8 m (150-ft)-long, 7.5 or 10 cm (3- or 4-in.)-diameter perforated distribution pipe runs above the second tier. Each of the two trenches is covered by 503 m (1,650 ft) of 5 cm (2-in.) planking, then tar paper. Deactivation was accomplished in 1967 by blanking the pipeline west of the 231-Z-151 Sump and backfilling the excavation with gravel. The site was interim stabilized in 1990. Seven monitoring wells surround this structure. Monitoring results indicate potential radionuclide contamination in the vadose zone.

2.0 INVESTIGATION APPROACH AND ACTIVITIES

This chapter summarizes the data collection activities performed during the 200-LW-1 and 200-LW-2 OU RI. These activities are described in detail in D&D-25461. The RI was conducted in accordance with the SAP found in Appendix A of the Work Plan (DOE/RL-2001-66). The RI needs for the 200-LW-1 and 200-LW-2 OUs were developed and presented in the DQO process summary reports (BHI-01589 and WMP-18098). The DQO process is used to develop a data collection strategy consistent with data uses and needs. The objectives identified include collecting data that will be used to define the nature and extent of radiological and chemical contamination, supporting evaluation of risks, and assisting in the evaluation, selection, and design of remediation alternatives.

Data were collected to characterize the nature and vertical extent of chemical and radiological contamination and the physical conditions in the vadose zone underlying the historical boundaries of the 216-T-28 Crib in the 200-LW-1 OU and of the 216-S-20 Crib and 216-Z-7 Crib in the 200-LW-2 OU. Borehole drilling and sampling, direct-push sampling, and surface and borehole geophysical surveys were conducted during the field activities. All boreholes were completed, and all samples were collected and analyzed for COPCs, as identified in the DQO reports and the SAP.

2.1 200-LW-1 AND 200-LW-2 OPERABLE UNIT REMEDIAL INVESTIGATION DRILLING

Three boreholes (C4175, C4176, and C4183) were drilled and sampled during the 200-LW-1 and 200-LW-2 OU RI. Boreholes were drilled through the 216-T-28 Crib, the 216-S-20 Crib, and the 216-Z-7 Crib from the ground surface to the water table at depths of approximately 69 m (226.5 ft), 74 m (243.5 ft), and 68 m (225 ft) bgs, respectively. The boreholes were drilled to better define stratigraphy and to assess the nature and vertical extent of chemical and radiological contamination as well as the physical properties of the soil beneath these waste sites.

Six direct-push holes (C4177, C4178, C4179, C4180, C4181 and C4182) were installed in the area of the 216-Z-7 Crib. Direct-push hole C4182 was completed to a depth of 16.5 m (54 ft), and the other five direct-push holes were completed to a depth of 15.3 m (50 ft). Geophysical logs were run in each cased hole to determine where borehole C4183 could be drilled and sampled in the area of highest contamination in this crib.

Cable-tool drilling equipment with drive-barrel cuttings technology was used to construct all three boreholes. Two telescoped, threaded carbon-steel temporary casing strings (0.273 m [10.75-in.] outside diameter and 0.219 m [8.625-in.] inside diameter) were used to keep each borehole open and minimize the potential for downhole cross-contamination. A hammer drill with casing of 0.168 m (6.625-in.) outside diameter and 0.152 m (6.0-in.) inside diameter was used to construct the six direct-push holes at the 216-Z-7 Crib. A split-spoon drive-barrel sampler with stainless steel liners was used for soil acquisition. Soil samples were collected from the three boreholes for chemical and radiological analyses. Additionally, one liner each from selected intervals was submitted for determination of physical properties.

After completion of sample collection from the boreholes and the geophysical logging of all holes, the boreholes and direct-push holes were backfilled to prevent the holes from becoming a preferential pathway for contaminant migration. As casing was extracted, silica sand was placed at the bottom of the borings to maintain natural groundwater flow below the water table. Granular bentonite then was placed from the top of the silica sand pack to a level just below the ground surface. Caution was taken during the casing extraction to maintain an overlap between the bentonite backfill and the casing(s), to prevent the surrounding formation from collapsing into the hole. A surface seal of poured cement grout or concrete was placed on top of the bentonite, and a brass survey tag was embedded on the surface cap to complete the decommissioning operations in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells."

The borehole locations at the three representative waste sites investigated during the RI and the six direct-push hole locations at 216-Z-7 Crib are shown in Figures 2-1 through 2-3.

2.1.1 200-LW-1 and 200-LW-2 Operable Unit Remedial Investigation Sampling and Analysis

Soil samples collected from the boreholes were screened in the field before sample collection for indications of contamination and to assist with determining discrete sample locations or depths. Samples were screened for volatile organic contamination using hand-held vapor analyzers. Soil samples were screened for alpha, beta, and gamma radioactivity to assist in modifying or selecting sample points, to support worker health and safety, and for sample shipping information. A radiation control technician performed the radiological screening using field screening instruments. Radiological activity greater than two times background was used as an indicator of high contamination.

Soil samples were collected for chemical and radiological analysis and determination of physical properties. Sample collection was guided by the sample schedule in the Work Plan (DOE/RL-2001-66, Appendix A). The sampling approach generally required a greater sample frequency near the bottom of each waste site, which is the area of highest suspected contamination. Parameters for the sample analyses performed at each borehole are presented in Tables 2-1 through 2-3. The distance between sample intervals generally increased below depths of about 15.2 to 27.4 m (50 to 90 ft).

Samples from 4.6 and 7.6 m (15 and 25 ft) bgs were considered critical to evaluate exposure scenarios and remedial alternatives. Samples from depths greater than 7.6 m (25 ft) bgs are used to verify conceptual contaminant models and to evaluate remedial action alternatives and groundwater impacts.

A total of 93 samples, including QA/QC samples, were collected for chemical and radioisotopic analysis. Twenty-three samples were QA/QC samples (trip blanks, equipment blanks, split samples, and duplicate samples). Eleven physical property samples were collected and analyzed for this RI.

Soil samples were analyzed for volatile organics, semivolatile organics (including polychlorinated biphenyls [PCBs]), inorganics (metals, ammonia, ammonium ion, chloride, fluoride, nitrate, nitrite, nitrogen, phosphate sulfate, sulfide), oil and grease, total petroleum hydrocarbons (TPH) (diesel, kerosene, and gasoline ranges), and radionuclides. Samples were analyzed selectively for field bulk density, moisture content, and particle size.

2.1.2 200-LW-1 and 200-LW-2 Operable Unit Remedial Investigation Borehole Geophysical Logging

A spectral gamma-ray logging system (SGLS) and a high-rate logging system (HRLS) were used to capture the down-hole radiometric signature at the three boreholes and six direct-push holes completed during the RI. The logging systems provided a continuous radiometric signature of the soils through a single thickness of casing to drilled depth.

In addition, selected existing boreholes in the vicinity of each waste site were logged using an SGLS and an HRLS. These boreholes are listed, along with the new boreholes and direct-push holes, in Table 2-4.

Where SGLS dead time exceeds 40 percent, peak spreading and pulse pile-up effects may result in an underestimation of activities. This effect is not entirely corrected by dead-time correcting, and the extent of error increases with increasing dead time. In these instances, the HRLS data were substituted for the SGLS data. Dead time corrections were required on some direct-push holes and existing boreholes that had less than 40 percent dead time. No water corrections were required for any of the direct-push holes or existing boreholes.

Passive neutron logging also was performed in each direct-push hole, to detect neutrons that may be generated by interactions of alpha particles in the soil or, to a lesser extent, from spontaneous fission.

Detailed reports of the borehole geophysical logging conducted in each borehole or direct-push hole are provided in D&D-25461.

2.2 OTHER 200-LW-1 AND 200-LW-2 OPERABLE UNIT ACTIVITIES

2.2.1 Surface Geophysical Surveys and Radiological Field Screening

Surface geophysical surveys were conducted at all borehole and direct-push locations before drilling. The surveys were performed to verify the location of waste sites and to identify potential underground hazards.

Because drilling up to 30.5 m (100 ft) bgs was classified as medium to low risk, continuous radiological field screening of the drill cuttings and the immediate work area occurred to that depth. Deeper than 30.5 m (100 ft) bgs, morning and afternoon radiological surveys were conducted for the remaining drilling. Radiological activity greater than two times background was the action level used as an indicator of high contamination. Background was established by measuring activity at ground surface adjacent to the borehole. Radiological field-screening data was used to modify or select sample locations and to support worker health and safety.

2.2.2 Air Monitoring

Air monitoring during the RI field activities was conducted in accordance with CCN 087338, "Environmental Restoration Program ALARACT Demonstration for Drilling – Drilling Activities Outside the Tank Farms Fence Line on the Hanford Site." Air monitoring for the drilling and direct-push activities was conducted by the Fluor Hanford Industrial Hygiene Group in accordance with protocols of the National Institute for Occupational Safety and Health, Occupational Safety and Health Administration, and the American Conference of Governmental Industrial Hygienists. Air monitoring was conducted to verify that the breathing zone remained free of contamination and that the drill crew was wearing the proper protective equipment.

2.2.3 Geodetic Survey

The boreholes were surveyed in accordance with GRP-EE-01-1.6, *Environmental Information Systems -- Survey Requirements and Techniques*. Vertical coordinates were recorded using *North American Vertical Datum of 1988* (NAVD88) and the horizontal coordinates were recorded using *North American Datum of 1983* (NAD83), as revised, for the Washington State Plane (South Zone), with the 1991 adjustment for horizontal coordinates. Survey data are presented in Table 2-4.

Figure 2-1. 216-T-28 Crib and Borehole Location Map.

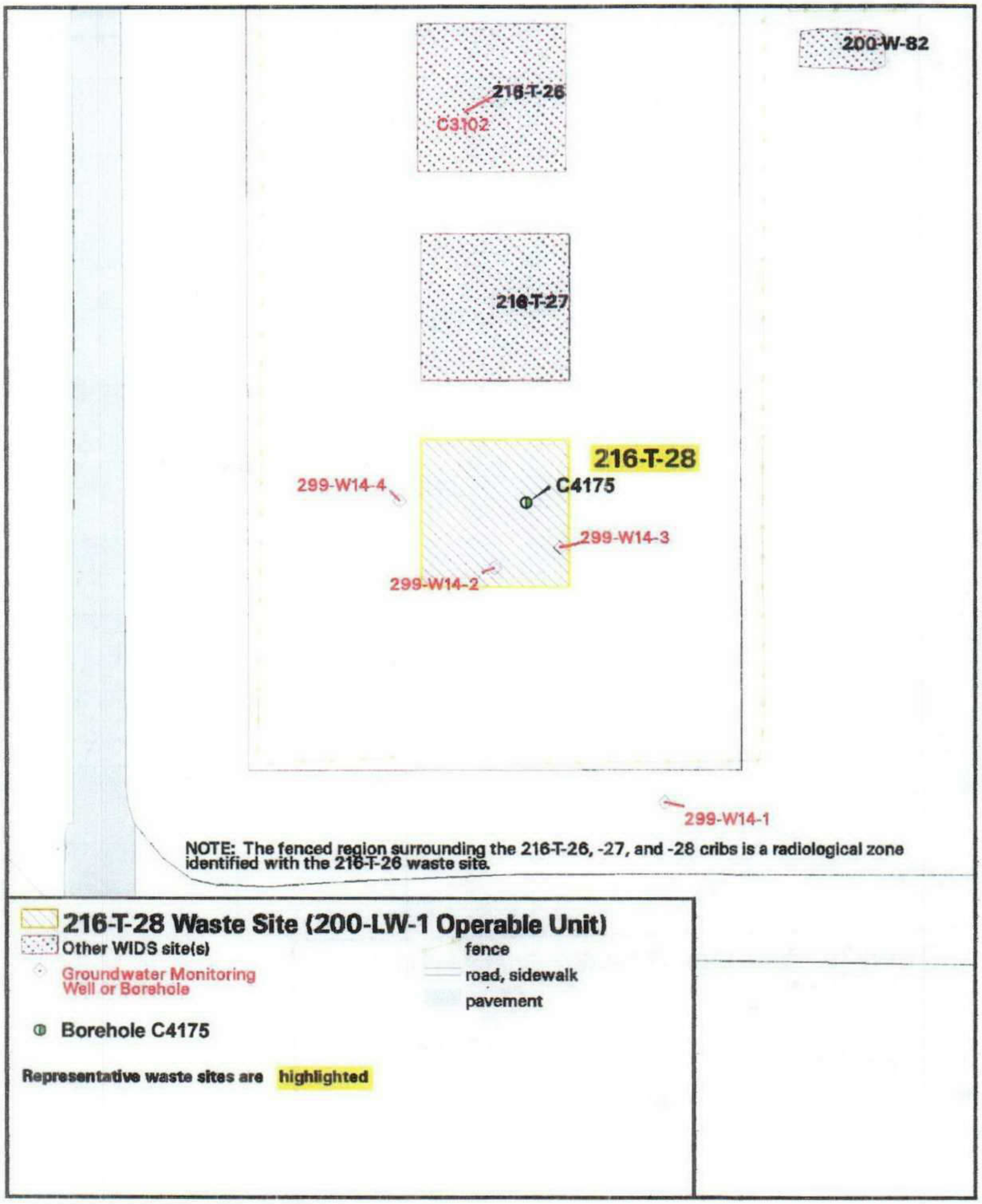

Figure 2-2. 216-S-20 Crib and Borehole Location Map.

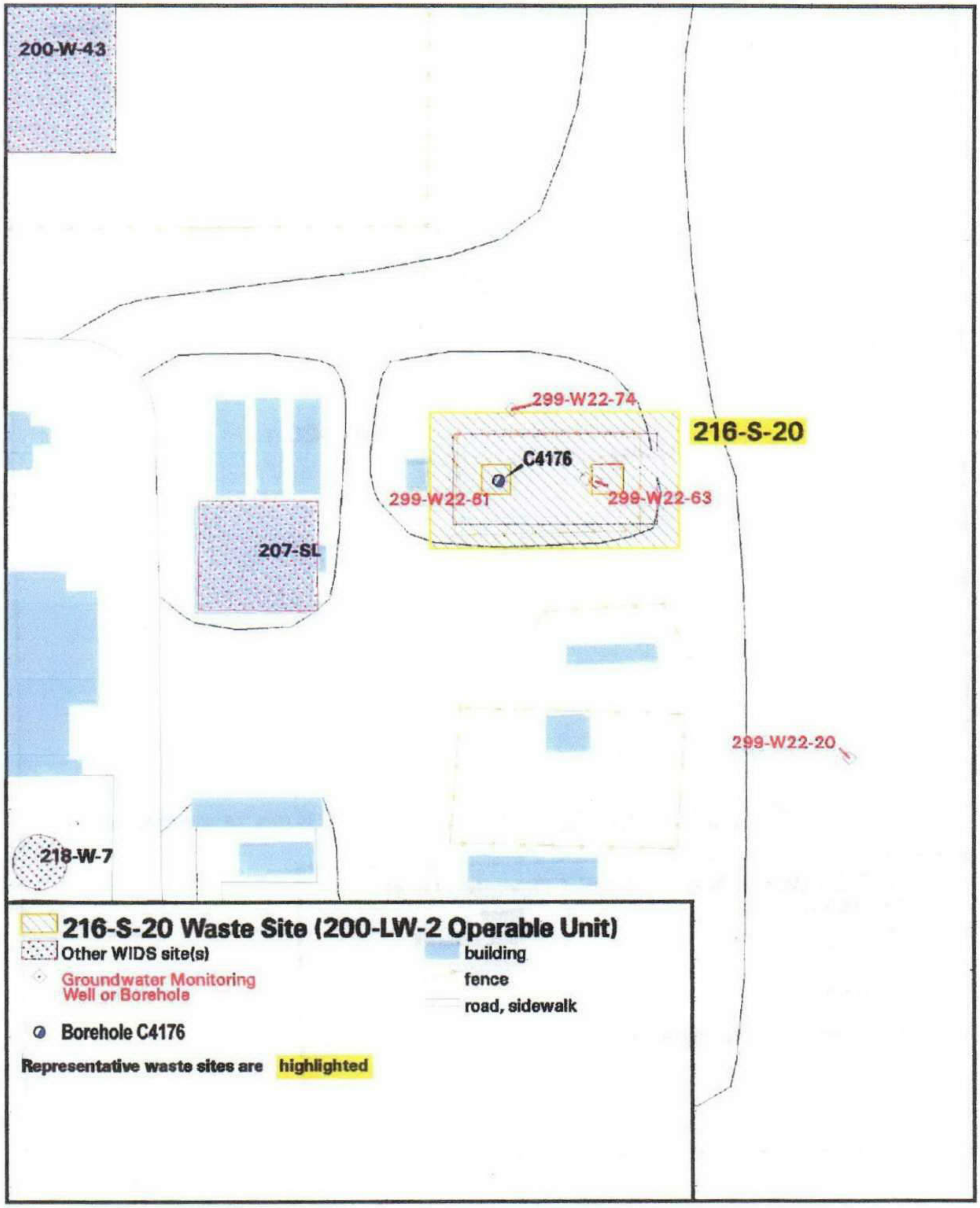

Figure 2-3. 216-Z-7 Crib and Borehole Location Map.

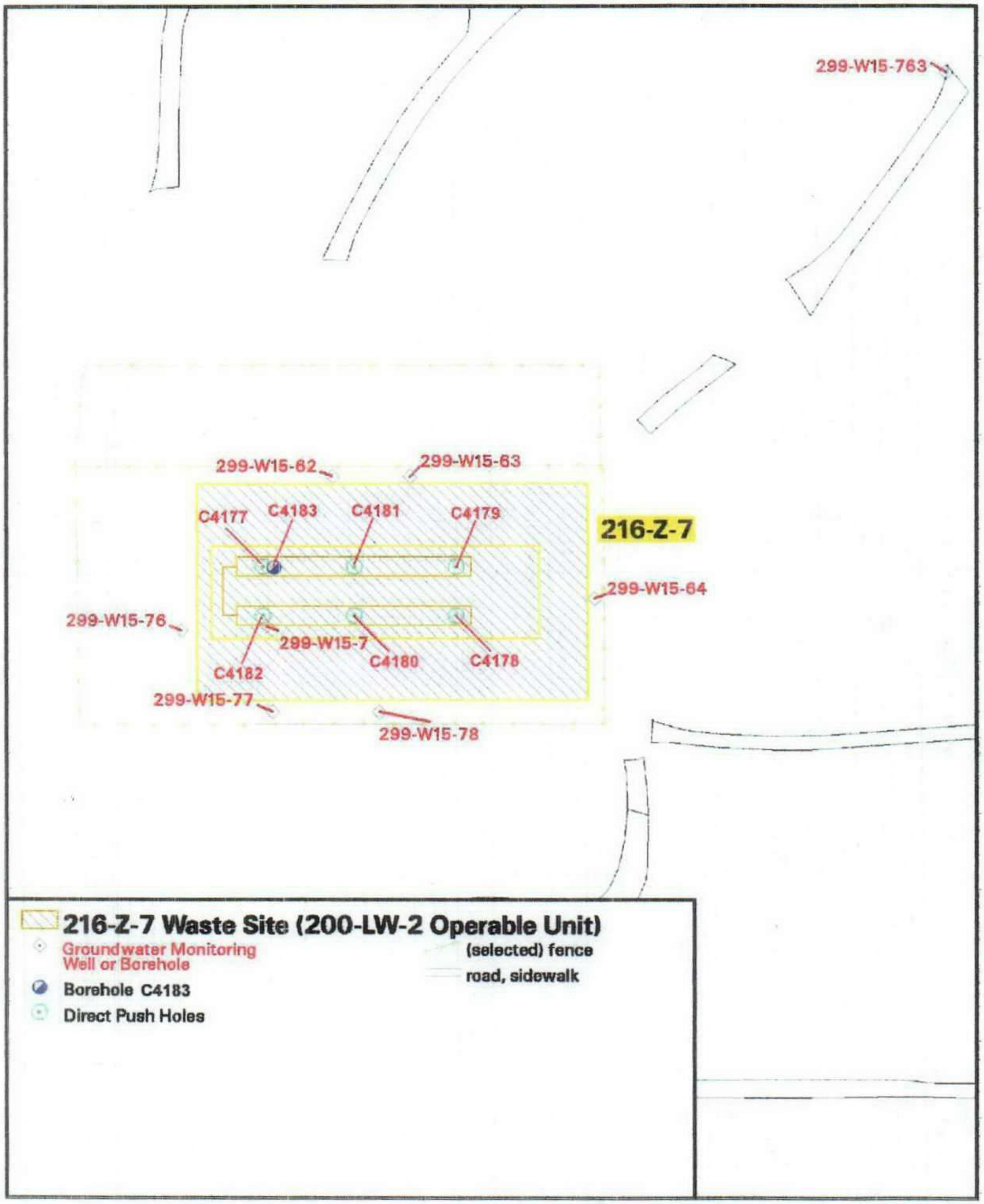

Table 2-1. Sample Collection Data, 200-LW-1 Operable Unit Borehole C4175 (216-T-28 Crib). (2 Pages)

HEIS	Date Collected	Data Package	Site	Depth Collected (ft bgs)	Depth Planned (ft bgs)	Laboratory[a]	Sample Analysis Performed[b]
B19182	09/20/04	WSCF20041686	C4175	QA/QC	QA/QC	WSCF	Metals, pH, SVOA, VOA, general chemistry, gross alpha & beta
B19183	09/20/04	H2756	C4175	QA/QC	QA/QC	Lionville	nitrate/nitrite, sulfide
B19184	11/15/04	WSCF20042147	C4175	QA/QC	QA/QC	WSCF	VOA
B19188	10/20/04	H2815	C4175	17.5 - 20	17.5 - 20	Eberline	Rad
B19188	10/20/04	W04380	C4175	17.5 - 20	17.5 - 20	STLSL	Metals, PCB, TPH, pH, VOA, SVOA, general chemistry
B19189	10/26/04	W04380	C4175	22.5 - 25	22.5 - 25	STLSL	Metals, PCB, TPH, pH, VOA, SVOA, general chemistry
B19189	10/26/04	WSCF20042054	C4175	22.5 - 25	22.5 - 25	WSCF	Rad
B191B2	10/26/04	H2815	C4175	22.5 - 25	22.5 - 25	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B193K1	10/26/04	W04380-S	C4175	22.5 - 25	22.5 - 25	STLRL	Rad
B193K1	10/26/04	W04380	C4175	22.5 - 25	22.5 - 25	STLSL	Oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B19HY6	10/26/04	H2815-S	C4175	22.5 - 25	22.5 - 25	Eberline & Lionville	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B19187	10/27/04	WSCF20042022	C4175	27.5 - 30	27.5 - 30	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B19190	10/27/04	WSCF20042022	C4175	27.5 - 30	27.5 - 30	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B191B0	10/27/04	H2819-D	C4175	27.5 - 30	27.5 - 30	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B191B3	10/27/04	H2819	C4175	27.5 - 30	27.5 - 30	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B19191	10/28/04	WSCF20042022	C4175	32.5 - 35	32.5 - 35	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B191B4	10/28/04	H2810	C4175	32.5 - 35	32.5 - 35	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B191C1	10/28/04	H2810	C4175	32.5 - 35	32.5 - 35	Shaw	Density, pH, percent moisture, particle size
B19192	11/01/04	WSCF20042022	C4175	47.5 - 50	47.5 - 50	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B191B5	11/01/04	H2810	C4175	47.5 - 50	47.5 - 50	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B19193	11/11/04	WSCF20042123	C4175	67.5 - 70	67.5 - 70	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B191B6	11/11/04	H2842	C4175	67.5 - 70	67.5 - 70	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}

Table 2-1. Sample Collection Data, 200-LW-1 Operable Unit Borehole C4175 (216-T-28 Crib). (2 Pages)

HEIS	Date Collected	Data Package	Site	Depth Collected (ft bgs)	Depth Planned (ft bgs)	Laboratory[a]	Sample Analysis Performed[b]
B191C2	11/11/04	H2842	C4175	67.5 - 70	67.5 - 70	Shaw	Density, pH, percent moisture, particle size
B19194	11/15/04	WSCF20042146	C4175	90 - 92.5	90 - 92.5	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B191B7	11/15/04	H2842	C4175	90 - 92.5	90 - 92.5	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B191C3	11/15/04	H2842	C4175	90 - 92.5	90 - 92.5	Shaw	Density, pH, percent moisture, particle size
B19195	11/20/04	WSCF20042201	C4175	157.5 - 160	157.5 - 160	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B191B8	11/20/04	H2856	C4175	157.5 - 160	157.5 - 160	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B19196	11/24/04	WSCF20042240	C4175	197.5 - 200	197.5 - 200	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B191B9	11/24/04	H2861	C4175	197.5 - 200	197.5 - 200	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B19441	11/24/04	H2861	C4175	197.5 - 200	197.5 - 200	Shaw	Density, pH, percent moisture, particle size
B19197	12/02/04	WSCF20042304	C4175	223.5 - 226	223.5 - 226	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B191C0	12/02/04	H2883	C4175	223.5 - 226	223.5 - 226	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}

[a]The analyses were performed by Eberline Services, Richmond, California; Lionville Laboratory, Inc., Exton, Pennsylvania; Severn Trent Laboratories, Inc., Earth City, Missouri (STLSL) with a laboratory in Richland, Washington (STLRL); Shaw Group, Inc. Geotechnical Laboratory, Oak Ridge, Tennessee; and Waste Sampling and Characterization Facility (WSCF), Hanford Site, Richland, Washington.

[b]See Appendix B for analytical methods.

bgs = below ground surface.
HEIS = *Hanford Environmental Information System* database.
PCB = polychlorinated biphenyl.
QA = quality assurance.
QC = quality control.
Rad = radionuclide.
SVOA = semivolatile organic analysis.
TPH = total petroleum hydrocarbon.
VOA = volatile organic analysis.

Table 2-2. Sample Collection Data, 200-LW-2 Operable Unit Borehole C4176 (216-S-20 Crib). (2 Pages)

HEIS	Date Collected	Data Package	Site	Depth Collected (ft bgs)	Depth Planned (ft bgs)	Laboratory[a]	Sample Analysis Performed[b]
B191D6	08/03/04	WSCF20041342	C4176	QA/QC	QA/QC	WSCF	Metals, pH, SVOA, VOA, general chemistry, gross alpha & beta
B191D7	08/03/04	H2662	C4176	QA/QC	QA/QC	Eberline	nitrate/nitrite, sulfide, ammonia
B191D8	09/01/04	WSCF20041519	C4176	QA/QC	QA/QC	WSCF	VOA
B191F0	08/10/04	WSCF20041392	C4176	12.5 - 15	12.5 - 15	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B191J1	08/10/04	H2679	C4176	12.5 - 15	12.5 - 15	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B191F1	08/18/04	222S20040166	C4176	29.5 - 32	32 - 34.5	222-S	PCB, pH, VOA, SVOA, mercury, general chemistry
B191F1	08/18/04	W04380	C4176	29.5 - 32	32 - 34.5	STLSL	Metals
B191J2	08/18/04	222S20040166	C4176	29.5 - 32	32 - 34.5	222-S	Sulfide
B191J2	08/18/04	H2704	C4176	29.5 - 32	32 - 34.5	Eberline	Rad
B191F3	08/18/04	WSCF20041462	C4176	32.5 - 35	35 - 37.5	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B191J4	08/18/04	H2704	C4176	32.5 - 35	35 - 37.5	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B193K0	08/18/04	W04366	C4176	32.5 - 35	35 - 37.5	STLRL	Rad
B193K0	08/18/04	W04366	C4176	32.5 - 35	35 - 37.5	STLSL	Oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B19HY8	08/18/04	H2704	C4176	32.5 - 35	35 - 37.5	Eberline & Lionville	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B191F2	08/19/04	WSCF20041448	C4176	40 - 42.5	40 - 42.5	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B191F4	08/19/04	WSCF20041448	C4176	40 - 42.5	40 - 42.5	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B191J3	08/19/04	H2691	C4176	40 - 42.5	40 - 42.5	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B191J5	08/19/04	H2691	C4176	40 - 42.5	40 - 42.5	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B191F5	08/25/04	WSCF20041476	C4176	47.5 - 50	47.5 - 50	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B191J6	08/25/04	H2691	C4176	47.5 - 50	47.5 - 50	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B191F6	08/31/04	WSCF20041511	C4176	72 - 74.5	72.5 - 75	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B191J7	08/31/04	H2708	C4176	72 - 74.5	72.5 - 75	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}

Table 2-2. Sample Collection Data, 200-LW-2 Operable Unit Borehole C4176 (216-S-20 Crib). (2 Pages)

HEIS	Date Collected	Data Package	Site	Depth Collected (ft bgs)	Depth Planned (ft bgs)	Laboratory[a]	Sample Analysis Performed[b]
B19443	08/31/04	H2708-A	C4176	72 - 74.5	72.5 - 75	Shaw	Density, pH, percent moisture, particle size
B191F7	09/01/04	WSCF20041518	C4176	97 - 99.5	97.5 - 100	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B191J8	09/01/04	H2708	C4176	97 - 99.5	97.5 - 100	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B191F8	09/07/04	WSCF20041555	C4176	151.5 - 154	158 - 160.5	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B191J9	09/07/04	H2714-A	C4176	151.5 - 154	158 - 160.5	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B19444	09/09/04	H2714	C4176	151.5 - 154	158 - 160.5	Shaw	Density, pH, percent moisture, particle size
B191F9	09/08/04	WSCF20041585	C4176	191.5 - 194	202 - 204.5	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B191K0	09/08/04	H2714-A	C4176	191.5 - 194	202 - 204.5	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B19445	09/08/04	H2720-A	C4176	191.5 - 194	202 - 204.5	Shaw	Density, pH, percent moisture, particle size
B191H0	09/13/04	WSCF20041599	C4176	238 - 240.5	230 - 232.5	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B191K1	09/13/04	H2720	C4176	238 - 240.5	230 - 232.5	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B19446	09/13/04	H2720-A	C4176	238 - 240.5	230 - 232.5	Shaw	Density, pH, percent moisture, particle size

[a]The analyses were performed by Eberline Services, Richmond, California; Lionville Laboratory, Inc., Exton, Pennsylvania; Severn Trent Laboratories, Inc., Earth City, Missouri (STLSL) with a laboratory in Richland, Washington (STLRL); Shaw Group, Inc. Geotechnical Laboratory, Oak Ridge, Tennessee; 222-S Laboratory Operations, Hanford Site, Richland, Washington; and Waste Sampling and Characterization Facility (WSCF), Hanford Site, Richland, Washington.

[b]See Appendix B for analytical methods.

bgs = below ground surface.
HEIS = *Hanford Environmental Information System* database.
PCB = polychlorinated biphenyl.
QA = quality assurance.
QC = quality control.
Rad = radionuclide.
SVOA = semivolatile organic analysis.
TPH = total petroleum hydrocarbon.
VOA = volatile organic analysis.

Table 2-3. Sample Collection Data, 200-LW-2 Operable Unit Borehole C4183 (216-Z-7 Crib). (2 Pages)

HEIS	Date Collected	Data Package	Site	Depth Collected (ft bgs)	Depth Planned (ft bgs)	Laboratory[a]	Sample Analysis Performed[b]
B19447	01/03/05	WSCF20050005	C4183	QA/QC	QA/QC	WSCF	Metals, VOA, SVOA, general chemistry, gross alpha and beta
B19448	01/03/05	H2961	C4183	QA/QC	QA/QC	Eberline	Sulfide, nitrate/nitrite, ammonia
B1BX40	02/08/05	WSCF20050331	C4183	QA/QC	QA/QC	WSCF	VOA
B1BX43	02/16/05	WSCF20050389	C4183	QA/QC	QA/QC	WSCF	VOA
B1BX44	02/22/05	WSCF20050509	C4183	QA/QC	QA/QC	WSCF	VOA
B1BX45	03/03/05	WSCF20050507	C4183	QA/QC	QA/QC	WSCF	VOA
B1BX46	03/04/05	WSCF20050523	C4183	QA/QC	QA/QC	WSCF	VOA
B1BX47	03/18/05	WSCF20050621	C4183	QA/QC	QA/QC	WSCF	VOA
B1BX48	03/23/05	WSCF20050658	C4183	QA/QC	QA/QC	WSCF	VOA
B1BX49	02/08/05	WSCF20050331	C4183	QA/QC	QA/QC	WSCF	VOA
B19402	02/08/05	WSCF20050329	C4183	12.5 -15	12.5 -15	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B19423	02/08/05	H3037	C4183	12.5 - 15	12.5 - 15	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B1BX65	02/08/05	H3037	C4183	12.5 - 15	12.5 - 15	Eberline	Rad
B19405	02/08/05	H3046	C4183	17.5 - 20	17.5 - 20	Eberline	Rad
B19405	02/08/05	W04523	C4183	17.5 - 20	17.5 - 20	STLSL	Metals, TPH, pH, VOA, SVOA, general chemistry
B19403	02/10/05	H3046	C4183	22.5 - 25	22.5 - 25	Eberline	Rad
B19403	02/10/05	W04523	C4183	22.5 - 25	22.5 - 25	STLRL	Rad
B19404	02/10/05	W04523	C4183	22.5 - 25	22.5 - 25	STLSL	Metals, TPH, pH, VOA, SVOA, general chemistry
B19406	02/14/05	W04523	C4183	27.5 - 30	27.5 - 30	STLSL	Metals, PCB, TPH, pH, VOA, SVOA, general chemistry
B19427	02/14/05	H3046	C4183	27.5 - 30	27.5 - 30	Eberline	Rad
B19407	02/16/05	WSCF20050388	C4183	40 - 42.5	40 - 42.5	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B19428	02/16/05	H3066	C4183	40 - 42.5	40 - 42.5	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B19408	02/22/05	WSCF20050508	C4183	57.5 - 60	57.5 - 60	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B19429	02/22/05	H3071	C4183	57.5 - 60	57.5 - 60	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B19435	02/22/05	H3071	C4183	57.5 - 60	57.5 - 60	Shaw	Density, pH, percent moisture, particle size
B19409	03/03/05	WSCF20050506	C4183	96.5 - 99	95 - 97.5	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B19430	03/03/05	H3071	C4183	96.5 - 99	95 - 97.5	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B19436	03/03/05	H3071	C4183	96.5 - 99	95 - 97.5	Shaw	Density, pH, percent moisture, particle size
B19410	03/04/05	WSCF20050520	C4183	117.5 - 120	117.5 - 120	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry

Table 2-3. Sample Collection Data, 200-LW-2 Operable Unit Borehole C4183 (216-Z-7 Crib). (2 Pages)

HEIS	Date Collected	Data Package	Site	Depth Collected (ft bgs)	Depth Planned (ft bgs)	Laboratory[a]	Sample Analysis Performed[b]
B19431	03/04/05	H3071	C4183	117.5 - 120	117.5 - 120	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B19411	03/18/05	WSCF20050622	C4183	197.5 - 200	197.5 - 200	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B19432	03/18/05	H3098	C4183	197.5 - 200	197.5 - 200	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}
B19437	03/18/05	H3098	C4183	197.5 - 200	197.5 - 200	Shaw	Density, pH, percent moisture, particle size
B19412	03/23/05	WSCF20050656	C4183	220 - 222.5	214 - 217.5	WSCF	Metals, PCB, TPH, pH, Rad, VOA, SVOA, general chemistry
B19433	03/23/05	H3098	C4183	220 - 222.5	214 - 217.5	Eberline & Lionville	Rad, oil/grease, sulfide, nitrate/nitrite, Cr^{+6}

[a]The analyses were performed by Eberline Services, Richmond, California; Lionville Laboratory, Inc., Exton, Pennsylvania; Severn Trent Laboratories, Inc., Earth City, Missouri (STLSL) with a laboratory in Richland, Washington (STLRL); Shaw Group, Inc. Geotechnical Laboratory, Oak Ridge, Tennessee; 222-S Laboratory Operations, Hanford Site, Richland, Washington; and Waste Sampling and Characterization Facility (WSCF), Hanford Site, Richland, Washington.

[b]See Appendix B for analytical methods.

bgs = below ground surface.
HEIS = *Hanford Environmental Information System* database.
PCB = polychlorinated biphenyl.
QA = quality assurance.
QC = quality control.
Rad = radionuclide.
SVOA = semivolatile organic analysis.
TPH = total petroleum hydrocarbon.
VOA = volatile organic analysis.

Table 2-4. List of New and Existing Boreholes for Spectral Gamma-Ray Logging.

Borehole Number	Approximate Location	Coordinates (Wash. State Plane, NAD83[91])	
		Northing	Easting
C4175[a]	216-T-28 Crib Area (new borehole)	136348.82	566931.9
C4176[a]	216-S-20 Crib Area (new borehole)	133914.01	567548.27
C4177[a]	216-Z-7 Crib Area (new push hole)	135930.1	566676.79
C4178[a]	216-Z-7 Crib Area (new push hole)	135922.76	566705.52
C4179[a]	216-Z-7 Crib Area (new push hole)	135929.6	5666706.98
C4180[a]	216-Z-7 Crib Area (new push hole)	135962.04	566699.9
C4181[a]	216-Z-7 Crib Area (new push hole)	135929.94	566691.67
C4182[a]	216-Z-7 Crib Area (new push hole)	135923.63	566675.65
C4183[a]	216-Z-7 Crib Area (new borehole)	135930.56	566676.87
299-W14-1	South of 216-T-28	136392.107	566932.165
299-W14-2	South area of 216-T-28	136392.107	566932.165
299-W14-3	Southeast boundary of 216-T-28	136392.107	566932.165
299-W14-4	Northwest of 216-T-28	136407.518	566933.853
299-W22-20	Southeast of 216-S-20	136730.748	573781.892
299-W22-61	West area of 216-S-20	136727.768	573785.436
299-W22-63	East area of 216-S-20	136736.73	573776.927
299-W22-74	Northwest boundary of 216-S-20	137422.659	573847.63
299-W15-7	West area of 216-Z-7	137397.913	573847.598
299-W15-62	North boundary of 216-Z-7	135949.766	566688.703
299-W15-63	North boundary of 216-Z-7	135949.782	566703.896
299-W15-64	East boundary of 216-Z-7	135925.733	566739.895
299-W15-76	West of 216-Z-7	137388.475	573797.295
299-W15-77	South boundary of 216-Z-7	137379.963	573802.064
299-W15-78	South of 216-Z-7	137412.003	573795.536

[a]New boreholes, and six direct-push holes drilled to locate borehole C4183.

NAD83(91), *North American Datum of 1983*, as revised.

3.0 REMEDIAL INVESTIGATION RESULTS

This chapter describes the hydrogeologic framework in the 200-LW-1 and 200-LW-2 OUs. It also describes the geophysical logging results and the nature and vertical extent of contamination at the three representative waste sites investigated during the RI.

3.1 HYDROGEOLOGIC FRAMEWORK

This section summarizes the hydrogeologic framework in the 200-LW-1 and 200-LW-2 OUs and incorporates site-specific data obtained during the RI with historical data from the 200 Areas. Additional information on the hydrogeologic setting of the OU can be found in the Implementation Plan (DOE/RL-98-28), the Work Plan (DOE/RL-2001-66), and other documents as cited in the text.

3.1.1 Topography

The 200-LW-1 and 200-LW-2 OUs include waste sites located in both the 200 East and the 200 West Areas on the Central Plateau, which is a broad, relatively flat, prominent terrace (Cold Creek Bar) that constitutes a local topographic high near the center of the Hanford Site (Figure 3-1). The Cold Creek Bar was formed about 13,000 years ago during the last cataclysmic flood from glacial Lake Missoula. The Cold Creek Bar trends generally east-west with elevations between 197 and 225 m (647 to 740 ft) above mean sea level. The plateau drops off rather steeply to the north and northwest into a former flood channel with elevation changes of between 15 and 30 m (50 and 100 ft). The plateau decreases more gently in elevation to the south into the Cold Creek valley and to the east toward the Columbia River. Most of the 200 West Area and the southern half of the 200 East Area are situated on the Cold Creek Bar, while the northern half of the 200 East Area lies within the former flood channel. A secondary flood channel running south from the main channel bisects the 200 West Area. More detail on the physical setting of the 200 Areas and vicinity is provided in the Implementation Plan, Appendix F (DOE/RL-98-28).

Waste sites in the 200 West Area are situated in a relatively flat area in a secondary flood channel. Surface elevations range from approximately 205 m (673 ft) to 217 m (712 ft) (NAVD88), and the surface slopes gently to the west. Waste site surface elevations in the 200 East Area and vicinity range from approximately 189 m (620 ft) in the northern portion of the 200 Areas to 230 m (755 ft) at waste sites just south of the 200 East Area (NAVD88). The surface of the 200 East Area slopes gently to the northeast. The 200-LW-1 and 200-LW-2 OU representative waste sites all are located in the 200 West Area on the Central Plateau.

3.1.2 Geology

The 200-LW-1 and 200-LW-2 OUs are located in the Pasco Basin, one of several structural and topographic basins of the Columbia Plateau. Basalts of the Columbia River Basalt Group and a sequence of suprabasalt sediments underlie the 200-LW-1 and 200-LW-2 OU waste sites.

From oldest to youngest, the major geologic units of interest are the Elephant Mountain Member, the Ringold Formation, the Cold Creek unit, the Hanford formation, and surficial deposits. Figure 3-2 shows a generalized stratigraphic column for the 200 Areas.

Elephant Mountain Member. The Elephant Mountain Member is the uppermost basalt unit (i.e., bedrock) in the 200 Areas (DOE/RL-98-28, Rev. 0, Appendix F). Except for a small area north of the 200 East Area boundary where it has been eroded away, the Elephant Mountain Member is laterally continuous throughout the 200 Areas. The RI field investigations did not penetrate to the basalt. The basalt is overlain by the Ringold Formation in the 200 East Area (D&D-25461).

Ringold Formation. The Ringold Formation consists of an interstratified fluvial-lacustrine sequence of unconsolidated to semiconsolidated clay, silt, sand, and granule-to-cobble gravel deposited by the ancestral Columbia River (PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System 200-East Area and Vicinity, Hanford Site, Washington*, and PNNL-13858, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington*). These sediments, shown in Figure 3-2, consist of four major units (from oldest to youngest): the fluvial gravel and sand of unit 9 (basal coarse); the buried soil horizons, overbank, and lake deposits of unit 8 (lower mud); the fluvial sand and gravel of unit 5 (upper coarse); and the lacustrine mud of unit 4 (upper fines). Units 9 and 5 consist of a silty-sandy gravel with secondary lenses and interbeds of gravelly sand, sand, and muddy sands to silt and clay. Unit 8 (lower mud) consists mainly of silt and clay. Unit 4 (upper fines) consists of silty over-bank deposits and fluvial sand. Units 6 and 7 are not present beneath the 200 West and 200 East Areas (PNNL-12261 and PNNL-13858). The Ringold Formation is overlain by the Cold Creek unit in the 200 West Area and parts of the 200 East Area.

Cold Creek Unit. The Cold Creek unit is the new standardized name for several post-Ringold Formation and pre-Hanford formation units present beneath the 200 East and 200 West Areas (DOE/RL-2002-39, *Standardized Stratigraphic Nomenclature for Post-Ringold Formation Sediments Within the Central Pasco Basin*). The Cold Creek unit includes the formations formerly described as the Plio-Pleistocene unit, caliche, early Palouse soil, Pre-Missoula gravels, and sidestream alluvial facies described in previous site 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 (sidestream alluvium, formerly sidestream alluvial facies) (DOE/RL-2002-39).

Hanford Formation. The Hanford formation is the informal stratigraphic name used to describe the Pleistocene cataclysmic flood deposits in the Pasco Basin (DOE/RL-2002-39). The Hanford formation consists predominantly of unconsolidated sediments that range from boulder-size gravel to sand, silty sand, and silt. The sorting ranges from poorly sorted (for gravel facies) to well sorted (for fine sand and silt facies). The Hanford formation is divided into three main lithofacies: interbedded sand- to silt-dominated (formerly called the Touchet beds or slackwater facies); sand-dominated (formerly called the sand-dominated flood facies); and gravel-dominated (formerly called the Pasco gravels) that have been further subdivided into 11 textural-structural lithofacies (DOE/RL-2002-39). Beneath the 200-PW-2 and 200-PW-4 OU waste sites the Hanford formation includes the gravel-dominated and sand-dominated facies. The gravel-dominated facies are cross-stratified, coarse-grained sands and granule-to-boulder gravel. The gravel is uncemented and matrix-poor. The sand-dominated facies are well-stratified fine- to coarse-grained sand and granule gravel. Silt in these facies is variable and may be interbedded with 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-98-28 and DOE/RL-2002-39). 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.

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. Silty deposits less than 1 m (approximately 3 ft) thick also have been documented at waste sites where fine-grained, wind-blown material has settled out through standing water over many years (DOE/RL-98-28, Rev. 0, Appendix F). Fill material was placed in and over representative waste sites during construction and for contamination control. The fill consists of reworked Hanford formation sediments and/or surficial sand and silt. The thickness of the fill material varies from 5.2 to 10.1 m (17 to 33 ft) at the representative waste sites (D&D-25461).

3.1.3 Hydrostratigraphy

The focus of the RI was on the distribution of contaminants within the vadose zone beneath the representative waste sites. Vadose zone hydrostratigraphic units in the 200-LW-1 and 200-LW-2 OUs include the Ringold Formation, the Cold Creek unit, the Hanford formation, and surficial deposits (see Figure 3-2). The base of the unconfined aquifer is the top of the Ringold Formation unit 8 (lower mud) at the 200 West Area waste sites and the top of basalt (Elephant Mountain Member) at the 200 East Area waste sites.

Vadose Zone. The vadose zone is the area between the ground surface and the water table. The vadose zone is approximately 104 m (340 ft) thick in the southern section of the 200 East Area and thins to the north to as little as 0.3 m (1 ft) near West Lake. Sediments in the vadose zone are dominated by the Ringold Formation and the Hanford formation. The Cold Creek unit may be present in a small area immediately above the basalt. Because erosion during cataclysmic flooding removed much of the Ringold Formation north of the central part of the 200 East Area, the vadose zone is dominantly composed of Hanford formation sediments between the northern part of the 200 Areas and Gable Mountain. Basalt projects above the water table north of the 200 East Area.

In the 200 West Area, the vadose zone thickness ranges from 40.2 m (132 ft) to 102 m (337 ft). Sediments in the vadose zone are 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.

Perched water historically has been documented above the Cold Creek unit at locations in the 200 West Area. While liquid waste disposal facilities were operating, localized areas of saturation or near saturation were created in the soil column. With the reduction of artificial recharge in the 200 Areas, downward flux of liquid in the vadose zone beneath these waste sites has been decreasing. However, moisture content in the vadose zone is expected to remain elevated over preoperational conditions for some time. As unsaturated conditions are reached, liquid flux at these disposal sites becomes increasingly less significant as a source of recharge and contaminant movement to groundwater. In the absence of artificial recharge, recharge from natural precipitation becomes the more dominant driving force for moving contamination remaining in the vadose zone to groundwater.

A limited number of soil samples were collected to determine moisture content, grain-size distribution, and bulk density. Laboratory moisture content ranged from 2.2 to 19.7 percent. Bulk densities ranged from 1.59 g/cm^3 to 2.29 g/cm^3. The physical property testing data collected during the RI is summarized in Table 3-1. The laboratory results are presented in D&D-25461.

Unconfined Aquifer. The unconfined aquifer in the 200 Areas occurs within the Cold Creek unit, the Hanford formation, or the Ringold Formation, depending on location. Groundwater in the unconfined aquifer generally flows from west to east and discharges to the Columbia River (PNNL-15070, *Hanford Site Groundwater Monitoring for Fiscal Year 2004*).

Figures 3-3 and 3-4 show March 2004 water table maps of the 200 West and 200 East Areas, respectively. The depth to water varies from about 133.5 m (438 ft) in the northeast corner to greater than 138 m (453 ft) in the southwest corner. Groundwater flow is predominately to the east (Figure 3-3). The water table beneath the 200 West Area is locally perturbed by discharges associated with the State-Approved Land Disposal Site, as well as by operation of two groundwater remediation pump-and-treat systems at the 200-UP-1 and 200-ZP-1 Groundwater OUs. The surface elevation of the water table beneath the 200 West Area has declined by an average of 0.21 m (0.69 ft) in those areas not influenced by the pump-and-treat remediation systems (PNNL-15070).

In the northern half of the 200 East Area, the water table is present within the Hanford formation, except in areas where basalt extends above the water table. Near the B-BX-BY waste management area, the water table occurs within the Cold Creek unit. In the central and southern sections of the 200 East Area, the water table is located near the contact between the Ringold Formation and the Hanford formation. The saturated thickness of the aquifer is predominantly within the Ringold Formation. Depth to groundwater in the 200 East Area and vicinity ranges from about 123 m (403.5 ft) near B Pond to about 122.5 m (402 ft) at the BC Cribs and Trenches Area. The water table across the 200 East Area is very flat (Figure 3-4), making groundwater flow direction difficult to determine based on water-level measurements from monitoring wells. The configuration of contaminant plumes, however, indicates that groundwater flows to the northwest in the northern half of the 200 East Area and to the east/southeast in the southern half of the 200 East Area. Identifying the specific location of the groundwater divide between the northern and southern sections is hampered by the flat water table. Highly transmissive Hanford formation sediments are the cause of the flat water table in the 200 East Area (PNNL-13116, *Hanford Site Groundwater Monitoring for Fiscal Year 1999*). The elevation of the water table declined by an average of 0.09 m (0.30 ft) between March 2003 and March 2004 (PNNL-15070).

Recharge to the unconfined aquifer within the 200 Areas is from artificial sources and less significant natural 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. PNNL-5506, *Hanford Site Water Table Changes 1950 through 1980, Data Observation and Evaluation*, reports that between 1943 and 1980, 6.33×10^{11} L (1.67×10^{11} gal) of liquid wastes were discharged to the soil column. Most sources of artificial recharge were terminated in 1995. The artificial recharge that does continue largely is limited to liquid discharges from sanitary sewers, two state-approved land-disposal structures, and 140 small-volume, uncontaminated miscellaneous liquid discharge streams. One of the approved land-disposal structures, the Treated Effluent Disposal Facility (a liquid waste disposal facility), is located 600 m (2,000 ft) east of the 216-B-3C lobe of B Pond and receives treated liquid wastes from the 200 East and 200 West Area facilities.

3.1.4 Summary of Hydrogeologic Conditions at Representative Sites

Stratigraphy and general location information about each of the representative waste sites is presented in this section. More descriptive information on the waste sites, their history, and their locations is presented in the following subsections. Stratigraphy diagrams for the representative waste sites are presented in Section 3.3.

3.1.4.1 216-T-28 Crib

The 216-T-28 Crib is located in a north-south-trending secondary flood channel in the 200 West Area (DOE/RL-92-05, *B Plant Source Aggregate Area Management Study Report*). The surface elevation at this site is approximately 204.7 m (671.7 ft) (NAVD88). Stratigraphic units of interest beneath the site (in ascending order) consist of the Ringold Formation (unit E and upper Ringold), early Palouse soil (Cold Creek unit), and the Hanford formation sand- and gravel-dominated sequences. The stratigraphy at the 216-T-28 Crib is shown in Figure 3-5 and is based on the geology at borehole C3102 (temporary borehole number assigned to the 216-T-26 Crib in 2001). Groundwater beneath the 216-T-28 Crib occurs within the Ringold Formation unit E, about 69 m (226 ft) bgs.

3.1.4.2 216-S-20 Crib

The 216-S-20 Crib is located in a north-south-trending secondary flood channel in the 200 West Area (DOE/RL-92-05). Ground surface elevation at this site is approximately 208.3 m (683.5 ft) (NAVD88). Stratigraphic units of interest near the site (in ascending order) consist of the Ringold Formation (unit E and upper Ringold), the Cold Creek unit, and the Hanford formation sand- and gravel-dominated sequences. The stratigraphy near the 216-S-20 Crib is shown in Figure 3-6 and is based on the geology at borehole 299-W22-19. Groundwater beneath the 216-S-20 Crib occurs within the Ringold Formation unit E, about 71 m (233 ft) bgs.

3.1.4.3 216-Z-7 Crib

The 216-Z-7 Crib is located in a north-south-trending secondary flood channel in the 200 West Area (DOE/RL-92-05). Ground surface elevation at this site is approximately 203.7 m (668.3 ft) (NAVD88). Stratigraphic units of interest beneath the site (in ascending order) consist of the

Ringold Formation unit E, the Cold Creek unit, and the Hanford formation sand- and gravel-dominated sequences. The stratigraphy near the 216-Z-7 Crib is shown in Figure 3-7 and is based on the geology at borehole 299-W15-76. Groundwater beneath the 216-Z-7 Crib occurs within the Ringold Formation unit E, about 66 m (218 ft) bgs.

3.2 OPERABLE UNIT CONTAMINATION

This section describes the nature and extent of contamination at the 200-LW-1 and 200-LW-2 OU representative waste sites (216-T-28 Crib, 216-S-20 Crib, and 216-Z-7 Crib). All of these sites were characterized in fiscal years 2004 and 2005.

Data collected from the RI representative waste sites are presented in Appendix B. The sites have both geophysical logging and laboratory characterization data available. The contamination found at each representative waste site is discussed generally in this section. A more detailed comparison of the characterization data against regulatory standards and background levels and a detailed RESRAD risk model discussion based on the characterization data are found in Chapters 4.0 and 5.0 of this RI report.

The geophysical logging results and observations described in the following sections were made during drilling activities at the 200-LW-1 and 200-LW-2 OUs. The probe runs, data collection, and reduction were conducted by S. M. Stoller Corporation Geophysical Services, Grand Junction, Colorado. The geophysical log data reports and analyses are provided in Appendix F of the borehole summary report (D&D-25461). Spectral gamma-ray logs supplement the analytical radionuclide data. They present a vertical distribution of radionuclides in the vadose zone beneath the waste sites and aid in geological interpretation of subsurface stratigraphy. Spectral gamma-ray logging equipment is calibrated annually. The calibration data are used to calculate casing attenuation factors that convert measured peak area count rates to radionuclide concentrations.

Borehole locations, drilling methods, and decommissioning are described in Section 2.1 of this RI report. Soil-sample screening methods, sampling approach, and the number and type of laboratory and soil bulk property samples are discussed in Section 2.1.1. A description of geophysical logging methodology is located in Section 2.1.2. Borehole geophysical logging was conducted both in existing boreholes in the vicinity of each waste site (DOE/RL-2001-66) and in the boreholes and direct-push holes installed as part of the RI (see D&D-25461). The laboratory data collected are summarized in Tables 2-1 through 2-3 and are presented in Appendix B, while the boreholes that were geophysically logged are listed in Table 2-4. Note that results for Sr-90 are based on analysis of total radioactive strontium.

3.2.1 Nature and Extent of Contamination in the 216-T-28 Crib

This section describes the nature and extent of contamination in the 216-T-28 Crib area. The 216-T-28 Crib is located inside the 200 West Area, south of 23rd Street and east of Camden Avenue (Figure 1-2).

The drilling of borehole C4175 began on September 30, 2004, with final decommissioning on January 13, 2005. Borehole C4175 was drilled to a total depth of 69.4 m (227.5 ft) bgs, and the water table was found at 69.4 m (226.5 ft) bgs. The upper 5.2 m (17 ft) consisted of crib-construction backfill material. From 5.2 to 9.5 m (17 to 31 ft) bgs, the gravel-dominated facies of the Hanford formation were observed. The sand dominated facies of the Hanford formation were observed from 9.5 to 22.3 m (31 to 73 ft) bgs. Interbedded sand- to silt-dominated facies were observed from 22.3 to 27.6 m (73 to 90.5 ft) bgs. The Cold Creek unit was observed from 27.5 to 47.3 m (90.5 to 155 ft) bgs, with a highly compacted caliche layer at approximately 30.5 to 31.3 m (100 to 102.5 ft) bgs, and another caliche layer between 33.6 and 34.2 m (110 and 112 ft) bgs. From 47.3 to 57.3 m (155 to 188 ft) bgs, a combination of silts, sands, and gravels were observed, and between 57.3 and 69.4 m (188 and 227.5 ft) bgs, unconsolidated clay, silt, and granule- to boulder-sized gravel were observed.

At 0.8 to 1.5 m (2.5 to 5 ft) bgs, the radiological control technician field screening detected 5,000 c/min beta-gamma on contact with the soils. At 3.8 to 4.6 m (12.5 to 15 ft) bgs, this increased to 40,000 c/min beta-gamma and 85 c/min alpha; this has an associated dose rate of 25 mR/h. The dose rate increased to a maximum of 200 mR/h at 5.3 to 6.1 m (17.5 to 20 ft) bgs, then dropped off to background levels past 18.3 m (60 ft) bgs. Other than an alpha 'spike' at 20.7 to 21.1 m (68 to 69.3 ft) bgs, no other radiological anomalies were detected during the drilling phase. No organic vapors were detected during drilling.

3.2.1.1 Geophysical Logging Summary at the 216-T-28 Crib

Geophysical logging of borehole C4175 was performed with the SGLS on November 8, 2004, and December 6, 2004, and with the HRLS on December 10, 2004. Cesium-137, Co-60, and Eu-154 were the man-made radionuclides detected in the borehole. Cesium-137 was detected from the ground surface to 21.4 m (70 ft) bgs and at a few sporadic locations below 21.4 m (70 ft) to total depth. A maximum concentration of approximately 3.9×10^6 pCi/g was measured at 5.3 m (17.5 ft) bgs.

Cobalt-60 was detected 10.7 to 25.3 m (35 to 83 ft) bgs and at 33.7 m (110.5 ft) bgs. The maximum concentration was approximately 0.9 pCi/g at 11.1 m (36.5 ft) bgs. It is likely that Co-60 exists in the high gamma activity zone between 3.1 and 10.7 m (10 and 35 ft) bgs. The minimum detection level (MDL) for Co-60 is significantly increased at this high-activity zone, such that it may not be detected.

Europium-154 was detected 10.7 to 33.9 m (35 to 111 ft) bgs and at 35.8 m (117.5 ft) bgs. The maximum concentration was approximately 110 pCi/g at 24.6 m (80.5 ft) bgs. It is likely that Eu-154 exists in the high gamma activity zone between 3.1 and 10.7 m (10 and 35 ft) bgs. The MDL for Eu-154 is significantly increased at this high activity zone, such that it may not be detected.

The potassium-uranium-thorium log showed some variations, suggesting lithology changes that may be correlated with adjacent boreholes. On December 12, 2004, the geophysical logging showed enhanced radon in the borehole between 19.8 and 68.6 m (65 and 225 ft) bgs.

Geophysical logging of four existing boreholes in the vicinity of the 216-T-28 Crib representative waste site, boreholes 299-W14-1, 299-W14-2, 299-W14-3, and 299-W14-4, also were logged with the SGLS. Boreholes 299-W14-2 and 299-14-3 are located within the waste site boundary, while boreholes 299-W14-1 and 299-W14-4 are located adjacent to the site. Logging results at these four locations were similar for Cs-137, except that the maximum concentration at borehole 299-W14-1 was only 2.6 pCi/g at 1.2 m (4 ft) bgs. Because borehole 299-W14-1 is at the greatest distance from the 216-T-28 Crib (DOE/RL-2001-66, Figure 4-1), this is not unexpected. Logging results were similar for Eu-154 and Co-60 at these locations, except that for Co-60 there were sporadic readings to total depth. Maximum logging results for Co-60 ranged from 0.2 to 2.0 pCi/g. The conceptual contaminant distribution model for the 216-T-28 Crib (DOE/RL-2001-66) correctly predicted significant impacts to existing boreholes 299-W14-2, 299-W14-3, and 299-W14-3.

Two of the existing boreholes, 299-W14-3 and 299-W14-4, reported detections of two additional man-made radionuclides, Eu-152 and Sn-126. Europium-152 was detected in borehole 299-W14-3 at depths between 9.5 and 36.9 m (31 and 121 ft) bgs, with a maximum concentration of 11 pCi/g at 96.5 m (81 ft) bgs. This report suggested that Eu-152 generally is expected to coexist with Eu-154. Europium-152 also was detected in borehole 299-W14-4 at 12.5 m (41 ft) and between 23.5 and 31.1 m (77 and 102 ft) bgs, with a maximum concentration of 2 pCi/g at 29.6 m (97 ft) bgs.

Tin-126 was detected in borehole 299-W14-3 between 9.2 and 12.8 m (30 and 42 ft) bgs, with a maximum concentration of 11 pCi/g at 9.8 m (32 ft) bgs. In borehole 299-W14-4, Sn-126 was detected at 12.5 m (41 ft) and between 23.5 and 31.1 m (77 and 102 ft) bgs, with a maximum concentration of 2 pCi/g at 29.6 m (97 ft) bgs. These reports both suggest that Sn-126 also exists in the high activity interval.

The laboratory sample results for Cs-137 from this borehole confirm the logging results. At 5.3 to 6.1 m (17.5 to 20 ft) bgs, the maximum laboratory result of 3,100,000 pCi/g was obtained. Then Cs-137 decreased with depth. Only two samples below 21.4 m (70 ft) resulted in detections of Cs-137; these were at 27.5 to 28.2 m (90 to 92.5 ft) and 48 to 48.8 m (157.5 to 160 ft) bgs. Their results of 0.05 and 0.018 pCi/g were only slightly above their respective minimum detectable activities (MDA) of 0.047 and 0.011 pCi/g.

All but one of the laboratory samples taken at or above 27.5 to 28.2 m (90 to 92.5 ft) bgs resulted in detections of Co-60. The highest result, 1,180 pCi/g, was reported at 5.3 to 6.1 m (17.5 to 20 ft) bgs. The remainder of results ranged from 0.052 to 1.77 pCi/g. These results generally confirm the logging results.

Laboratory results for Eu-154 also are consistent with logging, with this radionuclide detected in samples taken at 20.6 to 21.4 m (67.5 to 70 ft) bgs and at 27.5 to 28.2 m (90 to 92.5 ft) bgs and undetected in the next sample interval, at 48 to 48.8 m (157.5 to 160 ft) bgs. No samples were taken at 33.6 to 36.6 m (110 to 120 ft) bgs.

3.2.1.2 216-T-28 Crib Contamination–Laboratory Data

When it was actively receiving waste, the 216-T-28 Crib was 4.6 m (15 ft) deep. It received steam condensate decontamination waste and miscellaneous effluent from the 221-T Canyon Building, decontamination waste from the 2706-T Decontamination Facility Building, and 300 Area laboratory waste from the 340 Waste Neutralization Facility Building

(DOE/RL-96-81). This waste contained uranium, plutonium, Cs-137, Sr-90, and nitrates (DOE/RL-96-81).

Radioactive contamination was detected in the vadose zone beneath the 216-T-28 Crib in borehole C4175 to 68 m (223.5 ft) bgs. Maximum contaminant levels are shown in Appendix A and are summarized here. Because insufficient material was collected at 3.8 to 4.6 m (12.5 to 15 ft) bgs, samples for the shallow zone (< 4.6 m [15 ft] bgs) were not collected.

Maximum concentrations of radionuclides in deep soils with concentrations that were detected above background or that have no available background values were as follows:

- Americium-241 802 pCi/g at 5.3 to 6.1 m (17.5 to 20 ft) bgs
- Antimony-125 2.39 pCi/g at 8.4 to 9.2 m (27.5 to 30 ft) bgs
- Carbon-14 4.52 pCi/g at 27.5 to 28.2 m (90 to 92.5 ft) bgs
- Cesium-134 456 pCi/g at 5.3 to 6.1 m (17.5 to 20 ft) bgs
- Cesium-137 3,100,000 pCi/g at 5.3 to 6.1 m (17.5 to 20 ft) bgs
- Cobalt-60 1,180 pCi/g at 5.3 to 6.1 m (17.5 to 20 ft) bgs
- Europium-152 0.733 pCi/g at 27.5 to 28.2 m (90 to 92.5 ft) bgs
- Europium-154 43 pCi/g at 27.5 to 28.2 m (90 to 92.5 ft) bgs
- Europium-155 19.9 pCi/g at 27.5 to 28.2 m (90 to 92.5 ft) bgs
- Neptunium-237 0.011 pCi/g at 14.5 to 15.2 m (47.5 to 50 ft) bgs
- Nickel-63 843 pCi/g at 5.3 to 6.1 m (17.5 to 20 ft) bgs
- Plutonium-238 84.5 pCi/g at 5.3 to 6.1 m (17.5 to 20 ft) bgs
- Plutonium-239/240 1,110 pCi/g at 5.3 to 6 m (17.5 to 20 ft) bgs
- Technetium-99 1.61 pCi/g at 60.2 to 61.0 m (197.5 to 200 ft) bgs
- Total Radioactive Strontium 642,000 pCi/g at 5.3 to 6.1 m (17.5 to 20 ft) bgs
- Thorium-228 1.82 pCi/g at 6.9 to 7.6 m (22.5 to 25 ft) bgs
- Tritium 19,000 pCi/g at 27.5 to 28.2 m (90 to 92.5 ft) bgs
- Uranium-233/234 59.4 pCi/g at 6.9 to 7.6 m (22.5 to 25 ft) bgs
- Uranium-235 1.8 pCi/g at 6.9 to 7.6 m (22.5 to 25 ft) bgs
- Uranium-238 35.1 pCi/g at 6.9 to 7.6 m (22.5 to 25 ft) bgs.

Extensive tables in Chapters 4.0 and 5.0 of this report compare the nonradioactive COPCs against background and screening levels. For deep soils, contaminants that were detected above background or that have no available background are as follows (maximum detected levels shown):

- Oil and Grease 1,080,000 µg/kg at 60.2 to 61.0 m (197.5 to 200 ft) bgs
- TPH-diesel range 13,000 µg/kg at 60.2 to 61.0 m (197.5 to 200 ft) bgs
- TPH-kerosene range 13,000 µg/kg at 60.2 to 61.0 m (197.5 to 200 ft) bgs
- Antimony 5,030 µg/kg at 60.2 to 61.0 m (197.5 to 200 ft) bgs
- Arsenic 9,290 µg/kg at 27.5 to 28.2 m (90 to 92.5 ft) bgs
- Bismuth 202,000 µg/kg at 6.9 to 7.6 m (22.5 to 25 ft) bgs
- Chromium 81,700 µg/kg at 6.9 to 7.6 m (22.5 to 25 ft) bgs
- Lead 34,400 µg/kg at 60.2 to 61.0 m (197.5 to 200 ft) bgs
- Nickel 52,700 µg/kg at 6.9 to 7.6 m (22.5 to 25 ft) bgs
- Selenium 869 µg/kg at 48 to 48.8 m (157.5 to 160 ft) bgs
- Silver 4,980 µg/kg at 20.6 to 21.4 m (67.5 to 70 ft) bgs

• Uranium	113,000 µg/kg at 6.9 to 7.6 m (22.5 to 25 ft) bgs
• Hexavalent Chromium	1,500 µg/kg at 27.5 to 28.2 m (90 to 92.5 ft) bgs
• Mercury	6,840 µg/kg at 6.9 to 7.6 m (22.5 to 25 ft) bgs
• Aroclor-1254[1]	240 µg/kg at 5.3 to 6.1 m (17.5 to 20 ft ft) bgs
• Ammonia	14,500 µg/kg at 6.9 to 7.6 m (22.5 to 25 ft) bgs
• Ammonium ion	24,700 µg/kg at 20.6 to 21.4 m (67.5 to 70 ft) bgs
• Fluoride	39,600 µg/kg at 27.5 to 28.2 m (90 to 92.5 ft) bgs
• Nitrate	245,000 µg/kg at 27.5 to 28.2 m (90 to 92.5 ft) bgs
• Nitrite	2,530 µg/kg at 5.3 to 6.1 m (17.5 to 20 ft) bgs
• Nitrogen in nitrite and nitrate	45,800 µg/kg at 27.5 to 28.2 m (90 to 92.5 ft) bgs
• Phosphate	59,100 µg/kg at 6.9 to 7.6 m (22.5 to 25 ft) bgs
• 2-Butoxyethanol	150 µg/kg at 8.4 to 9.2 m (27.5 to 30 ft) bgs
• Acetone	8 µg/kg at 48 to 48.8 m (157.5 – 160 ft) bgs
• Diethylphthalate	730 µg/kg at 27.5 to 28.2 m (90 to 92.5 ft) bgs
• Di-n-butylphthalate	1,700 µg/kg at 8.4 to 9.2 m (27.5 to 30 ft) bgs
• Hexadecanoic acid (9Cl)	180 µg/kg at 6.9 to 7.6 m (22.5 to 25 ft) bgs
• Eicosane	970 µg/kg at 60.2 to 61.0 m (197.5 to 200 ft) bgs
• Methylene chloride	25 µg/kg at 6.9 to 7.6 m (22.5 to 25 ft) bgs
• 4-chloro-3-methylphenol	23 µg/kg at 6.9 to 7.6 m (22.5 to 25 ft) bgs
• bis(2-Ethylhexyl)phthalate	700 µg/kg at 6.9 to 7.6 m (22.5 to 25 ft) bgs
• n-hexanoic acid	570 µg/kg at 60.2 to 61.0 m (197.5 to 200 ft) bgs
• Phenol	24 µg/kg at 6.9 to 7.6 m (22.5 to 25 ft) bgs
• Pyrene	21 µg/kg at 6.9 to 7.6 m (22.5 to 25 ft) bgs
• Toluene	4.9 µg/kg at 6.9 to 7.6 m (22.5 to 25 ft) bgs.

In general, the conceptual contaminant distribution model is well supported by the data. The contaminant distribution model (DOE/RL-2001-66) indicates that the highest contamination will be found from the bottom of the crib to 32 m (107 ft) bgs, medium amounts of contamination from 32 to 50.3 m (107 to 165 ft) bgs, and low contamination below 50.3 m (165 ft). The radioactive contaminants at the 216-T-28 Crib are markedly elevated at the 5.3 to 6.1 m (17.5 to 20 ft) and 6.9 to 7.6 m (22.5 to 25 ft) bgs depths (i.e., just below the 4.6 m (15 ft) bgs historical base of the crib).

The conceptual contaminant distribution model (DOE/RL-2001-66) correctly predicted elevated levels of Cs-137, Co-60, Pu-239/240, Sr-90, uranium, tritium, and nitrates. It also correctly predicted that Cs-137 would be found near the point of release in high concentrations, while mobile contaminants such as nitrate would migrate deeper and might be detected in low concentrations to the water table.

A stratigraphy diagram for the 216-T-28 Crib is shown in Figure 3-5. Stratigraphy and data for radionuclide and nonradionuclide contamination are shown in Figures 3-8 and 3-9. Vertical profile plots of contaminants are shown in Figure 3-10.

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[1] Aroclor is an expired trademark.

3.2.2 Nature and Extent of Contamination in the 216-S-20 Crib

This section describes the nature and extent of contamination in the 216-S-20 Crib area. The 216-S-20 Crib is located southeast of the 202-S (Reduction-Oxidation Plant or S Plant) Facility (Figure 1-3).

Drilling activities at borehole C4176 began on August 10, 2004, with final decommissioning on October 14, 2004. Borehole C4176 was drilled to a total depth of 74.7 m (245 ft) bgs, and the water table was found at 74.3 m (243.5 ft) bgs. The upper 2.7 m (9 ft) consisted of sandy gravel stabilization material underlain by 6.1 m (20 ft) of sandy backfill and 1.2 m (4 ft) of gravels. From 10.1 to 41.0 m (33 to 134.5 ft) bgs, the sand dominated facies of the Hanford formation were observed. The interbedded sand- to silt-dominated facies of the Hanford formation were observed to a depth of 46.1 m (151 ft) bgs. The Cold Creek unit was observed from 46.1 to 58.1 m (151 to 190.5 ft) bgs, with minor traces of a caliche at approximately 57.8 m (189.5 ft) bgs. From 57.8 to 74.7 m (189.5 to 245 ft) bgs, a combination of silts, sands, and gravels of the Upper Ringold were observed.

Radiological control technician field screening detected 700 c/min alpha and 40,000 c/min beta-gamma on contact with the soils at 7.6 m (25 ft) bgs. At 8.8 to 9.8 m (29 to 32 ft) bgs, alpha increased to 1,400 c/min and beta-gamma dropped to 30,000 c/min. The detections dropped off to background levels past 10.7 m (35 ft) bgs. No other radiological anomalies were detected during the drilling phase. Organic vapors were detected at 4 parts per million (ppm) at 7.6 m (25 ft) bgs, at 3.5 ppm in the breathing zone at 15.2 m (50 ft) bgs, and at 1.2 ppm at 22.0 to 22.7 m (72 to 74.5 ft) bgs. No other organic vapor detections were made during drilling.

3.2.2.1 Geophysical Logging Summary for the 216-S-20 Crib

Geophysical logging of Borehole C4176 was performed with the SGLS on August 26, 2004, September 14 and 15, 2004, and September 28 and 29, 2004. Geophysical logging with HRLS was performed on October 7, 2004. Geophysical logging with the Neutron Moisture Logging System (NMLS) was performed on September 20, 2004.

Cesium-137, Co-60, and man-made U-238 (based on the Pa-234m gamma line at 1,001 keV) were detected in the borehole. Cesium-137 was detected near the ground surface, with a maximum concentration of 131 pCi/g at 0.3 m (1 ft) bgs. An interval of high Cs-137 occurs between 5.8 and 16.8 m (19 and 55 ft) bgs, with the maximum Cs-137 concentration of approximately 85,000 pCi/g appearing to occur in two very thin beds at about 8.8 and 9.5 m (29 and 31 ft) bgs.

Man-made U-238 and Co-60 occur immediately below the zone of high gamma activity associated with Cs-137. The maximum concentration of man-made U-238 is 201 pCi/g at 10.1 m (33 ft) bgs, decreasing to about 10 pCi/g at 12.2 m (40 ft) bgs. It is likely that man-made U-238 exists in the high gamma activity zone associated with Cs-137 as well. The MDL for Co-60 is significantly increased at this high activity zone, such that it may not be detected.

Cobalt-60 was detected continuously from 10.1 to 11.6 m (33 to 38 ft) and intermittently from 11.9 to 15.9 m (39 to 52 ft) bgs. Maximum concentration was 1.4 pCi/g at 10.1 m (33 ft) bgs. As with man-made U-238, it is likely that Co-60 occurs within the Cs-137 high activity interval.

Cesium-137 was detected in the 20.1 to 73.5 m (66 to 241 ft) bgs interval in concentrations of 1.3 to 3 pCi/g. Contamination of the SGLS sonde was suspected, and it was cleaned. The borehole was swabbed and no contamination was detected on the swab. Later readings indicated isolated intervals of Cs-137, generally at or near the MDL of 0.2 to 0.3 pCi/g. Traces of Cs-137 were detected from 17.1 to 17.7 m (56 to 58 ft), 25.9 to 26.2 m (85 to 86 ft), 47.6 to 47.9 m (156 to 157 ft), and 70.5 to 71.1 m (231 to 233 ft) bgs. A concentration of about 3.5 pCi/g was detected at 73.4 m (240.5 ft) bgs. There is a possibility that these detections may represent contamination inside the casing.

Neutron moisture data was collected in the interval below 16.8 m (55 ft) bgs. Moisture values ranged from 2 to 12 percent by volume, with many relatively thin beds of higher moisture content between 41.2 and 71.1 m (135 and 233 ft) bgs. Analytical results were provided at four depths within this interval. They ranged from 2.9 to 19.7 percent and generally confirm the logged values.

Geophysical logging of four existing boreholes in the vicinity of the 216-S-20 Crib representative waste site, boreholes 299-W22-20, 299-W22-61, 299-W22-63, and 299-W22-74, also were logged with the SGLS. Two of these boreholes (299-W22-61 and 299-W22-63) are located within the waste site boundary (DOE/RL-2001-66, Figure 4-2). Logging results at the two locations within the waste site boundary were similar to logging results at borehole C4176 for Cs-137, Co-60, and Eu-154. Logging in borehole 299-W22-20 detected Cs-137 only, with a maximum concentration of 0.4 pCi/g at 0.6 m (2 ft) bgs. Because borehole 299-W22-20 is at the greatest distance from the 216-S-20 Crib, this is not unexpected. Logging in borehole 299-W22-74 detected Cs-137 only sporadically, at or near the MDL, and detected Co-60 from 8.8 to 12.2 m (29 to 40 ft) bgs, with a maximum concentration of 0.5 pCi/g at 11.6 m (38 ft) bgs.

The two existing boreholes located within the waste site boundary, boreholes 299-W22-61 and 299-W22-63, also reported detections of one additional man-made radionuclide, U-235. Uranium-235 was detected in borehole 299-W22-61 at depths between 11.3 and 12.8 m (37 and 42 ft) bgs, with a maximum concentration of 24 pCi/g at 11.6 m (38 ft) bgs. Uranium-235 also was detected in borehole 299-W22-63 at 11.0 to 15.6 m (36 to 51 ft) bgs and 18.3 to 19.2 m (60 to 63 ft) bgs, with a maximum concentration of 17 pCi/g at 11.6 m (38 ft) bgs. Both reports suggest that U-235 generally is expected to exist in the high activity zone, even though it was not detected.

The laboratory sample results generally confirmed the logging results. The maximum laboratory result for Cs-137 (95,600 pCi/g) was at 9.0 to 9.8 m (29.5 to 32 ft) bgs. The maximum laboratory result for U-238 (270 pCi/g) was at 9.9 to 10.7 m (32.5 to 35 ft) bgs. The maximum laboratory result for Co-60 (104 pCi/g) was at 9.0 to 9.8 m (29.5 to 32 ft) bgs.

3.2.2.2 216-S-20 Crib Contamination–Laboratory Data

When it was actively receiving waste, the top of the 216-S-20 Crib was 5.5 m (18 ft) below grade and the crib was 2.7 m (9 ft) high, making the bottom of the crib about 8.2 m (27 ft) bgs. The crib received miscellaneous waste from laboratory hoods and decontamination sinks from 202-S Plant, miscellaneous waste from laboratory hoods and decontamination sinks in the 222-S Analytical Laboratory, and effluent from the 207-SL Retention Basin, 219-S Retention Building, and 300 Area laboratories (DOE/RL-91-52 and HW-18700-DEL). It received waste containing uranium, plutonium, Cs-137, Sr-90, and nitrates (DOE/RL-96-81).

Radioactive contamination was detected in the vadose zone beneath the 216-S-20 Crib in borehole C4176 to 72.6 m (238 ft) bgs. Maximum contaminant levels are shown in Appendix A and are summarized here.

The only radioactive contamination detected in shallow soils (<4.6 m [<15 ft]) bgs above background or that had no available background value was Eu-155 at 0.062 pCi/g at 3.8 to 4.6 m (12.5 to 15 ft) bgs.

Maximum concentrations of radionuclides in deep soils detected above background or that have no available background values were as follows:

- Americium-241 — 12.3 pCi/g at 9.9 to 10.7 m (32.5 - 35 ft) bgs
- Carbon-14 — 35.6 pCi/g at 9.0 to 9.8 m (29.5 to 32 ft) bgs
- Cesium-137 — 95,600 pCi/g at 9.0 to 9.8 m (29.5 to 32 ft) bgs
- Cobalt-60 — 104 pCi/g at 9.0 to 9.8 m (29.5 to 32 ft) bgs
- Europium-154 — 70.8 pCi/g at 9.0 to 9.8 m (29.5 to 32 ft) bgs
- Europium-155 — 0.144 pCi/g at 46.2 to 47 m (151.5 to 154 ft) bgs
- Neptunium-237 — 0.084 pCi/g at 9.9 to 10.7 m (29.5 to 32 ft) bgs
- Nickel-63 — 4,580 pCi/g at 9.0 to 9.8 m (29.5 to 32 ft) bgs
- Plutonium-238 — 2.6 pCi/g at 9.9 to 10.7 m (32.5 to 35 ft) bgs
- Plutonium-239/240 — 78 pCi/g at 9.9 to 10.7 m (32.5 to 35 ft) bgs
- Technetium-99 — 9.18 pCi/g at 9.0 to 9.8 m (29.5 to 32 ft) bgs
- Total Radioactive Strontium — 96,300 pCi/g at 9.0 to 9.8 m (29.5 to 32 ft) bgs
- Thorium-228 — 15.9 pCi/g at 9.0 to 9.8 m (29.5 to 32 ft) bgs
- Thorium-232 — 1.41 pCi/g at 9.9 to 10.7 m (32.5 to 35 ft) bgs
- Tritium — 63.1 pCi/g at 9.0 to 9.8 m (29.5 to 32 ft) bgs
- Uranium-233/234 — 250 pCi/g at 9.9 to 10.7 m (32.5 to 35 ft) bgs
- Uranium-235 — 26.4 pCi/g at 9.9 to 10.7 m (32.5 to 35 ft) bgs
- Uranium-238 — 270 pCi/g at 9.9 to 10.7 m (32.5 to 35 ft) bgs.

Extensive tables in Chapters 4.0 and 5.0 of this report compare the nonradioactive COPCs against background and screening levels. For shallow soils, contaminants that were detected above background or have no available background are as follows (maximum detected levels shown):

- Arsenic — 6,700 μg/kg at 3.8 to 4.6 m (12.5 to 15 ft) bgs
- Nitrogen in nitrite and nitrate — 2,800 μg/kg at 3.8 to 4.6 m (12.5 to 15 ft) bgs.

For deep soils, contaminants that were detected above background or that have no available background are as follows (maximum detected levels shown):

• Antimony	2,900 µg/kg at 9.0 to 9.8 m (29.5 to 32 ft) bgs
• Arsenic	9,160 µg/kg at 29.6 to 30.3 m (97 to 99.5 ft) bgs
• Barium	136,000 µg/kg at 9.9 to 10.7 m (32.5 to 35 ft) bgs
• Beryllium	2,700 µg/kg at 9.9 to 10.7 m (32.5 to 35 ft)bgs
• Bismuth	202,000 µg/kg at 9.0 to 9.8 m (29.5 to 32 ft) bgs
• Boron	13,500 µg/kg at 9.0 to 9.8 m (29.5 to 32 ft) bgs
• Chromium	259,000 µg/kg at 9.0 to 9.8 m (29.5 to 32 ft) bgs
• Hexavalent Chromium	1,280 µg/kg at 9.9 to 10.7 m (32.5 to 35 ft) bgs
• Copper	122,000 µg/kg at 9.0 to 9.8 m (29.5 to 32 ft) bgs
• Lead	489,000 µg/kg at 9.0 to 9.8 m (29.5 to 32 ft) bgs
• Nickel	55,000 µg/kg at 9.0 to 9.8 m (29.5 to 32 ft) bgs
• Silver	6,000 µg/kg at 9.0 to 9.8 m (29.5 to 32 ft) bgs
• Uranium	818,000 µg/kg at 9.9 to 10.7 m (32.5 to 35 ft) bgs
• Mercury	69,200 µg/kg at 9.0 to 9.8 m (29.5 to 32 ft) bgs
• Aroclor-1254	170 µg/kg at 9.0 to 9.8 m (29.5 to 32 ft) bgs
• Ammonium Ion	2,870 µg/kg at 14.5 to 15.2 m (47.5 to 50 ft) bgs
• Fluoride	6,510 µg/kg at 9.0 to 9.8 m (29.5 to 32 ft) bgs
• Nitrate	18,600 µg/kg at 9.0 to 9.8 m (29.5 to 32 ft) bgs
• Nitrogen in nitrite and nitrate	3,400 µg/kg at 9.9 to 10.7 m (32.5 to 35 ft) bgs
• Sulfide	23,900 µg/kg at 9.0 to 9.8 m (29.5 to 32 ft) bgs
• Di-n-butylphthalate	1,200 µg/kg at 12.2 to 12.2 m (40 to 42.5 ft) bgs
• Methylene chloride	4.7 µg/kg at 9.9 to 10.7 m (32.5 to 35 ft) bgs.

In general, the contaminant distribution model is well supported by the data. The contaminant distribution model (DOE/RL-2000-61) indicates that the highest contamination will be found from the bottom of the crib to 13.7 m (45 ft) bgs, medium amounts of contamination from 13.7 to 48.2 m (45 to 158 ft) bgs, and low contamination below 48.2 m (158 ft). The radioactive contaminants at the 216-S-20 Crib are markedly elevated at the 9.0 to 9.8 m (29.5 to 32 ft) and 9.9 to 10.7 m (32.5 to 35 ft) bgs depths (i.e., just below the 5.5 m (18 ft) bgs historical base of the crib).

The conceptual contaminant distribution model (DOE/RL-2001-66) correctly predicted elevated levels of Cs-137, Co-60, Pu-239/240, Sr-90, uranium, tritium, and nitrates. It also correctly predicted that Cs-137 would be found near the point of release in high concentrations, while mobile contaminants such as nitrate would migrate deeper and might be detected in low concentrations to the water table.

A stratigraphy diagram for the 216-S-20 Crib is shown in Figure 3-6. Stratigraphy and data for radionuclide and nonradionuclide contamination are shown in Figures 3-11 and 3-12. Vertical profile plots of contaminants are shown in Figure 3-13.

3.2.3 Nature and Extent of Contamination in the 216-Z-7 Crib

This section describes the nature and extent of contamination in the 216-Z-7 Crib area. The 216-Z-7 Crib is located east of the 231-Z Plutonium Isolation Plant Building and north of 19th Street (Figure 1-2).

3.2.3.1 Geophysical Logging Summary for the 216-Z-7 Crib

The six 216-Z-7 Crib direct-push holes were geophysically logged in July 2005. Geophysical logging was performed on the 216-Z-7 Crib borehole (C4183) on February 24, 2005, and March 24 and 28, 2005. Four man-made radionuclides, Cs-137, Co-60, Pu-239, and Eu-154 were found with SGLS. A comparison of radionuclide data for the six direct-push holes and borehole C4183 for Cs-137, Co-60 and Eu-154 is shown in Table 3-2.

The data from the various sources agree within the bounds of error expected with SGLS and given the expected variation among the different boreholes. In general, logging data give a general picture of contamination but are more prone to error than are laboratory data and are considered less reliable. Logging results are subject to the judgment of the personnel involved in taking and interpreting results and are dependent on many assumptions such as moisture level, distance from surface, thickness of casings, and homogeneity of soil.

The Cs-137 logging detects start just below the surface, with maximum concentrations of up to 100,000 pCi/g at 4.4 to 5.8 m (14.5 to 19 ft) bgs. Detections ceased at about 14.6 to 15.6 m (48 to 51 ft) bgs. The laboratory sample data show Cs-137 at 2,800 pCi/g at 5.3 to 6.1 m (17.5 to 20 ft) bgs, with detections continuing to below the 12.2 to 13.0 m (40 to 42.5 ft) bgs sample depth. Because the next sample interval is at 17.5 to 18.3 m (57.5 to 60 ft) bgs, this is consistent with logging.

Cobalt-60 was detected from 4.0 to 16.0 m (13 to 52.5 ft) bgs, with maximum concentrations of up to 35 pCi/g. The maximum concentration at each hole was at between 4.6 and 9.5 m (15 and 31 ft) bgs. The laboratory sample data show Co-60 at 58.3 pCi/g at 5.3 to 6.1 m (17.5 to 20 ft) bgs and 17.5 pCi/g at 6.9 to 7.6 m (22.5 to 25 ft) bgs. Although laboratory analysis showed Co-60 results at depths greater than 9.5 m (31 ft) bgs, the highest of these was only 0.044 pCi/g.

Europium-154 was detected from 4.0 to 14.3 m (13 to 47 ft) bgs, with maximum concentrations of up to 60 pCi/g. The maximum concentration at each hole was between 2.7 and 7.0 m (9 and 23 ft) bgs. The laboratory sample data show Eu-154 at 10.5 pCi/g at 5.3 to 6.1 m (17.5 to 20 ft) bgs and 5.54 pCi/g at 6.9 to 7.6 m (22.5 to 25 ft) bgs. Although laboratory analysis showed Eu-154 results at depths greater than 14.3 m (47 ft) bgs, the highest of these was only 0.153 pCi/g.

Plutonium-239 was detected in two direct-push holes, from 4.0 to 5.8 m (13 to 19 ft) bgs, with a maximum concentration of 240,000 pCi/g at 5.0 m (16.5 ft) bgs. Passive neutron detector measurements infer the presence of Pu-239 in the high gamma activity zone in the borehole and remaining direct-push holes, but the data available were inconclusive. The laboratory sample data show Pu-239 at 472,000 pCi/g at 5.3 to 6.1 m (17.5 to 20 ft) bgs and 33,900 pCi/g at

6.9 to 7.6 m (22.5 to 25 ft) bgs. These laboratory results are consistent with the logged results in two direct-push holes and inferred results in the remainder of the holes.

Changes in the natural potassium-uranium-thorium logs that occurred in borehole C4183 at approximately 13.7 m (45 ft) bgs and in the direct-push holes at 12.2 to 12.8 m (40 to 42 ft) bgs suggest a lithology change at these depths.

Geophysical logging of seven existing boreholes in the vicinity of the 216-Z-7 Crib representative waste site, boreholes 299-W15-7, 299-W15-62, 299-W15-63, 299-W15-64, 299-W15-76, 299-W15-77, and 299-W15-78, also were logged with the SGLS. Only one of these boreholes, 299-W15-7, is located within the waste site boundary (DOE/RL-2001-66, Figure 4-2). For Cs-137 and Co-60, logging results for the seven existing holes were not markedly similar to logging results for the six direct-push holes and borehole C4183. For Cs-137, one maximum concentration was 2 pCi/g, and the other maximums ranged from near the MDL to 0.75 pCi/g. This is lower than the maximum concentration found in borehole C4183 and five of the six direct-push holes. Depths of maximum concentration were similar to those logged for borehole C4183 and the direct-push holes.

For Co-60, the maximum concentrations in the existing boreholes ranged from 0 to 35 pCi/g, which is similar to logging results for the direct-push holes and borehole C4183. However, the radionuclide was found at greater depths, from 7.6 to 83.3 m (25 to 273 ft) bgs, with depth of maximum concentration from 14.9 to 58.9 m (49 to 193 ft) bgs. For Eu-154, maximum concentrations in the existing boreholes ranged from 0 to 5 pCi/g, which is lower than in borehole C4183 and three of the direct-push holes. The depths of maximum concentration were greater, from 15.3 to 39 m (50 to 128 ft) bgs. Plutonium-239 was not logged in any of the existing holes. Europium-152 was logged in borehole 299-W15-63 at 34.5 and 41.8 m (113 and 137 ft) bgs, with a maximum concentration of 0.3 pCi/g at 34.5 m (113 ft) bgs.

3.2.3.2 216-Z-7 Crib Contamination–Laboratory Data

When it was actively receiving waste, the bottom of the 216-Z-7 Crib was about 3.7 m (12 ft) bgs. It received process waste from the 231-Z Plutonium Isolation Plant Building and 300 Area liquid waste from the 340 Waste Neutralization Facility. This waste contained uranium, plutonium, Cs-137, Sr-90, and nitrates (DOE/RL-96-81).

Radioactive contamination was detected in the vadose zone beneath the 216-Z-7 Crib in borehole C4183 to 67.9 m (222.5 ft) bgs. Maximum contaminant levels are shown in Appendix A and are summarized here.

Radionuclides in shallow soils (<4.6 m [<15 ft]) with concentrations above background or that have no available background values were Cs-137 at 0.0835 pCi/g, Eu-155 at 0.0734 pCi/g, and Np-237 at 0.059 pCi/g, all at 3.8 to 4.6 m (12.5 to 15 ft) bgs.

Maximum concentrations of radionuclides in deep soils with concentrations above background or that have no available background values were as follows:

- Americium-241 — 60,600 pCi/g at 5.3 to 6.1 m (17.5 to 20 ft) bgs
- Cesium-137 — 2,800 pCi/g at 5.3 to 6.1 m (17.5 to 20 ft) bgs

• Cobalt-60	58.3 pCi/g at 5.3 to 6.1 m (17.5 to 20 ft) bgs
• Europium-154	10.5 pCi/g at 5.3 to 6.1 m (17.5 to 20 ft) bgs
• Europium-155	0.0829 pCi/g at 17.5 to 18.3 m (57.5 to 60 ft) bgs
• Neptunium-237	0.059 pCi/g at 5.3 to 6.1 m (17.5 to 20 ft) bgs
• Plutonium-238	5,770 pCi/g at 5.3 to 6.1 m (17.5 to 20 ft) bgs
• Plutonium-239/240	472,000 pCi/g at 5.3 to 6.1 m (17.5 to 20 ft) bgs
• Technetium-99	11 pCi/g at 6.9 to 7.6 m (22.5 to 25 ft) bgs
• Total Radioactive Strontium	437,000 pCi/g at 5.3 to 6.1 m (17.5 to 20 ft) bgs
• Tritium	9.54 pCi/g at 35.8 to 36.6 m (117.5 to 120 ft) bgs.

Extensive tables in Chapters 4.0 and 5.0 of this report compare the nonradioactive COPCs against background and screening levels. For shallow soils, contaminants that were detected above background or that have no available background are as follows (maximum detected levels shown):

• Arsenic	13,400 µg/kg at 3.8 to 4.6 m (12.5 to 15 ft) bgs
• Cyanide	3,950 µg/kg at 3.8 to 4.6 m (12.5 to 15 ft) bgs
• Nitrogen in nitrite and nitrate	2,000 µg/kg at 3.8 to 4.6 m (12.5 to 15 ft) bgs.

For deep soils, contaminants that were detected above background or have no available background are as follows (maximum detected levels shown):

• Antimony	2,800 µg/kg at 5.3 to 6.1 m (17.5 to 20 ft) bgs
• Arsenic	13,400 µg/kg at 3.8 to 4.6 m (12.5 to 15 ft) bgs
• Bismuth	123,000 µg/kg at 8.4 to 9.2 m (27.5 to 30 ft) bgs
• Boron	3,100 µg/kg at 8.4 to 9.2 m (27.5 to 30 ft) bgs
• Chromium	193,000 µg/kg at 5.3 to 6.1 m (17.5 to 20 ft) bgs
• Hexavalent chromium	2,050 µg/kg at 60.2 to 61 m (197.5 to 200 ft) bgs
• Lead	14,300 µg/kg at 5.3 to 6.1 m (17.5 to 20 ft) bgs
• Nickel	23,400 µg/kg at 60.2 to 61.0 m (197.5 to 200 ft) bgs
• Silver	4,700 µg/kg at 29.4 to 30.2 m (96.5 to 99 ft) bgs
• Uranium	27,900 µg/kg at 5.3 to 6.1 m (17.5 to 20 ft) bgs
• Mercury	5,600 µg/kg at 5.3 to 6.1 m (17.5 to 20 ft) bgs
• Cyanide	3,950 µg/kg at 3.8 to 4.6 m (12.5 to 15 ft) bgs
• Ammonium ion	649 µg/kg at 60.2 to 61 m (197.5 to 200 ft) bgs
• Nitrate	19,744 µg/kg at 12.2 to 12.8 m (40 to 42.5 ft) bgs
• Nitrogen in nitrite and nitrate	2,500 µg/kg at 12.2 to 12.8 m (40 to 42.5 ft) bgs
• Phosphate	13,000 µg/kg at 6.9 to 7.6 m (22.5 to 25 ft) bgs
• Methylene chlorine	24 µg/kg at 6.9 to 7.6 m (22.5 to 25 ft) bgs
• Oil & grease	727,000 µg/kg at 67.1 to 67.9 m (220 to 222.5 ft) bgs
• 1,2,3-Trichlorobenzene	7.5 µg/kg at 6.9 to 7.6 m (22.5 to 25 ft) bgs
• Carbon disulfide	1.1 µg/kg at 5.3 to 6.1 m (17.5 to 20 ft) bgs
• Diethylphthalate	460 µg/kg at 67.1 to 67.9 m 220 to 222.5 ft bgs
• Di-n-butylphthalate	2,100 µg/kg at 29.4 to 30.2 m (96.5 to 99 ft) bgs
• Ethyl acetate	5.5 µg/kg at 8.4 to 9.2 m (27.5 to 30 ft) bgs
• Nonadecane	1,500 µg/kg at 60.2 to 61.0 m (197.5 to 200 ft) bgs
• Trichloroethene	2 µg/kg at 5.3 to 6.1 m (17.5 to 20 ft) bgs.

In general, the contaminant distribution model is well supported by the data. The contaminant distribution model (DOE/RL-2000-61) indicates that the highest contamination will be found from the bottom of the crib to 17.7 m (58 ft) bgs, medium amounts of contamination from 17.7 to 33.6 m (58 to 110 ft) bgs, and low contamination below 33.6 m (110 ft). The radioactive contaminants at the 216-Z-7 Crib are markedly elevated at the 3.8 to 4.6 m (12.5 to 15 ft) and 5.3 to 6.1 m (17.5 to 20 ft) bgs depths (i.e., just below the 3.7 m (12 ft) bgs historical base of the crib).

The conceptual contaminant distribution model (DOE/RL-2001-66) correctly predicted elevated levels of Cs-137, Co-60, Pu-239/240, Sr-90, uranium, tritium, and nitrates. It also correctly predicted that Cs-137 would be found near the point of release in high concentrations, while mobile contaminants such as nitrate would migrate deeper and might be detected in low concentrations to the water table.

A stratigraphy diagram for the 216-Z-7 Crib is shown in Figure 3-7. Stratigraphy and data for radionuclide and nonradionuclide contamination are shown in Figures 3-14 and 3-15. Vertical profile plots of contaminants are shown in Figure 3-16.

3.3 IMPACTS TO GROUNDWATER

Groundwater is routinely monitored Sitewide. More than 700 monitoring wells are sampled annually to characterize groundwater flow; groundwater contamination by metals, radionuclides, and nonradiological constituents; and the extent of the contamination. Groundwater remediation progress, ingestion risk, and dose also are assessed. The Work Plan summarized the results of groundwater monitoring near each representative waste site, based on information in PNNL-13401, *Hanford Site Groundwater Monitoring for Fiscal Year 2000*). In this section, the status of groundwater monitoring near each representative waste site is updated, based on information reported in PNNL-15070.

Each of the representative waste sites has a discharge effluent volume greater than its waste site soil-column pore volume. This suggests that the volume of effluent released was sufficient to reach the aquifer during operation of the waste sites. Monitoring indicates that contamination of the groundwater is related to numerous waste sites, including waste sites outside the 200-LW-1 and 200-LW-2 OUs.

Figures 3-17 through 3-20 show the major groundwater plumes in the vicinity of the 200-LW-1 and 200-LW-2 OU waste sites. Future impacts to groundwater are evaluated in Chapter 4.0.

3.3.1 Current Impact to Groundwater in the 216-T-28 Crib Area

The effluent volume (42,300 m^3) discharged at the 216-T-28 Crib was more than 62 times greater than the soil pore volume (680 m^3) beneath the footprint of the waste site to the groundwater table (DOE/RL-96-81). This suggests that effluent may have reached groundwater at this site. When the Work Plan was written, current information in PNNL-13401 indicated that nitrate, carbon tetrachloride, trichloroethylene, I-129, and tritium exceeded groundwater protection standards/guidelines in the vicinity of the 216-T-28 Crib. Of these contaminants, only nitrate, I-129, and tritium were potentially associated with waste disposal practices at the crib.

PNNL-15070 indicates that nitrate, carbon tetrachloride, I-129, and tritium exceed drinking water standards in the area of the 216-T-28 Crib. The waste site also is on the edge of groundwater contaminant plumes for Tc-99 and trichloroethylene and may exceed drinking water standards for these contaminants.

3.3.2 Current Impact to Groundwater in the 216-S-20 Crib Area

The effluent volume (135,300 m^3) discharged at this site was more than 22 times greater than the soil pore volume (6,020 m^3) beneath the footprint of the waste site to the groundwater table (DOE/RL-96-81). This suggests that effluent may have reached groundwater at this site. When the Work Plan was written, current information in PNNL-13401 indicated that that nitrate, carbon tetrachloride, I-129, uranium, and tritium exceed groundwater protection standards/guidelines in the vicinity of the 216-S-20 Crib. Of these contaminants, only nitrate, I-129, and tritium may have been associated with waste disposal practices at the crib.

PNNL-15070 indicates that trichloroethene and tritium exceed drinking water standards in the area of the 216-S-20 Crib. The waste site also is on the edge of groundwater contaminant plumes for nitrate and I-129 and may exceed drinking water standards for these contaminants.

3.3.3 Current Impact to Groundwater in the 216-Z-7 Crib Area

The effluent volume (79,000 m^3) discharged at this site was more than 2.6 times greater than the soil pore volume (30,000 m^3) beneath the footprint of the waste site to the groundwater table (DOE/RL-96-81). This suggests that effluent may have reached groundwater at this site. When the Work Plan was written, current information in PNNL-13401 indicated that nitrate, carbon tetrachloride, trichloroethylene, Tc-99, I-129, and tritium exceed groundwater protection standards/guidelines in the vicinity of the 216-Z-7 Crib. Of these contaminants, only nitrate and tritium may have been associated with waste disposal practices at the crib.

PNNL-15070 indicates that nitrate, carbon tetrachloride, and trichloroethylene exceed drinking water standards in the area of the 216-Z-7 Crib.

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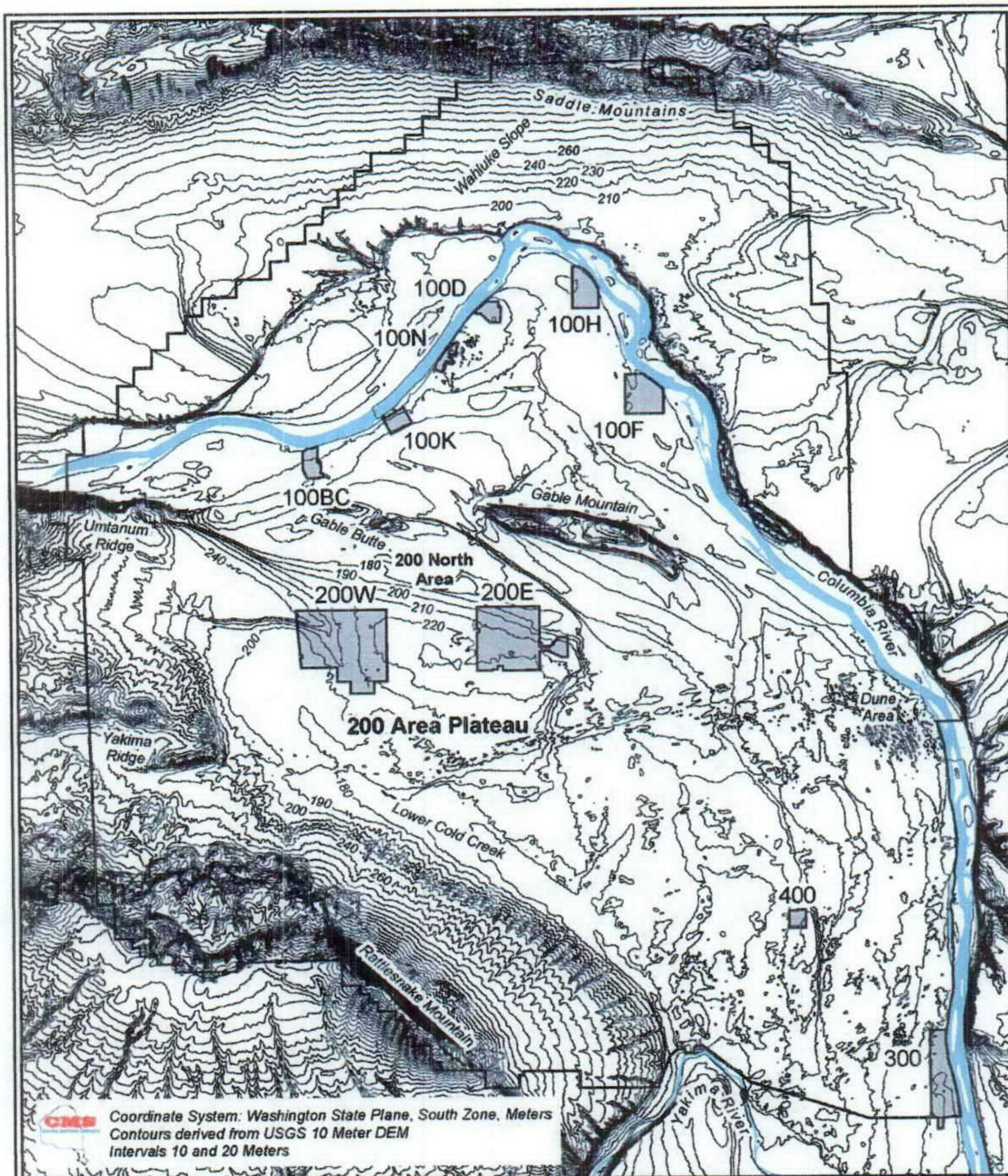
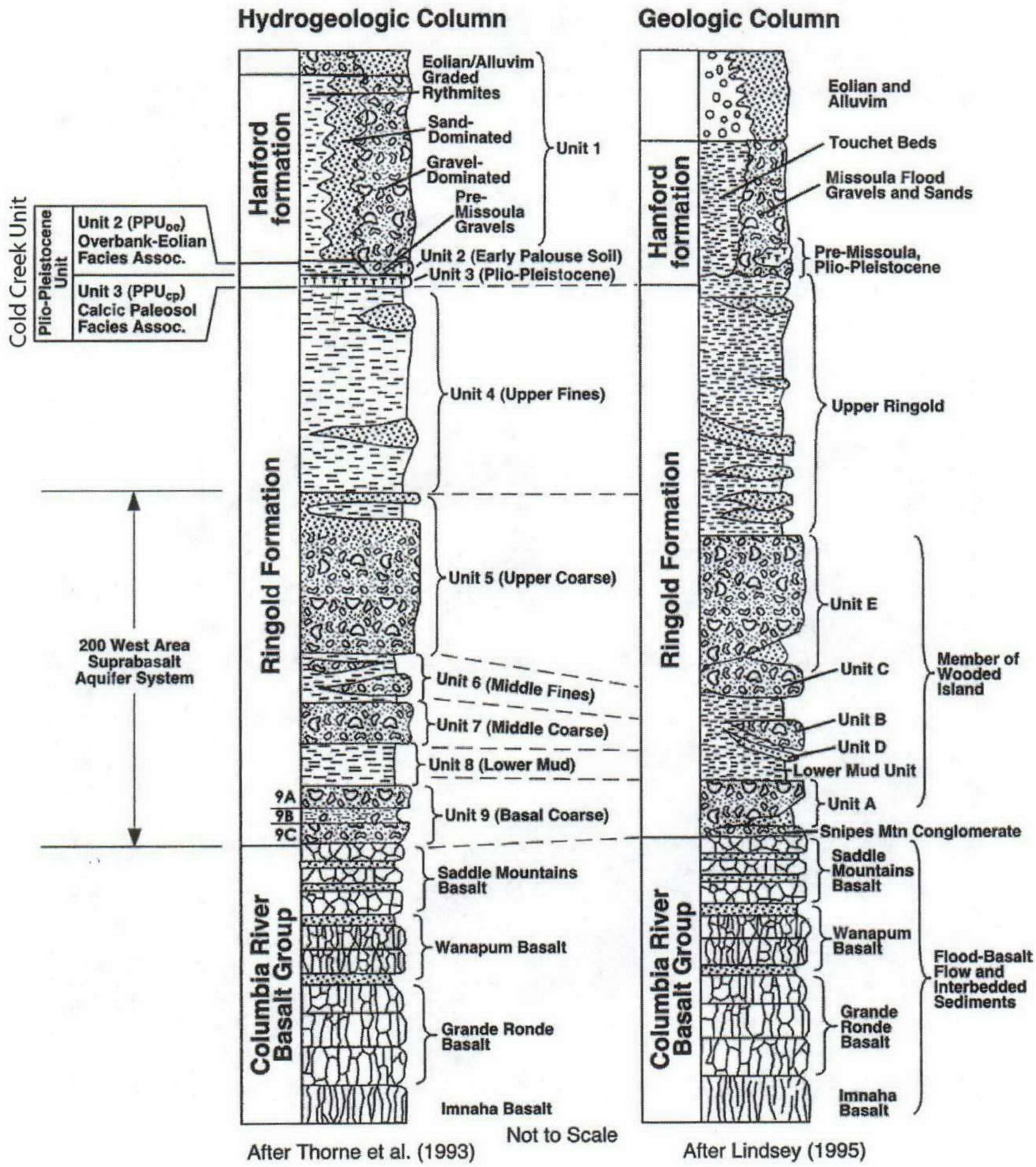
Figure 3-1. Topographic Map of the Hanford Site.



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

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



After Bjornstad et al. (2002)

Figure 3-3. Water-Table Map of the 200 West Area, March 2004 (from PNNL-15070).

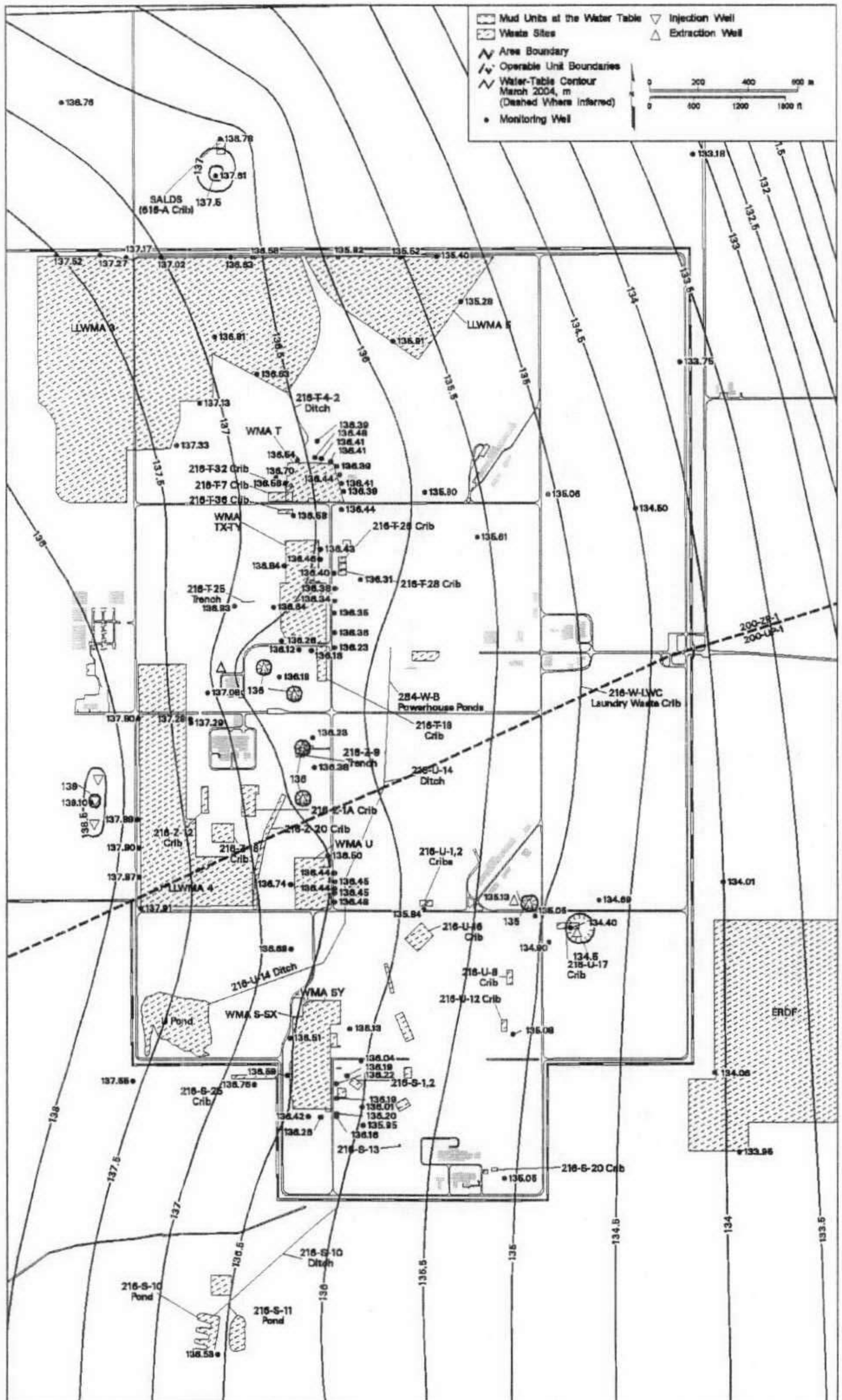


Figure 3-5. Stratigraphy Diagram for the 216-T-28 Crib.

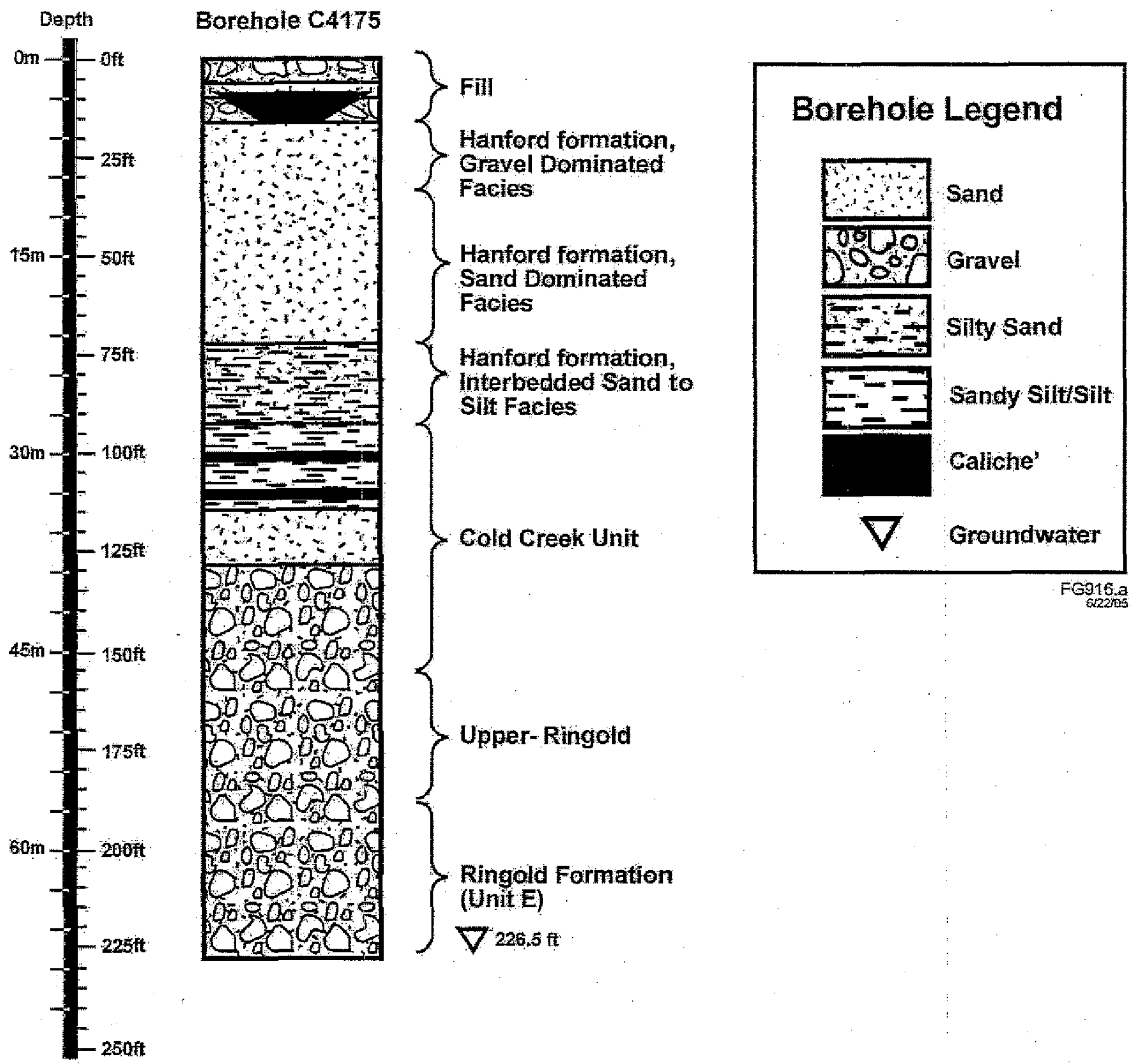


Figure 3-6. Stratigraphy Diagram for the 216-S-20 Crib.

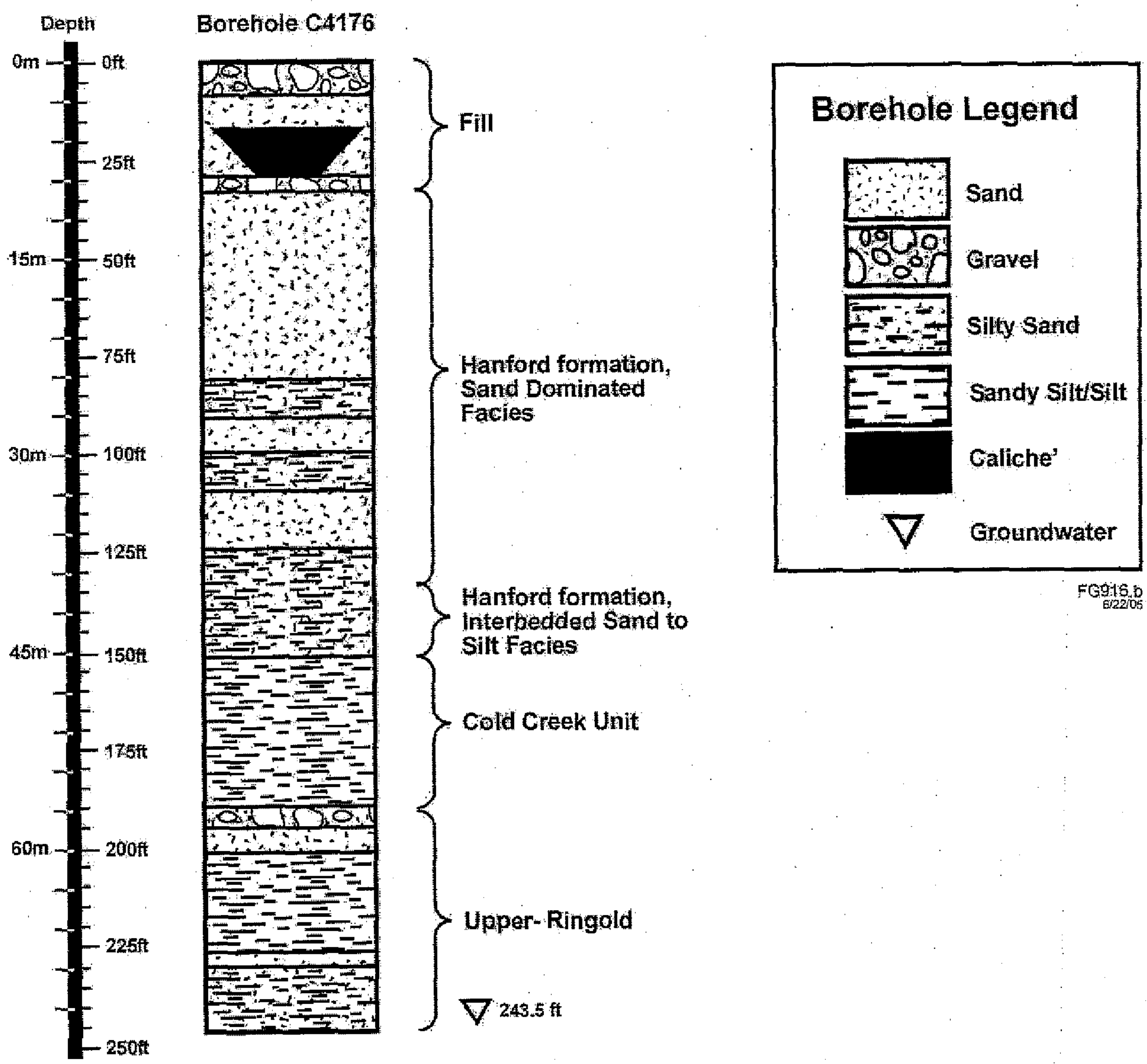


Figure 3-7. Stratigraphy Diagram for the 216-Z-7 Crib.

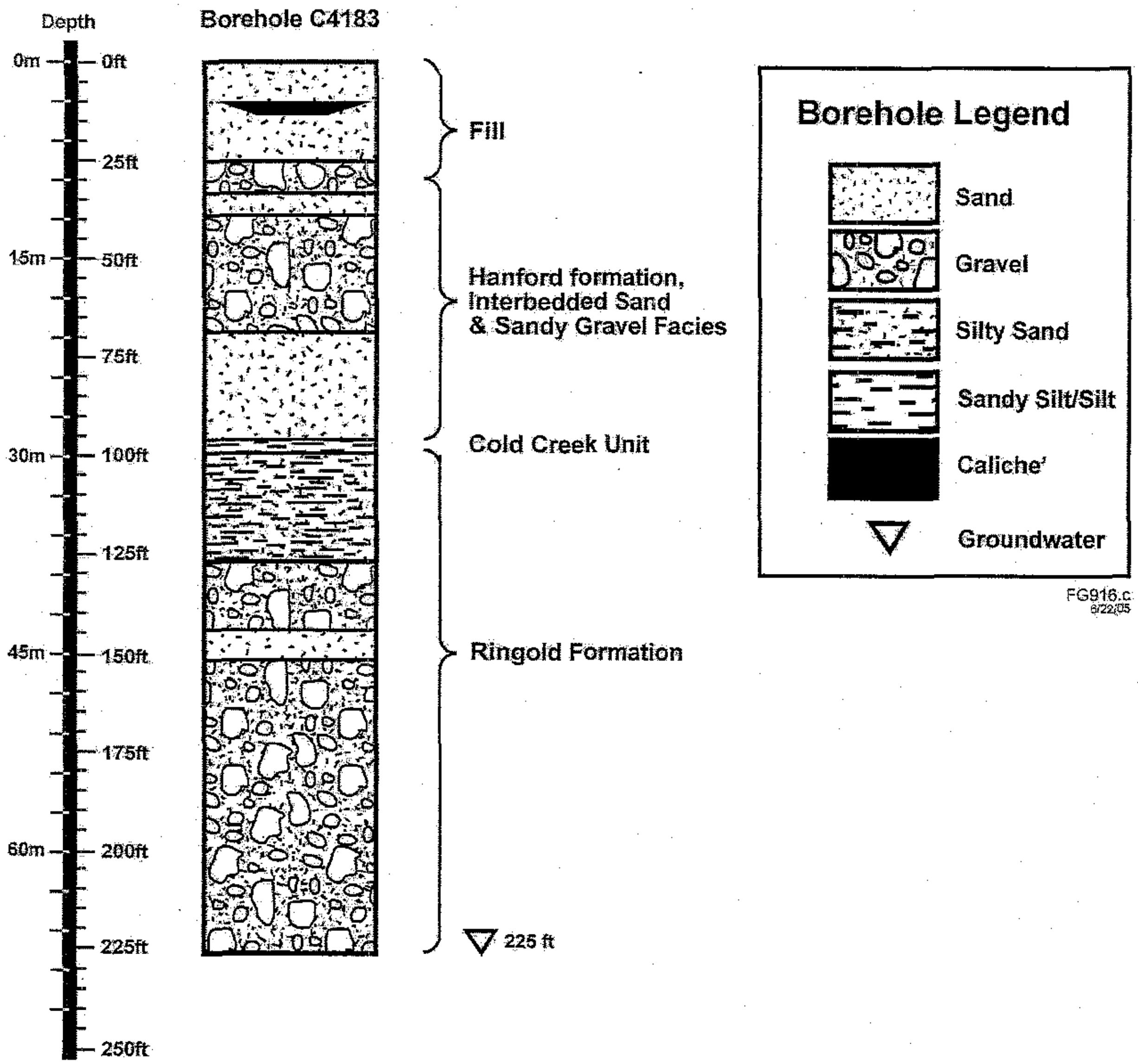


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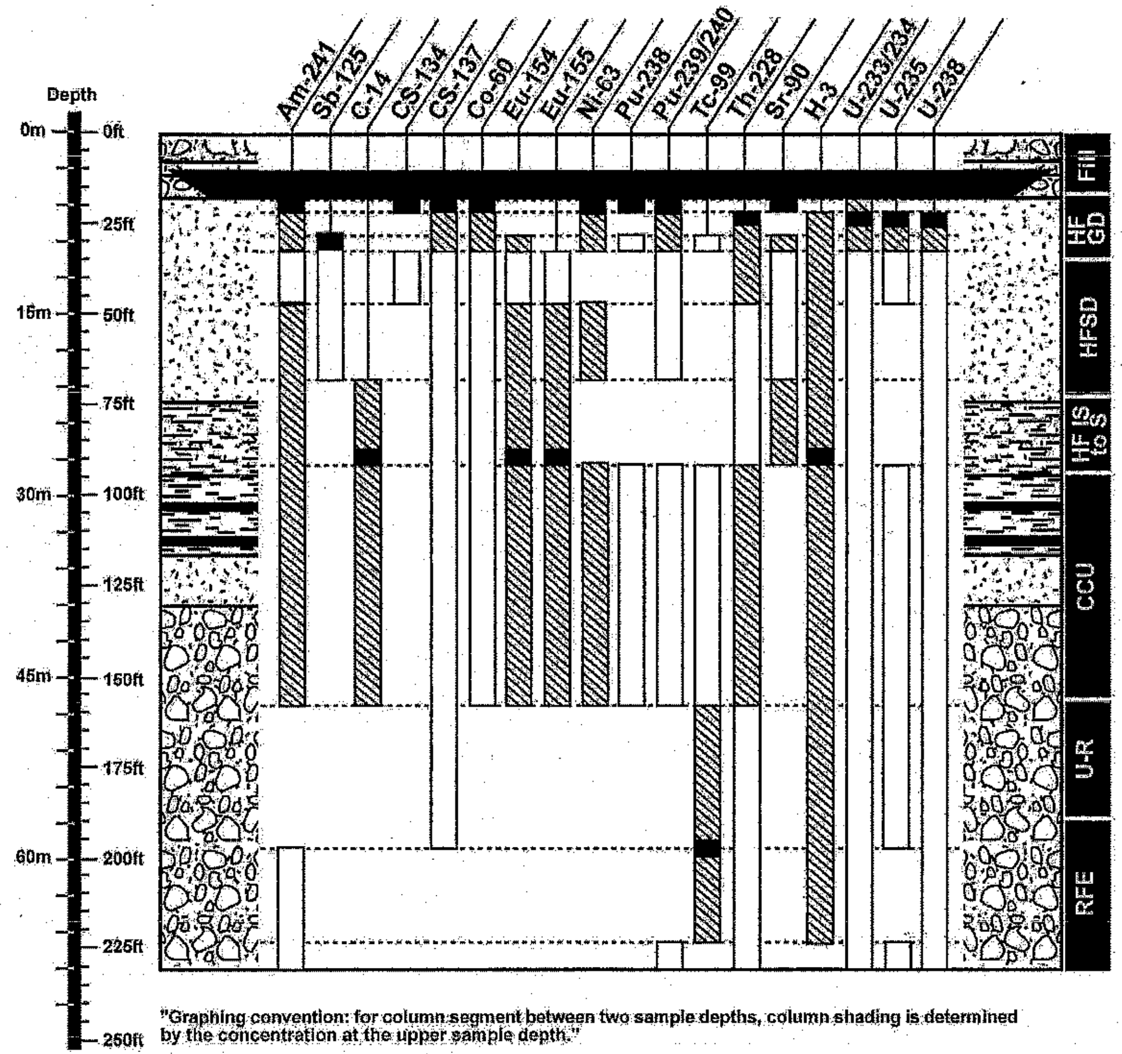
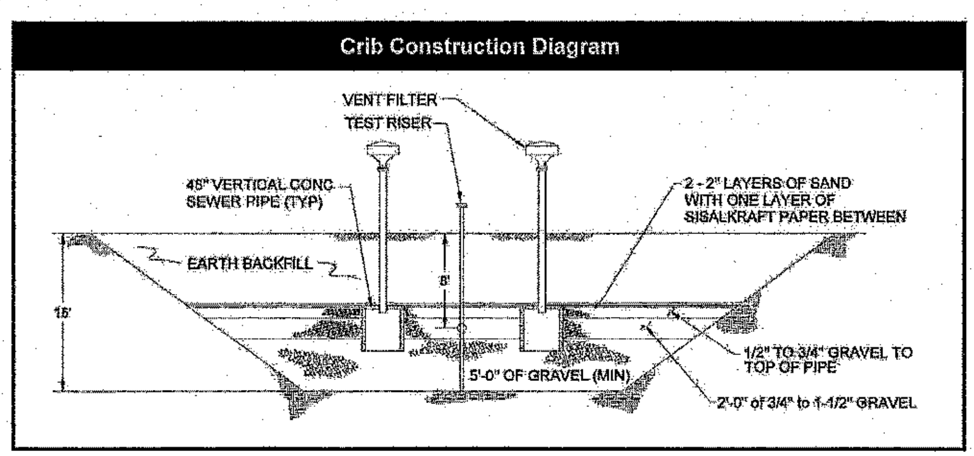
Figure 3-8. Stratigraphy and Radionuclide Contaminant Data for the 216-T-28 Crib.



"Graphing convention: for column segment between two sample depths, column shading is determined by the concentration at the upper sample depth."



216-T-28 Crib - Borehole C4175 - Radionuclides with max concentration exceeding bkg and > 1 pCi/g

Sample Depth	Am-241*	Sb-125	C-14	Cs-134	Cs-137	Co-60	Eu-154	Eu-155	Ni-63	Pu-238	Pu-239/240	Tc-99	Th-228*	Sr-90	H-3	U-233/234	U-235*	U-238*
ft bgs	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
17.5-20	802	ND	ND	456	3E+06	1180	ND	ND	843	84.5	1110	ND	ND	6.E+05	ND	41.6	ND	ND
22.5-25	9.15	ND	ND	ND	6560	1.77	ND	ND	140	ND	13	1.1	2.69	4010	15	59.4	3.44	35.1
27.5-30	4.4	2.39	ND	ND	2720	1.01	1.4	ND	54.6	0.41	5.9	0.92	1.79	1220	13.2	36	1.7	27
32.5-35	0.26	0.074	ND	0.03	0.886	0.052	0.205	0.115	ND	ND	0.072	ND	1.13	0.342	5.36	0.15	0.007	0.12
47.5-50	3.1	0.117	ND	ND	0.724	0.524	4.65	2.14	5.81	ND	0.19	ND	0.984	0.239	26.4	0.24	ND	0.2
67.5-70	3.6	NR	3.18	NR	0.845	0.134	8.68	3.71	ND	ND	ND	ND	0.64	1.84	127	0.18	ND	0.14
90-92.5	20	NR	4.52	NR	0.05	0.151	43	19.9	3.36	0.059	0.02	0.974	1.16	ND	19000	0.31	0.016	0.26
157.5-160	ND	NR	ND	NR	0.018	ND	ND	ND	ND	ND	ND	1.22	0.496	ND	13.4	0.14	0.014	0.19
197.5-200	0.034	NR	ND	NR	ND	ND	ND	ND	ND	ND	ND	1.61	0.559	ND	7.81	0.15	ND	0.13
223.5-226	0.058	NR	ND	NR	ND	ND	ND	ND	ND	ND	0.017	ND	0.62	ND	0.792	0.12	0.006	0.16

Am Americium
Sb Antimony
C Carbon
Cs Cesium
Co Cobalt
Eu Europium
Ni Nickel
Pu Plutonium
Tc Technetium
Th Thorium
Sr Strontium (total beta)
H-3 Tritium
U Uranium
ND Not Detected
NR No Result Reported

ND Not Detected
NR No Result Reported
[box] Maximum Concentrations
*See App A for multiple-result selection criteria

1) The 216-T-28 Crib consists of a 36-cm (14-in.) steel inlet pipe reducing to a 25.4-cm (10-in.) steel pipe, 2.4 m (8-ft) below grade. The pipe branches to four 20.3-cm (8-in.) steel pipes, each one extending to a 1.2-m (4-ft)-long by 1.2-m (4-ft)-diameter, open-end, vertically-oriented, concrete sewer pipe. This structure rests in an excavation that is 4.6 m (15-ft) deep by 9 by 9 m (30 by 30 ft), filled with 2.4 m (8-ft) of gravel and 2.1 m (7-ft) of earth.

2) Acidic to basic, low salt, low organic liquid waste containing cesium-137, cobalt-60, plutonium-239/240, Strontium-90, uranium, nitrate, and other contaminants were discharged to the 216-T-28 Crib between 1960 and 1966. The crib received a total volume of 42,300,000 L (11,200,000 gallons) of wastewater.

3) Once discharged, wastewater and contaminants migrate vertically downward beneath the crib. Lateral spreading of wastewater occurs associated with the bottom of the crib, and at formation interfaces. Contaminant impacts are significant in boreholes 299-W-14-2 and 299-W14-3, which are located in the crib, and borehole 299-W14-4, which is located adjacent to the site. 125 ft southeast of the crib, low levels of contamination were detected in borehole 299-W14-1. Concentrations near the crib may in part be associated with contamination from adjacent waste sites 216-T-26 and 216-T-27.

4) Immobile contaminants such as cesium-137 normally sorb near the point of release of high concentrations. Beneath the crib, cesium-137 concentrations were > 2000 pCi/g to a depth of 27-5-30 ft, based on sample data. Contaminant concentrations were < 1 pCi/g below the 27.5-30 ft bgs sample interval.

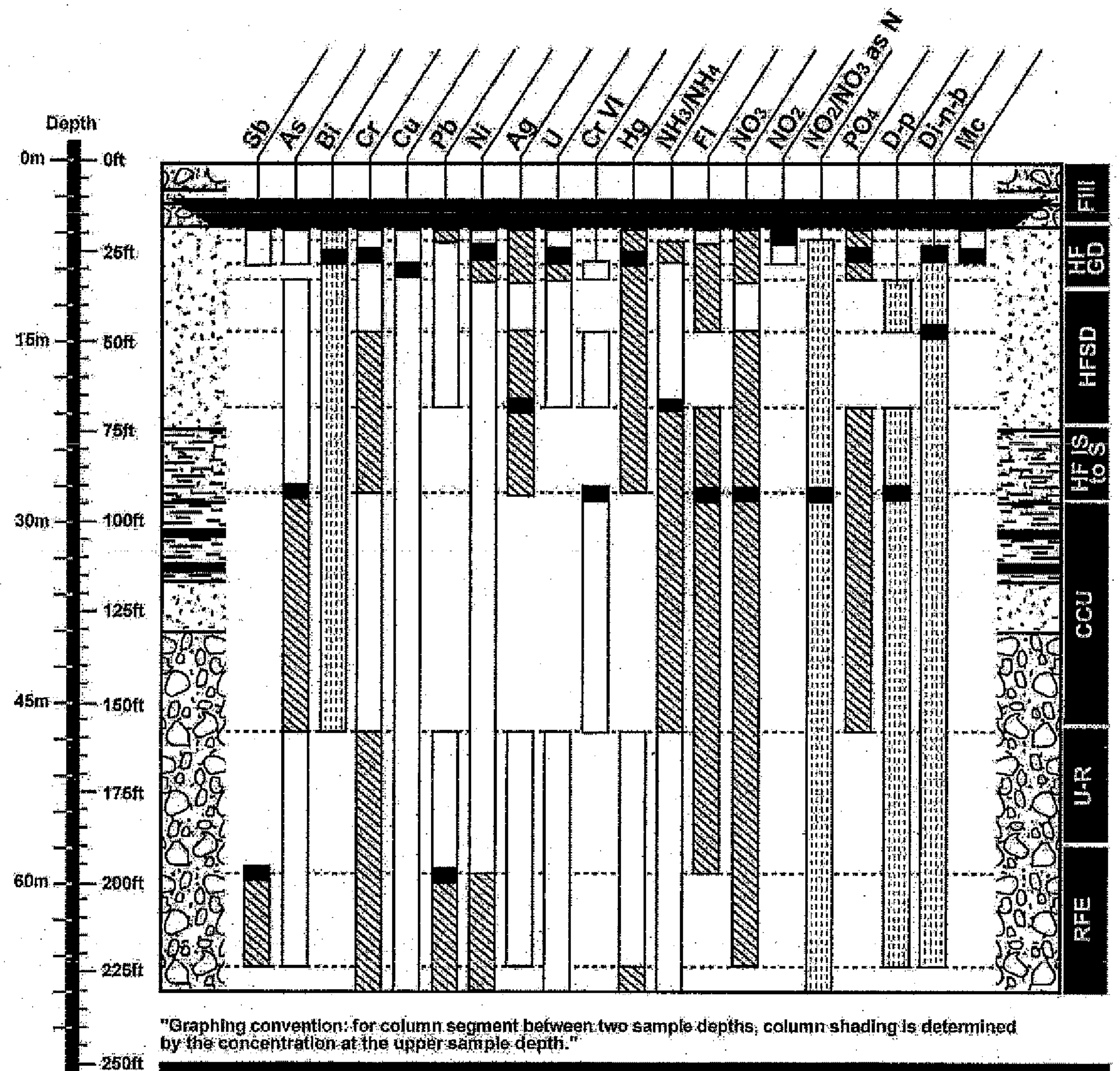
5) Mobile contaminants like nitrate migrate with the moisture front and may be detected in low concentrations to the water table.

6) Wastewater and mobile contaminants likely impact groundwater, since effluent volume discharged to the soil column (42,300 m³) is greater than the soil column pore volume (680 m³). Nitrate, technetium-99, and tritium may exceed groundwater protection standards near the crib.

Formation Legend	Strata Legend	Constituent Legend
F - Fill HFGD - Hanford formation Gravel Dominated HFSD - Hanford formation Sand Dominated HF IS to S - Hanford formation, Interbedded Sand to Silt CCU - Cold Creek Unit U - R - Upper - Ringold RF - Ringold Formation RFE - Ringold Formation (Unit E)	Sand Gravel Silty Sand Sandy Silt/Silt Caliche'	Highest Concentration ≥ 1 pCi/g < 1 pCi/g ----- Sample Depth Depth of Crib ▽ Water Table

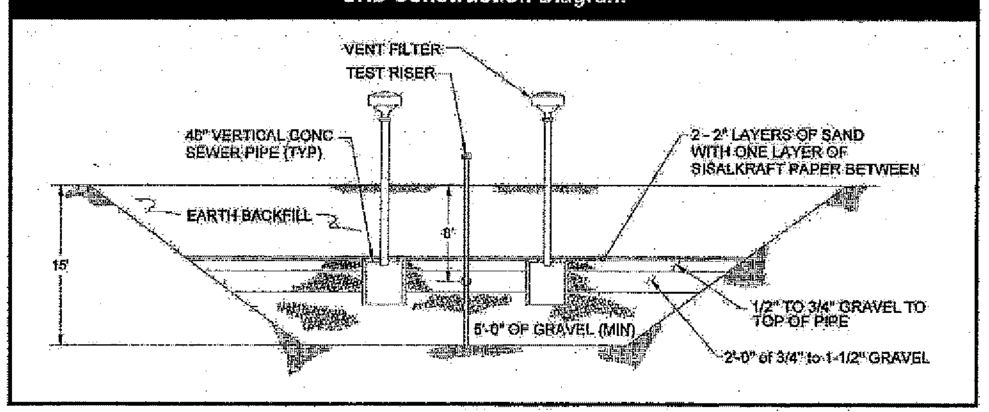
FG916.9 11/14/05

Figure 3-9. Stratigraphy and Nonradionuclide Contaminant Data for the 216-T-28 Crib.



"Graphing convention: for column segment between two sample depths, column shading is determined by the concentration at the upper sample depth."

Crib Construction Diagram



216-T-28 Crib - Borehole C4175 - Select Chemical Constituents

Sample Depth	Sb	As	Bi	Cr	Cu	Pb	Ni	Ag	U	Cr VI	Hg	NH_3/NH_4	Fl	NO_3	NO_2	N in NO_2/NO_3	PO_4	Diethyl-phthalate	Di-n-butyl-phthalate	Methylene chloride
ft bgs	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg
17.5-20	600	740	166000	6100	15100	16700	8900	1300	60.8	NR	6590	ND	2300	16800	2530	NR	26200	ND	ND	3.7
22.5-25	1400	2000	202000	81700	19700	5100	52700	2100	125000	ND	8840	14500	3400	34500	1450	24900	59100	NR	1700	25
27.5-30	ND	ND	5540	13400	19800	4440	12600	1060	113000	240	3990	1730	4240	26900	ND	4000	55800	NR	1300	ND
32.5-35	ND	3240	5850	16900	18100	3490	14300	113	491	ND	1000	1170	3620	11100	ND	1300	ND	370	970	ND
47.5-50	ND	4270	4900	18500	15000	6060	17800	827	1240	250	1040	1930	ND	19300	ND	3700	ND	NR	1700	ND
67.5-70	ND	6820	3910	19800	14500	ND	17300	4980	ND	ND	1550	24700	5950	51800	ND	11600	15900	410	870	ND
90-92.5	ND	9290	5890	9830	16300	ND	17000	ND	ND	1500	ND	22800	39600	245000	ND	45800	21000	730	630	ND
157.5-160	ND	2370	ND	65800	18200	2990	18500	79	536	ND	230	771	4060	100000	ND	30500	ND	230	340	ND
197.5-200	5030	2380	ND	79900	16800	34400	20200	32	564	ND	99	3820	ND	173000	ND	48400	ND	200	1200	ND
223.5-226	ND	ND	ND	28600	12600	8860	21600	ND	305	ND	638	267	ND	ND	ND	900	ND	NR	NR	ND

Sb Antimony
As Arsenic
Bi Bismuth
Cr Chromium
Cu Copper
Pb Lead
Ni Nickel
Ag Silver
U Uranium
Hg Mercury
NH_3 Ammonia
NH_4 Ammonium ion
Fl Fluoride
NO_3 Nitrate
NO_2 Nitrite
PO_4 Phosphate
D-p Diethylphthalate
D-n-b Di-n-butylphthalate
Mc Methylene chloride
ND Not Detected
NR No Result Reported
[box] Maximum Concentrations

1) The 216-T-28 Crib consists of a 36-cm (14-in.) steel inlet pipe reducing to a 25.4-cm (10-in.) steel pipe, 2.4 m (8-ft) below grade. The pipe branches to four 20.3-cm (8-in.) steel pipes, each one extending to a 1.2-m (4-ft)-long by 1.2-m (4-ft)-diameter, open-end, vertically-oriented, concrete sewer pipe. This structure rests in an excavation that is 4.6 m (15-ft) deep by 9 by 9 m (30 by 30 ft), filled with 2.4 m (8-ft) of gravel and 2.1 m (7-ft) of earth.

2) Acidic to basic, low salt, low organic liquid waste containing cesium-137, cobalt-60, plutonium-239/240, Strontium-90, uranium, nitrate, and other contaminants were discharged to the 216-T-28 Crib between 1960 and 1966. The crib received a total volume of 42,300,000 L (11,200,000 gallons) of wastewater.

3) Once discharged, wastewater and contaminants migrate vertically downward beneath the crib. Lateral spreading of wastewater occurs associated with the bottom of the crib, and at formation interfaces. Contaminant impacts are significant in boreholes 299-W-14-2 and 299-W14-3, which are located in the crib, and borehole 299-W14-4, which is located adjacent to the site. 125 ft southeast of the crib, low levels of contamination were detected in borehole 299-W14-1. Concentrations near the crib may in part be associated with contamination from adjacent waste sites 216-T-26 and 216-T-27.

4) Immobile contaminants such as cesium-137 normally sorb near the point of release of high concentrations. Beneath the crib, cesium-137 concentrations were > 2000 pCi/g to a depth of 27-5-30 ft, based on sample data. Contaminant concentrations were < 1 pCi/g below the 27.5-30 ft bgs sample interval.

5) Mobile contaminants like nitrate migrate with the moisture front and may be detected in low concentrations to the water table.

6) Wastewater and mobile contaminants likely impact groundwater, since effluent volume discharged to the soil column (42,300 m^3) is greater than the soil column pore volume (680 m^3). Nitrate, technetium-99, and tritium may exceed groundwater protection standards near the crib.

Formation Legend

F - Fill
HFGD - Hanford formation Gravel Dominated
HFSD - Hanford formation Sand Dominated
HF IS to S - Hanford formation, Interbedded Sand to Silt
CCU - Cold Creek Unit
U - R - Upper - Ringold
RF - Ringold Formation
RFE - Ringold Formation (Unit E)

Strata Legend

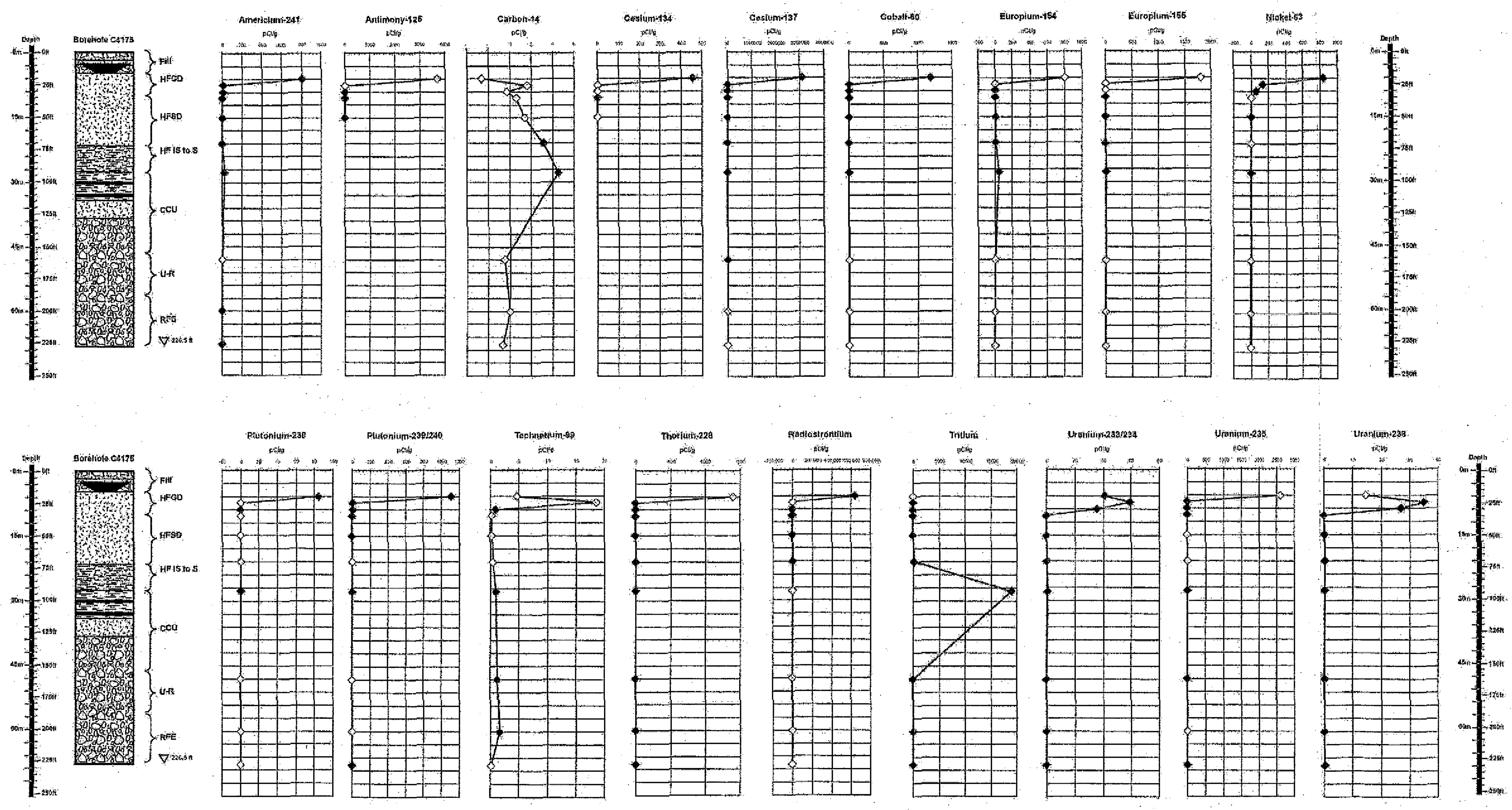
Sand
Gravel
Silty Sand
Sandy Silt/Silt
Caliche'

Constituent Legend

Highest Concentration
≥ background or PAL
< background or PAL
Detected (no background or PAL)
Sample Depth
Depth of Crib
Water Table
(PAL - Preliminary Action Level)

FG916.10

Figure 3-10. Vertical Profile Plots of Contaminants for the 216-T-28 Crib. (3 Pages)



216-T-28 Crib - Borehole C4175

F - Fill
HFGD - Hanford formation Gravel Dominated
HFSD - Hanford formation Sand Dominated
HF IS to S - Hanford formation, Interbedded Sand to Silt
RFE - Ringold Formation (Unit E)
CCU - Cold Creek Unit
U - R - Upper - Ringold

Concentration Legend

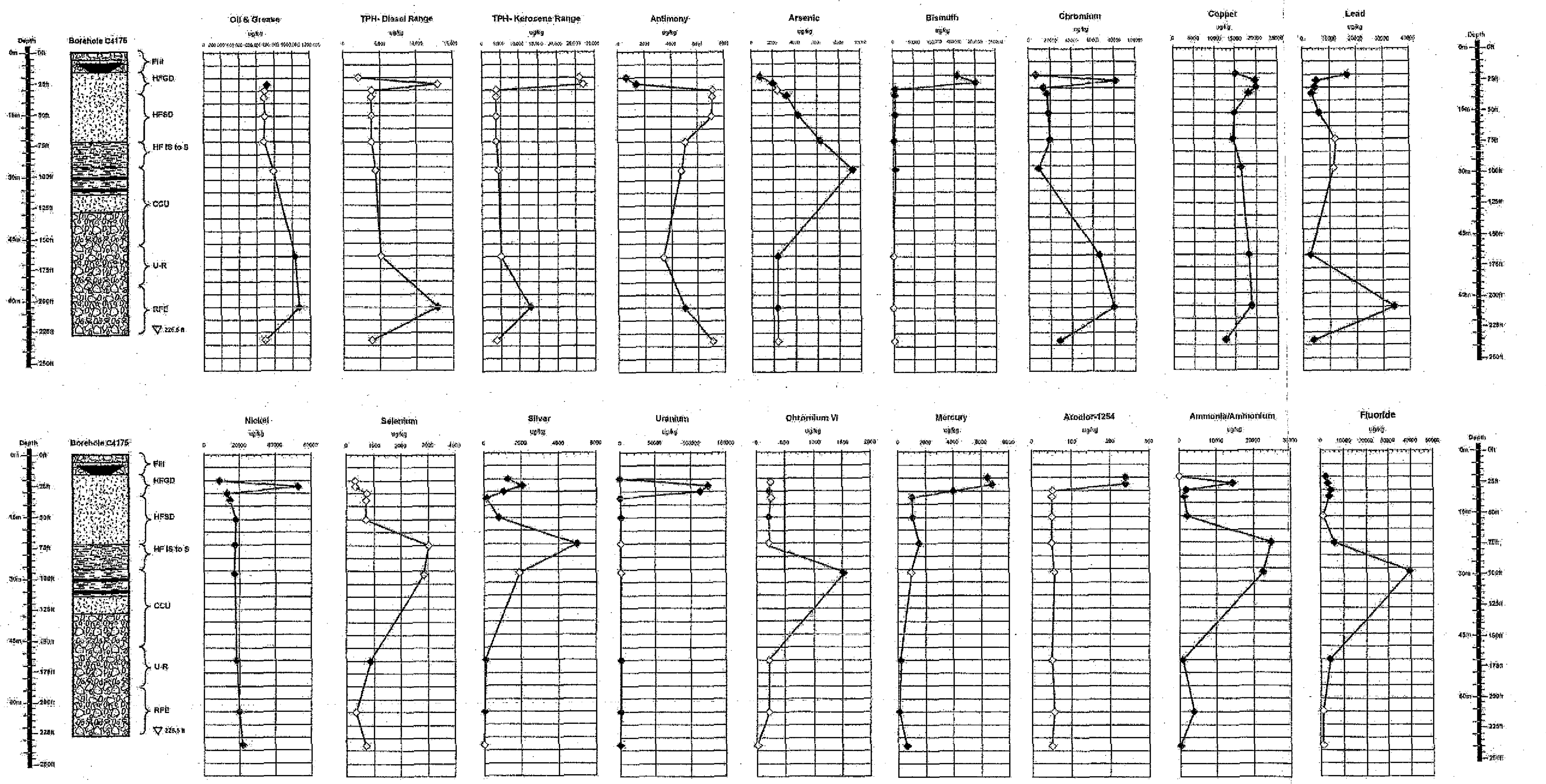
Analyte	Background	Analyte	Background	Analyte	Background
Thorium-228	1.32 pCi/g	Beryllium	1.51 mg/kg	Uranium	3.21 mg/kg
Thorium-232	1.32 pCi/g	Chromium	18.5 mg/kg	Ammonium ion as N	9.23 mg/kg
Uranium-233/234	1.10 pCi/g	Copper	22 mg/kg	Ammonia as N	9.23 mg/kg
Uranium-235	0.109 pCi/g	Lead	10.2 mg/kg	Fluoride	2.81 mg/kg
Uranium-238	1.06 pCi/g	Mercury	0.33 mg/kg	Nitrate as N	12 mg/kg
Arsenic	6.47 mg/kg	Nickel	19.1 mg/kg	Phosphate	0.785 mg/kg
Barium	132 mg/kg	Silver	0.73 mg/kg		

Borehole Legend

Sand
Silty Sand
Caliche'
Gravel
Sandy Silt/Silt
▽ Water Table ◆ Positive Detect ◇ Non-detect

FG916.4
6/23/05

Figure 3-10. Vertical Profile Plots of Contaminants for the 216-T-28 Crib. (3 Pages)



216-T-28 Crib - Borehole C4175

F - Fill
HFGD - Hanford formation Gravel Dominated
HFSD - Hanford formation Sand Dominated
HF IS to S - Hanford formation, Interbedded Sand to Silt
RFE - Ringold Formation (Unit E)
CCU - Cold Creek Unit
U - R - Upper - Ringold

Concentration Legend

Analyte	Background	Analyte	Background	Analyte	Background
Thorium-228	1.32 pCi/g	Beryllium	1.51 mg/kg	Uranium	3.21 mg/kg
Thorium-232	1.32 pCi/g	Chromium	16.5 mg/kg	Ammonium ion as N	9.23 mg/kg
Uranium-233/234	1.10 pCi/g	Copper	22 mg/kg	Ammonia as N	9.23 mg/kg
Uranium-235	0.109 pCi/g	Lead	10.2 mg/kg	Fluoride	2.81 mg/kg
Uranium-238	1.06 pCi/g	Mercury	0.33 mg/kg	Nitrate as N	12 mg/kg
Arsenic	6.47 mg/kg	Nickel	19.1 mg/kg	Phosphate	0.785 mg/kg
Barium	132 mg/kg	Silver	0.73 mg/kg		

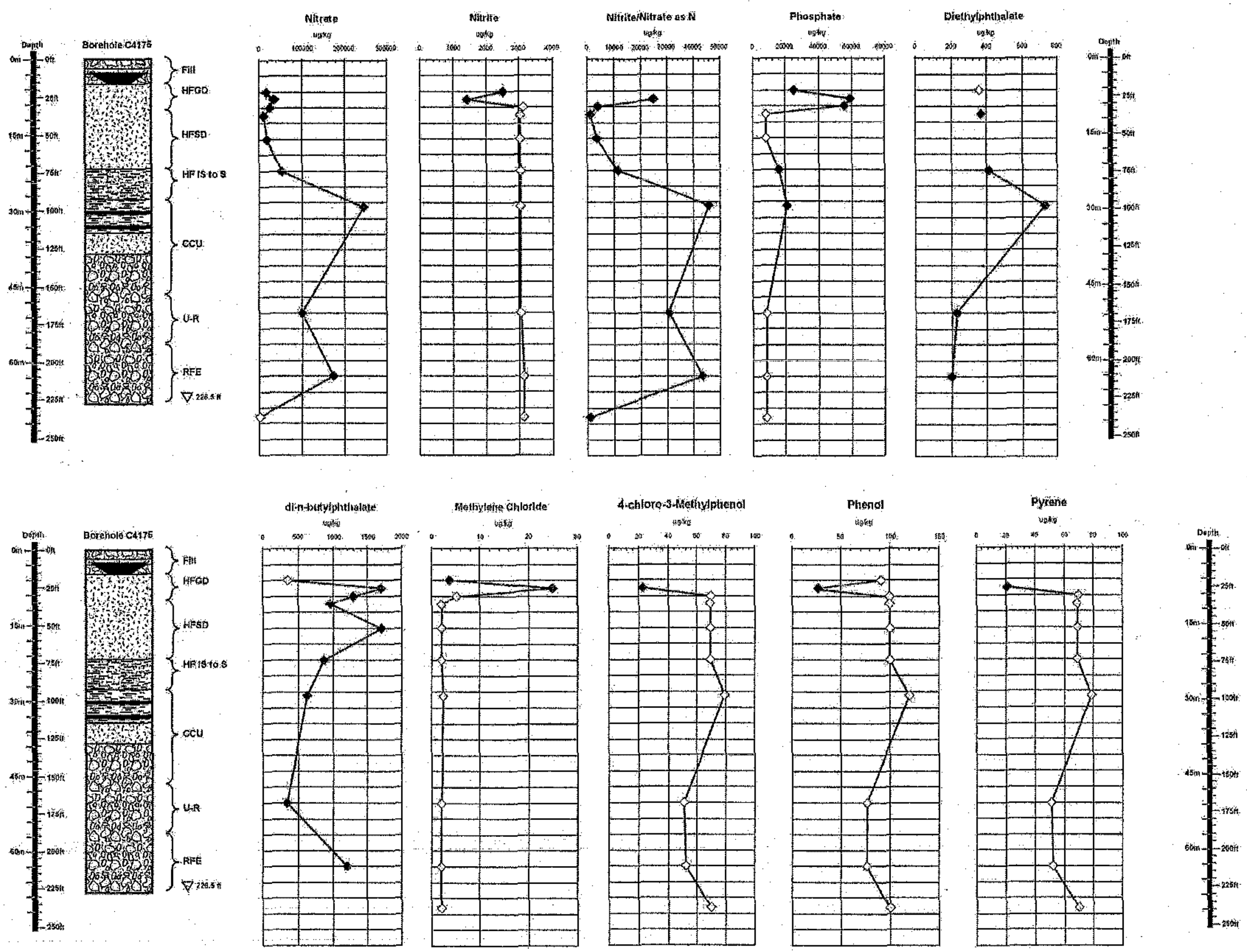
Borehole Legend

Sand; Gravel; Silty Sand; Sandy Silt/Silt; Caliche

▽ Water Table ◆ Positive Detect ◇ Non-detect

FG916.5

Figure 3-10. Vertical Profile Plots of Contaminants for the 216-T-28 Crib. (3 Pages)



216-T-28 Crib - Borehole C4175

F - Fill
HFGD - Hanford formation Gravel Dominated
HFSD - Hanford formation Sand Dominated
HF IS to S - Hanford formation, Interbedded Sand to Silt
RFE - Ringold Formation (Unit E)
CCU - Cold Creek Unit
U - R - Upper - Ringold

Concentration Legend

Analyte	Background	Analyte	Background	Analyte	Background
Thorium-228	1.32 pCi/g	Beryllium	1.51 mg/kg	Uranium	3.21 mg/kg
Thorium-232	1.32 pCi/g	Chromium	18.5 mg/kg	Ammonium ion as N	9.23 mg/kg
Uranium-233/234	1.10 pCi/g	Copper	22 mg/kg	Ammonia as N	9.23 mg/kg
Uranium-235	0.109 pCi/g	Lead	10.2 mg/kg	Fluoride	2.81 mg/kg
Uranium-238	1.06 pCi/g	Mercury	0.33 mg/kg	Nitrate as N	12 mg/kg
Arsenic	6.47 mg/kg	Nickel	19.1 mg/kg	Phosphate	0.785 mg/kg
Barium	132 mg/kg	Silver	0.73 mg/kg		

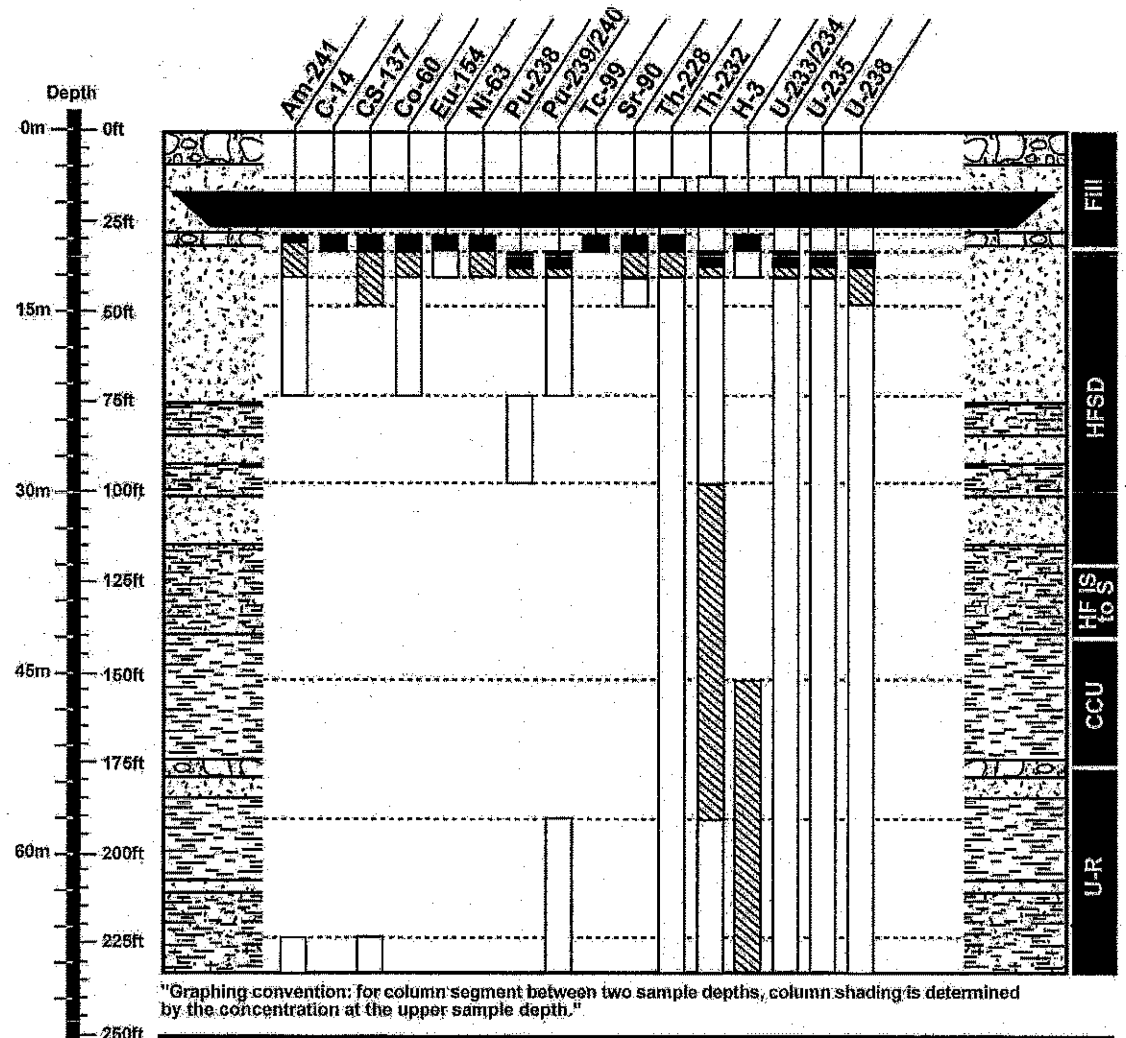
Borehole Legend

Sand, Silty Sand, Caliche, Gravel, Sandy Silt/Silt

Water Table, Positive Detect, Non-detect

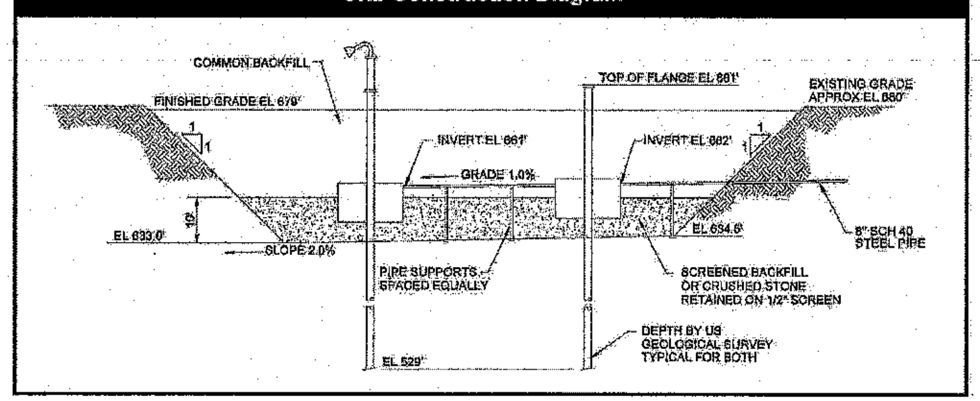
FG916.6
6/23/05

Figure 3-11. Stratigraphy and Radionuclide Contaminant Data for the 216-S-20 Crib.



"Graphing convention: for column segment between two sample depths, column shading is determined by the concentration at the upper sample depth."

Crib Construction Diagram



216-S-20 Crib - Borehole C4176 - Radionuclides with max concentration exceeding bkg and > 1 pCi/g

Sample Depth	Am-241	C-14	Cs-137	Co-60	Eu-154	Ni-63	Pu-238	Pu-239/240	Tc-99	Sr-90	Th-228*	Th-232*	H-3	U-233/234*	U-235*	U-238*
ft bgs	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
12.5-15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.64	0.958	ND	0.19	0.02	0.22
29.5-32	5800	35.6	95600	104	70.8	4580	NR	NR	9.18	96300	15.9	ND	63.1	NR	ND	ND
32.5-35	25	ND	813	2	0.711	19.1	2.6	78	ND	5920	2	1.41	0.187	250	26.4	270
40-42.5	0.074	ND	1.71	0.051	ND	ND	ND	0.31	ND	0.576	0.788	0.702	ND	0.99	0.064	1.1
47.5-50	0.058	ND	ND	0.026	ND	ND	ND	0.19	ND	ND	0.791	0.869	ND	0.16	0.008	0.15
72-74.5	ND	ND	ND	ND	ND	ND	0.078	ND	ND	ND	0.822	0.987	ND	0.19	0.027	0.21
97-99.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.01	1.02	ND	0.2	0.02	0.22
151.5-154	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.19	1.08	2.5	0.22	0.01	0.24
191.5-194	ND	ND	ND	ND	ND	ND	ND	0.023	ND	ND	0.558	0.461	6.88	0.22	0.017	0.18
236-240.5	0.12	ND	0.058	ND	ND	ND	ND	0.014	ND	ND	0.752	0.988	3.34	0.42	0.059	0.62

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

ND Not Detected
NR No Result Reported
[box] Maximum Concentrations

*See App A for multiple-result selection criteria

1) The 216-S-20 Crib has a side slope of 1H:1V (Horizontal:Vertical) and contains two 3.7- by 3.7- by 2.7-m (12- by 12- by 9-ft) (LxWxH) wooden structures, 15-m (50 ft) apart, with the crib top of each located 5.5 m (18 ft) below grade. The bottom of each wooden structure is suspended in a gravel fill that is 1.2 m (4-ft) above the bottom of the unit.

2) Acidic to basic, low salt, low organic liquid waste containing cesium-137, cobalt-60, plutonium-239/240, strontium-90, uranium, nitrate, and other contaminants were discharged to the 216-S-20 Crib between 1952 and 1972. The crib received a total volume of 135,000,000 L (35,640,000 gallons) of wastewater.

3) Once discharged, wastewater and contaminants migrate vertically downward beneath the crib. The data suggests lateral spreading may not be significant beneath the crib, but occurs associated with formation interfaces.

4) Immobile contaminants such as cesium-137 normally sorb near the point of release of high concentrations. Contaminant concentrations decreased with depth. Beneath the crib, cesium-137 concentrations were > 2000 pCi/g to a depth above 35-37.5 ft, based on sample data. Contaminant concentrations were < 1 pCi/g below the 40-42.5 ft bgs sample interval.

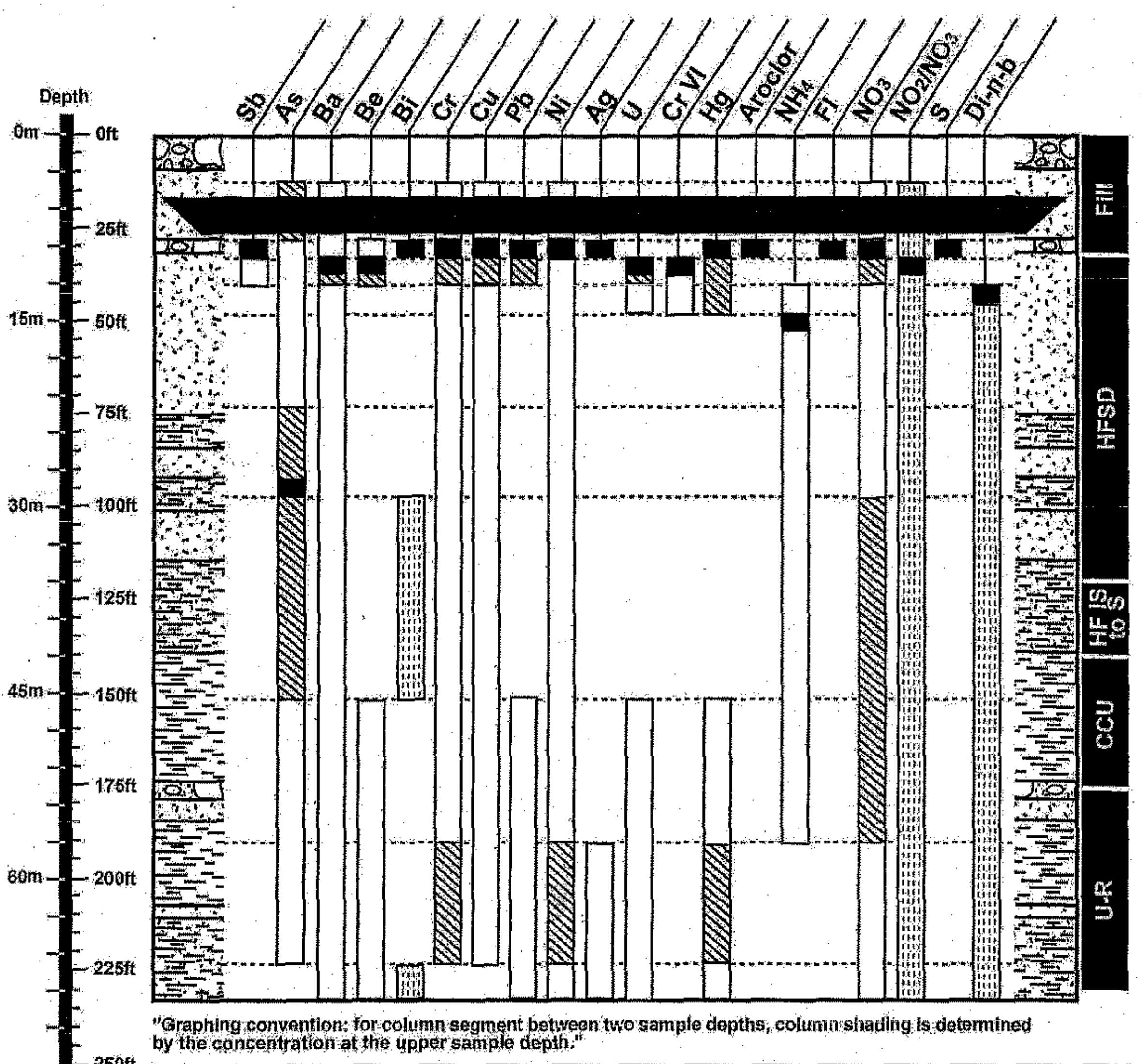
5) Mobile contaminants like nitrate migrate with the moisture front and were detected to the water table.

6) Wastewater and mobile contaminants likely impact groundwater, since effluent volume discharged to the soil column (135,000 m^3) is greater than the soil column pore volume (6,020 m^3). Nitrate, uranium, and tritium exceed groundwater protection standards near the crib.

Formation Legend	Strata Legend	Constituent Legend
F - Fill HFGD - Hanford formation Gravel Dominated HFSD - Hanford formation Sand Dominated HF IS to S - Hanford formation, Interbedded Sand to Silt CCU - Cold Creek Unit U - R - Upper - Ringold RF - Ringold Formation RFE - Ringold Formation (Unit E)	Sand Gravel Silty Sand Sandy Silt/Silt Caliche'	Highest Concentration ≥ 1 pCi/g < 1 pCi/g Sample Depth Depth of Crib Water Table

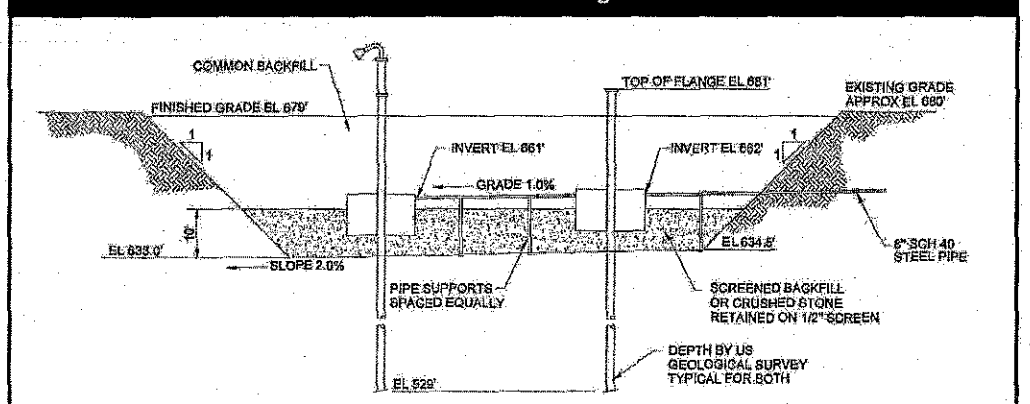
FG916.13 11/14/05

Figure 3-12. Stratigraphy and Nonradionuclide Contaminant Data for the 216-S-20 Crib.



"Graphing convention: for column segment between two sample depths, column shading is determined by the concentration at the upper sample depth."

Crib Construction Diagram



216-S-20 Crib - Borehole C4176 - Select Chemical Constituents

Sample Depth	Sb	As	Ba	Be	Bi	Cr	Cu	Pb	Ni	Ag	U	Cr VI	Hg	Aroclor-1254	NH_4	Fl	NO_3	N in NO_2/NO_3	Sulfide	Di-n-b
ft bgs	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg
12.5-15	ND	6700	112000	ND	ND	5840	14500	ND	10400	ND	ND	ND	ND	ND	ND	ND	7390	2800	ND	NR
29.5-32	2900	1200	127000	270	202000	259000	122000	489000	55000	6000	NR	NR	69200	170	ND	6510	18600	NR	23900	NR
32.5-35	1200	5650	136000	2700	ND	22600	31300	15300	12000	ND	818000	1280	1800	ND	ND	ND	15400	3400	ND	NR
40-42.5	ND	3930	99800	ND	ND	11000	14200	ND	11600	ND	2880	330	ND	ND	927	ND	5580	1100	ND	1200
47.5-50	ND	5230	94700	ND	ND	7940	11700	ND	9710	ND	ND	ND	ND	ND	2870	ND	11000	610	ND	NR
72-74.5	ND	8530	56000	ND	ND	8100	10900	ND	13000	ND	ND	ND	ND	ND	373	ND	9610	770	ND	100
97-99.5	ND	9160	69200	ND	3200	11000	10700	ND	11400	ND	ND	ND	ND	ND	358	ND	13900	2000	ND	390
151.5-154	ND	5650	87900	244	ND	13700	19200	6620	18000	ND	476	ND	293	ND	376	ND	17200	3020	ND	170
191.5-194	ND	2550	97100	213	ND	33400	14600	2710	23800	14	409	ND	898	ND	ND	ND	11400	1380	ND	140
238-240.5	ND	ND	50000	234	2940	7980	12000	4510	15400	36	365	ND	295	ND	ND	ND	5620	ND	ND	99

Sb Antimony; As Arsenic; Ba Barium; Be Beryllium; Bi Bismuth; Cr Chromium
Cu Copper; Pb Lead; Ni Nickel; Ag Silver; U Uranium; Hg Mercury
NH_4 Ammonium Ion; Fl Fluoride; NO_3 Nitrate; NO_2 Nitrite; S Sulfide; PO_4 Phosphate
Di-n-b Di-n-butylphthelate; ND Not Detected; NR No Result Reported
[box] Maximum Concentrations

1) The 216-S-20 Crib has a side slope of 1H:1V (Horizontal:Vertical) and contains two 3.7- by 3.7- by 2.7-m (12- by 12- by 9-ft) (LxWxH) wooden structures, 15-m (50 ft) apart, with the crib top of each located 5.5 m (18 ft) below grade. The bottom of each wooden structure is suspended in a gravel fill that is 1.2 m (4-ft) above the bottom of the unit.

2) Acidic to basic, low salt, low organic liquid waste containing cesium-137, cobalt-60, plutonium-239/240, strontium-90, uranium, nitrate, and other contaminants were discharged to the 216-S-20 Crib between 1952 and 1972. The crib received a total volume of 135,000,000 L (35,640,000 gallons) of wastewater.

3) Once discharged, wastewater and contaminants migrate vertically downward beneath the crib. The data suggests lateral spreading may not be significant beneath the crib, but occurs associated with formation interfaces.

4) Immobile contaminants such as cesium-137 normally sorb near the point of release of high concentrations. Contaminant concentrations decreased with depth. Beneath the crib, cesium-137 concentrations were > 2000 pCi/g to a depth above 35-37.5 ft, based on sample data. Contaminant concentrations were < 1 pCi/g below the 40-42.5 ft bgs sample interval.

5) Mobile contaminants like nitrate migrate with the moisture front and were detected to the water table.

6) Wastewater and mobile contaminants likely impact groundwater, since effluent volume discharged to the soil column (135,000 m^3) is greater than the soil column pore volume (6,020 m^3). Nitrate, uranium, and tritium exceed groundwater protection standards near the crib.

Formation Legend

- F - Fill
- HFGD - Hanford formation Gravel Dominated
- HFSD - Hanford formation Sand Dominated
- HF IS to S - Hanford formation, Interbedded Sand to Silt
- CCU - Cold Creek Unit
- U - R - Upper - Ringold
- RF - Ringold Formation
- RFE - Ringold Formation (Unit E)

Strata Legend

Sand; Gravel; Silty Sand; Sandy Silt/Silt; Caliche'

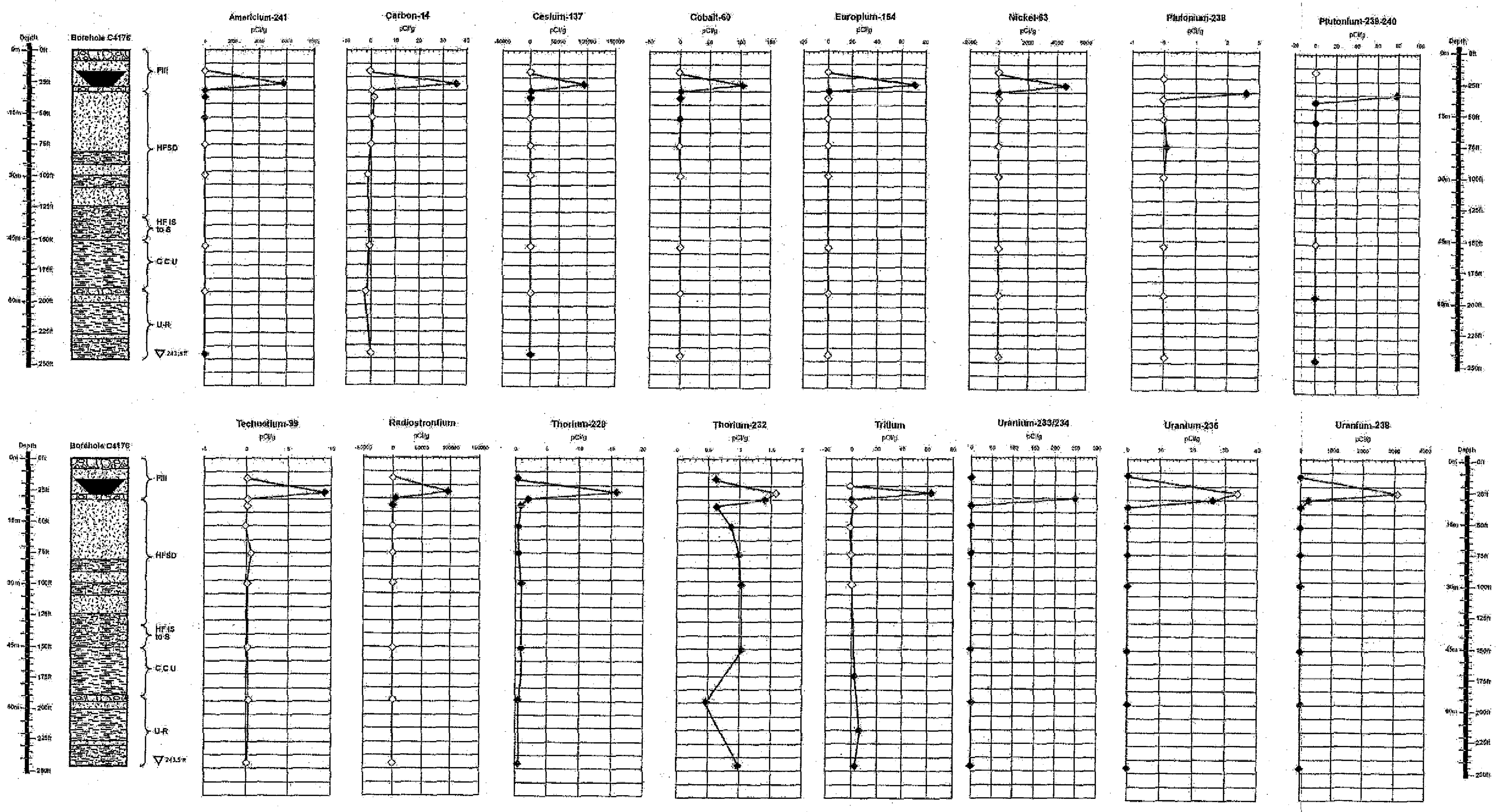
Constituent Legend

- Highest Concentration
- ≥ background or PAL
- < background or PAL
- Detected (no background or PAL)
- Sample Depth
- Depth of Crib
- Water Table

(PAL - Preliminary Action Level)

FG916.14 11/8/05

Figure 3-13. Vertical Profile Plots of Contaminants for the 216-S-20 Crib. (2 Pages)



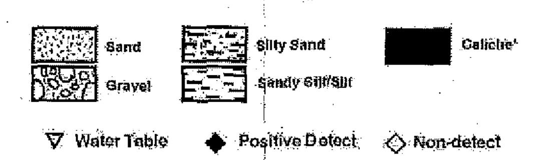
216-S-20 Crib - Borehole C4176

F - Fill
HFGD - Hanford formation Gravel Dominated
HFSD - Hanford formation Sand Dominated
HF IS to S - Hanford formation, Interbedded Sand to Silt
RFE - Ringold Formation (Unit E)
CCU - Cold Creek Unit
U - R - Upper - Ringold

Concentration Legend

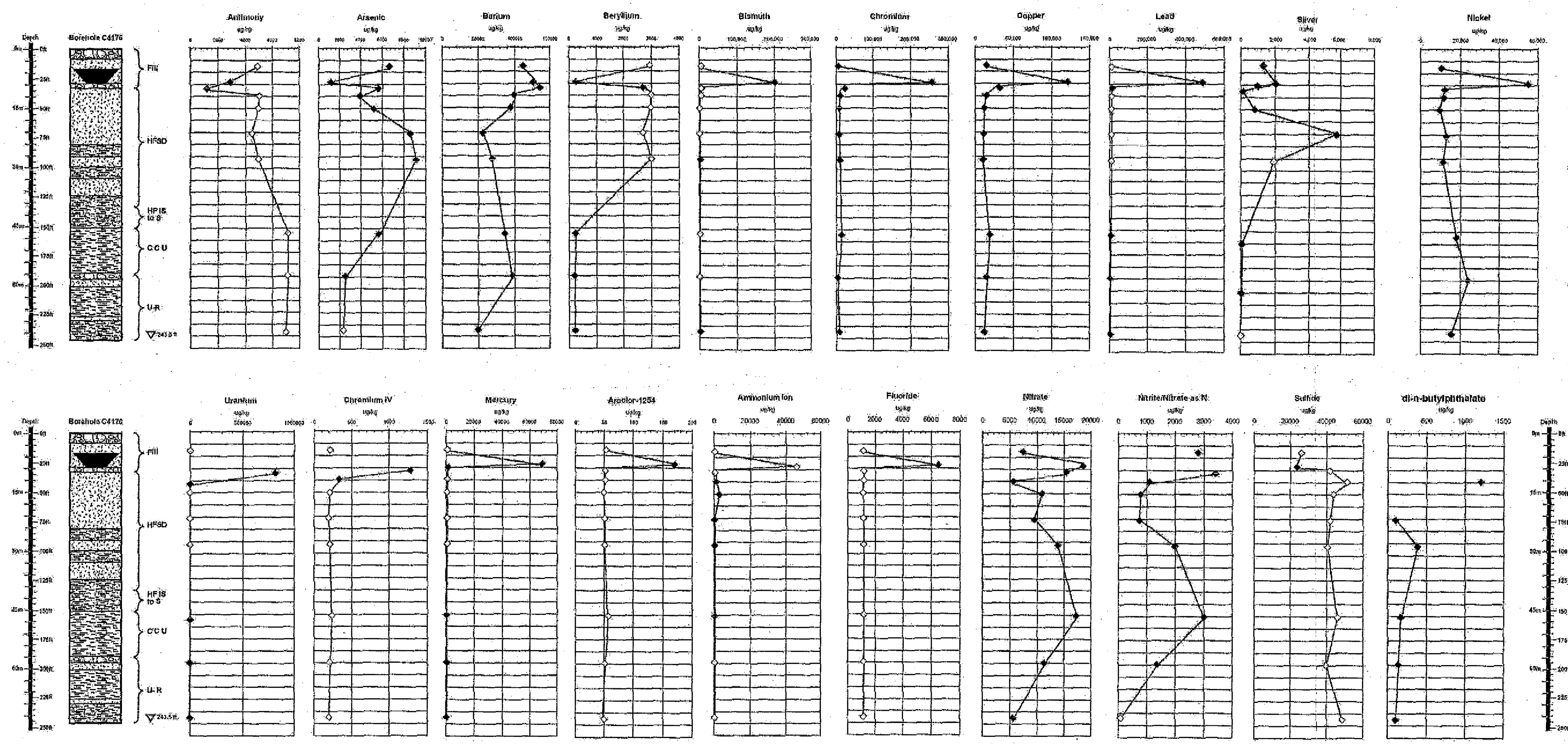
Analyte	Background	Analyte	Background	Analyte	Background
Thorium-228	1.32 pCi/g	Beryllium	1.51 mg/kg	Uranium	3.21 mg/kg
Thorium-232	1.32 pCi/g	Chromium	18.5 mg/kg	Ammonium ion as N	9.23 mg/kg
Uranium-233/234	1.10 pCi/g	Copper	22 mg/kg	Ammonia as N	9.23 mg/kg
Uranium-235	0.109 pCi/g	Lead	10.2 mg/kg	Fluoride	2.81 mg/kg
Uranium-238	1.06 pCi/g	Mercury	0.33 mg/kg	Nitrate as N	12 mg/kg
Arsenic	6.47 mg/kg	Nickel	19.1 mg/kg	Phosphate	0.786 mg/kg
Barium	132 mg/kg	Silver	0.73 mg/kg		

Borehole Legend



FG916.2

Figure 3-13. Vertical Profile Plots of Contaminants for the 216-S-20 Crib. (2 Pages)



216-S-20 Crib - Borehole C4176

F - Fill
HFGD - Hanford formation Gravel Dominated
HFSD - Hanford formation Sand Dominated
HF IS to S - Hanford formation, Interbedded Sand to Silt
RFE - Ringold Formation (Unit E)
CCU - Cold Creek Unit
U - R - Upper - Ringold

Concentration Legend

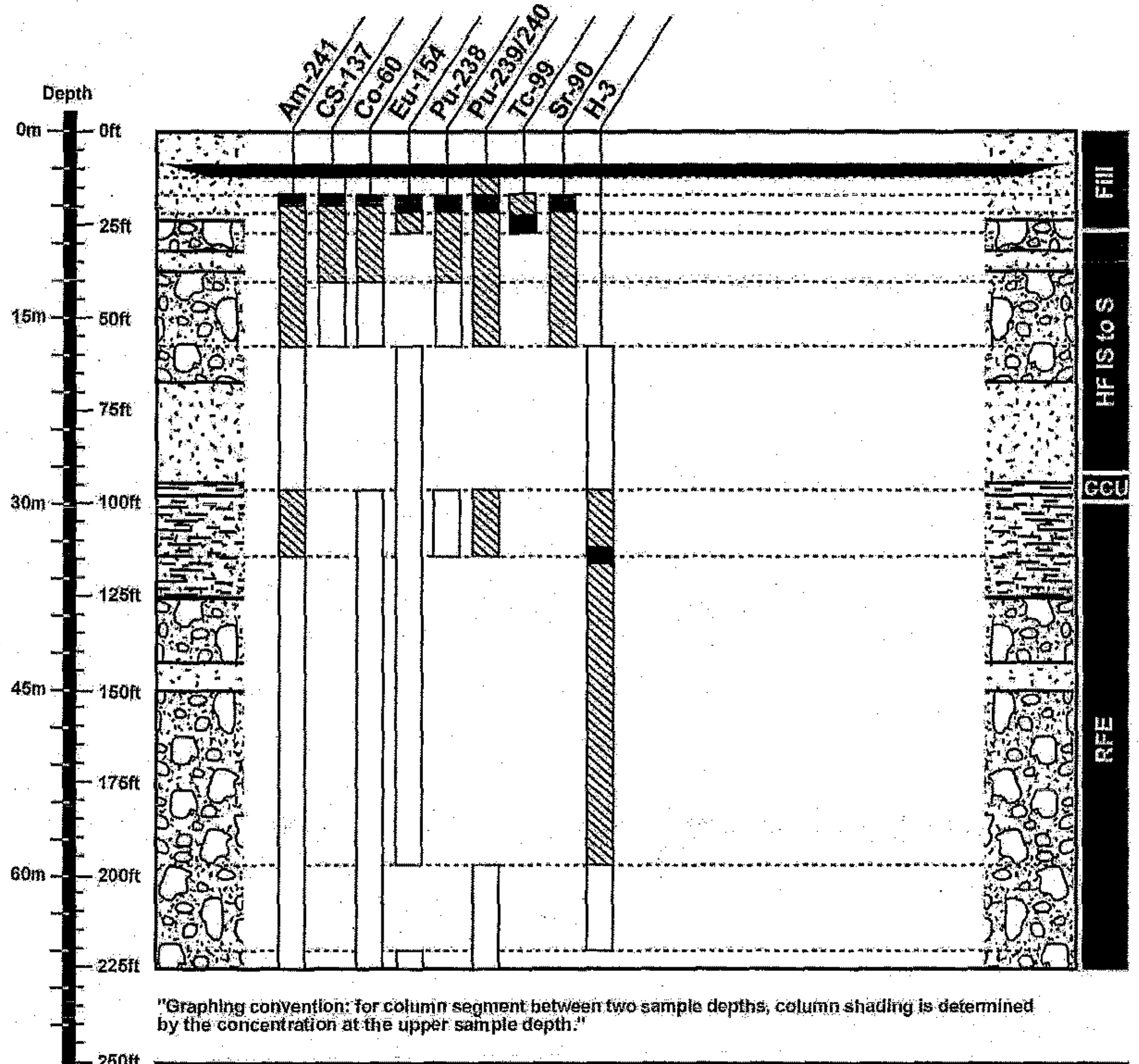
Analyte	Background	Analyte	Background	Analyte	Background
Thorium-228	1.32 pCi/g	Beryllium	1.51 mg/kg	Uranium	3.21 mg/kg
Thorium-232	1.32 pCi/g	Chromium	18.5 mg/kg	Ammonium ion as N	9.23 mg/kg
Uranium-233/234	1.10 pCi/g	Copper	22 mg/kg	Ammonia as N	9.23 mg/kg
Uranium-235	0.109 pCi/g	Lead	10.2 mg/kg	Fluoride	2.81 mg/kg
Uranium-238	1.06 pCi/g	Mercury	0.33 mg/kg	Nitrate as N	12 mg/kg
Arsenic	6.47 mg/kg	Nickel	19.1 mg/kg	Phosphate	0.785 mg/kg
Barium	132 mg/kg	Silver	0.73 mg/kg		

Borehole Legend

Sand; Silty Sand; Caliche'; Gravel; Sandy Silt/Silt
▽ Water Table ◆ Positive Detect ◇ Non-detect

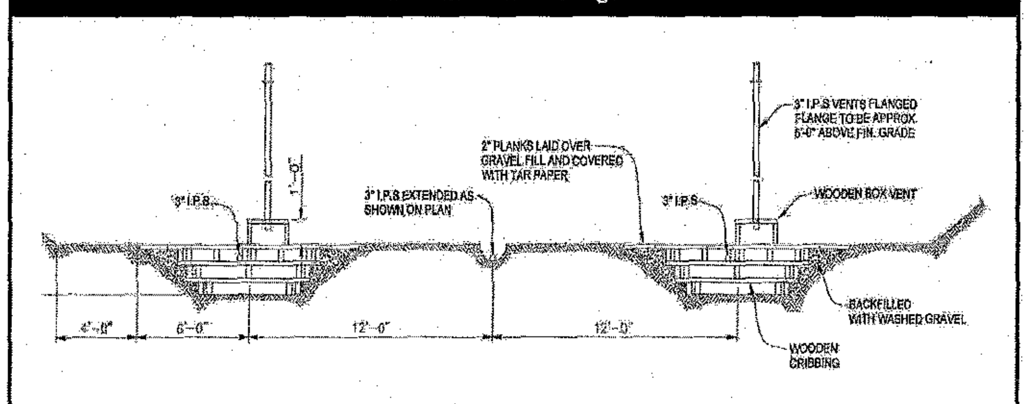
FG916.3
6/23/05

Figure 3-14. Stratigraphy and Radionuclide Contaminant Data for the 216-Z-7 Crib.



"Graphing convention: for column segment between two sample depths, column shading is determined by the concentration at the upper sample depth."

Crib Construction Diagram



216-Z-7 Crib - Borehole C4183 - Radionuclides with max concentration exceeding bkg and > 1 pCi/g									
Sample Depth	Am-241	Cs-137	Co-60	Eu-154	Pu-238	Pu-239/240	Tc-99	Sr-90	H-3
ft bgs	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
12.5-15	ND	0.084	ND	ND	ND	1.2	ND	ND	ND
17.5-20	60600	2800	58.3	10.5	5770	472000	5.67	437000	ND
22.5-25	5340	563	17.5	5.54	388	33900	11	34200	ND
27.5-30	65.4	1.03	2.68	ND	NR	NR	ND	5100	ND
40-42.5	3.79	0.011	0.044	ND	0.53	9.1	ND	34.8	ND
57.5-60	0.12	ND	ND	0.046	ND	ND	ND	ND	0.631
96.5-99	2.5	ND	0.107	0.043	0.43	7.9	ND	ND	3.43
117.5-120	0.77	ND	0.069	0.153	ND	ND	ND	ND	9.54
197.5-200	0.12	ND	0.017	ND	ND	0.032	ND	ND	0.668
220-222.5	0.1	ND	0.016	0.046	ND	0.022	ND	ND	ND

Am Americium; Cs Cesium; Co Cobalt; Eu Europium
Pu Plutonium; Tc Technetium; Sr Strontium (total beta); H-3 Tritium
ND Not Detected; NR No Result Reported
[boxed] Maximum Concentrations

1) The 216-Z-7 Crib consists of two parallel wooden structures 45.7 m (150 ft) long by 1.5 m (5 ft) wide by 0.6 m (2 ft) high, placed in a 1.5-m (5 ft)-deep excavation. However, the entire 216-Z-7 area surrounding the crib was excavated to approximately 3 m (10 ft). Surface stabilization of 0.6 m (2 ft) is assumed for this site. Thus, the total depth from the current 216-Z-7 Crib surface to the bottom of the structure is approximately 3.6 m (12 ft). Each wooden structure was constructed of three overlapping tiers. A 45.8-m (150 ft)-long 7.5- or 10-cm (3 or 4 in.)-diameter perforated distribution pipe ran above the second tier. Each of the two trenches was covered by 503 m (1,650 ft) of 5-cm (2-in.) planking topped with tar paper. The excavation was backfilled with gravel.

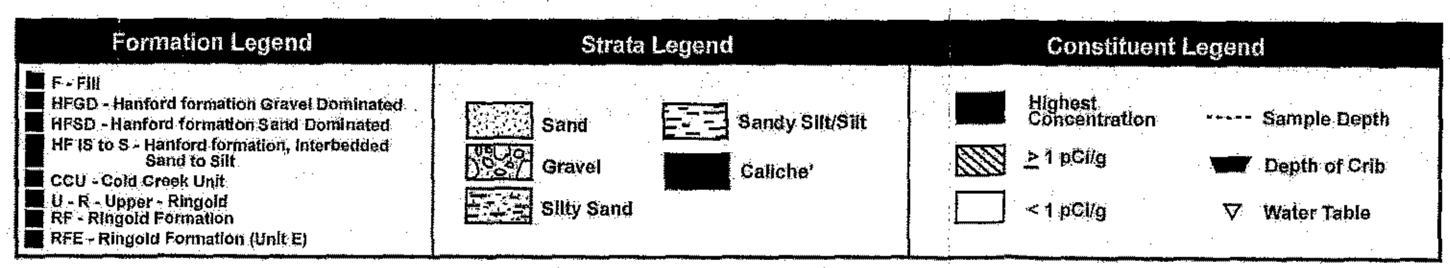
2) Acidic to basic, low salt, low organic liquid waste containing cesium-137, cobalt-60, plutonium-239/240, strontium-90, uranium, nitrate, and other contaminants were discharged to the 216-Z-7 Crib between 1947 and 1967. The crib received a total volume of 79,000,000 L (21,094,000 gallons) of wastewater.

3) Once discharged, wastewater and contaminants migrate vertically downward beneath the crib. The data suggests lateral spreading may not be significant beneath the crib, but occurs associated with formation interfaces.

4) Immobile contaminants such as cesium-137 normally sorb near the point of release of high concentrations. Contaminant concentrations decreased with depth. Beneath the crib, cesium-137 concentrations were > 2000 pCi/g to a depth above 22.5-25 ft bgs, based on sample data. Contaminant concentrations were < 1 pCi/g below the 27.5-30 ft bgs sample interval.

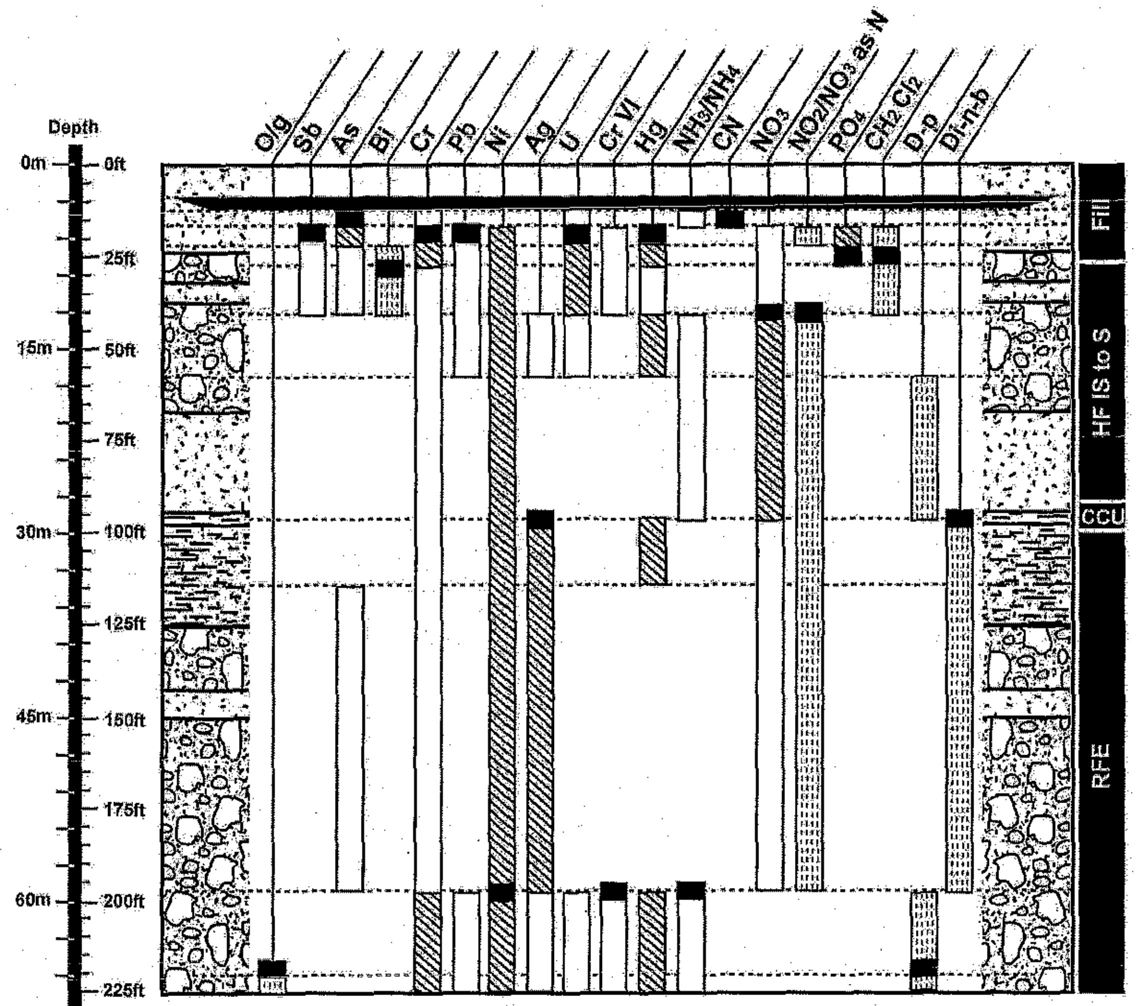
5) Mobile contaminants like nitrate migrate with the moisture front and were detected to the water table.

6) Wastewater and mobile contaminants likely impact groundwater, since effluent volume discharged to the soil column (79,000 m^3) is greater than the soil column pore volume (30,000 m^3). Nitrate, technetium-99, and tritium exceed groundwater protection standards near the crib.



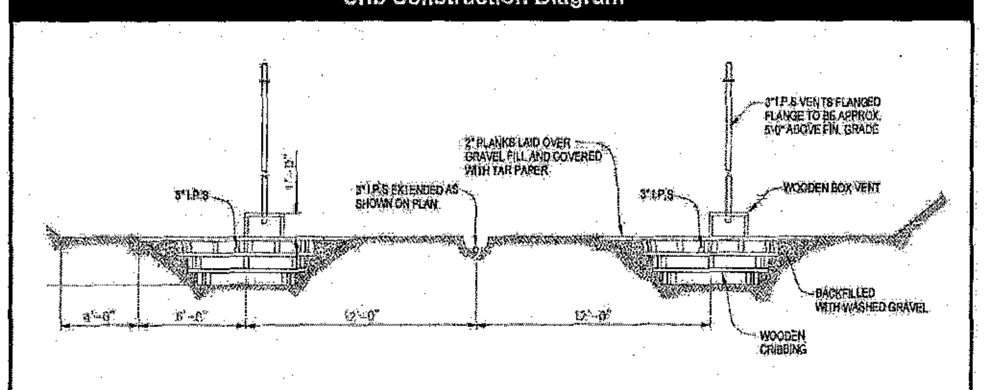
FG916.11

Figure 3-15. Stratigraphy and Nonradionuclide Contaminant Data for the 216-Z-7 Crib.



"Graphing convention: for column segment between two sample depths, column shading is determined by the concentration at the upper sample depth."

Crib Construction Diagram



216-Z-7 Crib - Borehole C4183 - Select Chemical Constituents

Sample Depth	O/g	Sb	As	Bi	Cr	Pb	Ni	Ag	U	Cr VI	Hg	NH_3/ NH_4	CN	NO_3	N in NO_2/ NO_3	PO_4	CH_2Cl_2	D-p	Di-n-b
ft bgs	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg
12.5-15	ND	ND	13400	ND	7380	ND	11600	ND	1310	ND	ND	304	3960	10846	2000	ND	ND	NR	NR
17.5-20	ND	2800	3100	116,000	193,000	14,300	6,800	ND	27900	730	5,600	ND	ND	5,312	ND	7,100	4.3	NR	NR
22.5-25	ND	1800	1500	108,000	47,200	2,200	6,900	ND	5060	730	810	ND	ND	4,427	ND	13,000	24	NR	NR
27.5-30	ND	540	1300	123,000	6,200	1,800	5,800	ND	NR	ND	37	ND	ND	2,435	ND	ND	3.1	NR	NR
40-42.5	ND	ND	ND	ND	12000	3040	10400	249	2670	ND	1850	336	ND	19744	2500	ND	ND	NR	NR
57.5-60	ND	ND	ND	ND	7600	ND	7680	ND	ND	ND	ND	297	ND	13812	710	ND	ND	180	NR
96.5-99	ND	ND	ND	ND	11000	ND	9350	4700	ND	ND	1230	ND	ND	9075	440	ND	ND	NR	2100
117.5-120	ND	ND	5530	ND	7580	ND	9580	2440	ND	ND	ND	ND	ND	6507	360	ND	ND	NR	200
197.5-200	ND	ND	ND	ND	42100	4070	23400	30	214	2050	388	649	ND	ND	ND	ND	ND	450	NR
220-222.5	727000	ND	ND	ND	35800	1960	21000	163	208	1340	677	373	ND	ND	ND	ND	ND	460	NR

O/g Oil & grease; Sb Antimony; As Arsenic; Bi Bismuth; Cr Chromium; Pb Lead; Ni Nickel; Ag Silver; U Uranium; Hg Mercury; NH_3 Ammonia; NH_4 Ammonium; CN Cyanide; NO_3 Nitrate; NO_2 Nitrite; PO_4 Phosphate; CH_2Cl_2 Methylene Chloride; D-p Diethylphthalate; Di-n-p Di-n-butylphthalate; ND Not Detected; NR No Result Reported; [box] Maximum Concentrations

1) The 216-Z-7 Crib consists of two parallel wooden structures 45.7 m (150 ft) long by 1.5 m (5 ft) wide by 0.6 m (2 ft) high, placed in a 1.5-m (5 ft)-deep excavation. However, the entire 216-Z-7 area surrounding the crib was excavated to approximately 3 m (10 ft). Surface stabilization of 0.6 m (2 ft) is assumed for this site. Thus, the total depth from the current 216-Z-7 Crib surface to the bottom of the structure is approximately 3.6 m (12 ft). Each wooden structure was constructed of three overlapping tiers. A 45.8-m (150 ft)-long 7.5- or 10-cm (3 or 4 in.)-diameter perforated distribution pipe ran above the second tier. Each of the two trenches was covered by 503 m (1,650 ft) of 5-cm (2-in.) planking topped with tar paper. The excavation was backfilled with gravel.

2) Acidic to basic, low salt, low organic liquid waste containing cesium-137, cobalt-60, plutonium-239/240, strontium-90, uranium, nitrate, and other contaminants were discharged to the 216-Z-7 Crib between 1947 and 1967. The crib received a total volume of 79,000,000 L (21,094,000 gallons) of wastewater.

3) Once discharged, wastewater and contaminants migrate vertically downward beneath the crib. The data suggests lateral spreading may not be significant beneath the crib, but occurs associated with formation interfaces.

4) Immobile contaminants such as cesium-137 normally sorb near the point of release of high concentrations. Contaminant concentrations decreased with depth. Beneath the crib, cesium-137 concentrations were > 2000 pCi/g to a depth above 22.5-25 ft bgs, based on sample data. Contaminant concentrations were < 1 pCi/g below the 27.5-30 ft bgs sample interval.

5) Mobile contaminants like nitrate migrate with the moisture front and were detected to the water table.

6) Wastewater and mobile contaminants likely impact groundwater, since effluent volume discharged to the soil column (79,000 m³) is greater than the soil column pore volume (30,000 m³). Nitrate, technetium-99, and tritium exceed groundwater protection standards near the crib.

Formation Legend

- F - Fill
- HFGD - Hanford formation Gravel Dominated
- HFSD - Hanford formation Sand Dominated
- HF IS to S - Hanford formation, Interbedded Sand to Silt
- CCU - Cold Creek Unit
- U - R - Upper - Ringold
- RF - Ringold Formation
- RFE - Ringold Formation (Unit E)

Strata Legend

- Sand
- Gravel
- Silty Sand
- Sandy Silt/Silt
- Caliche*

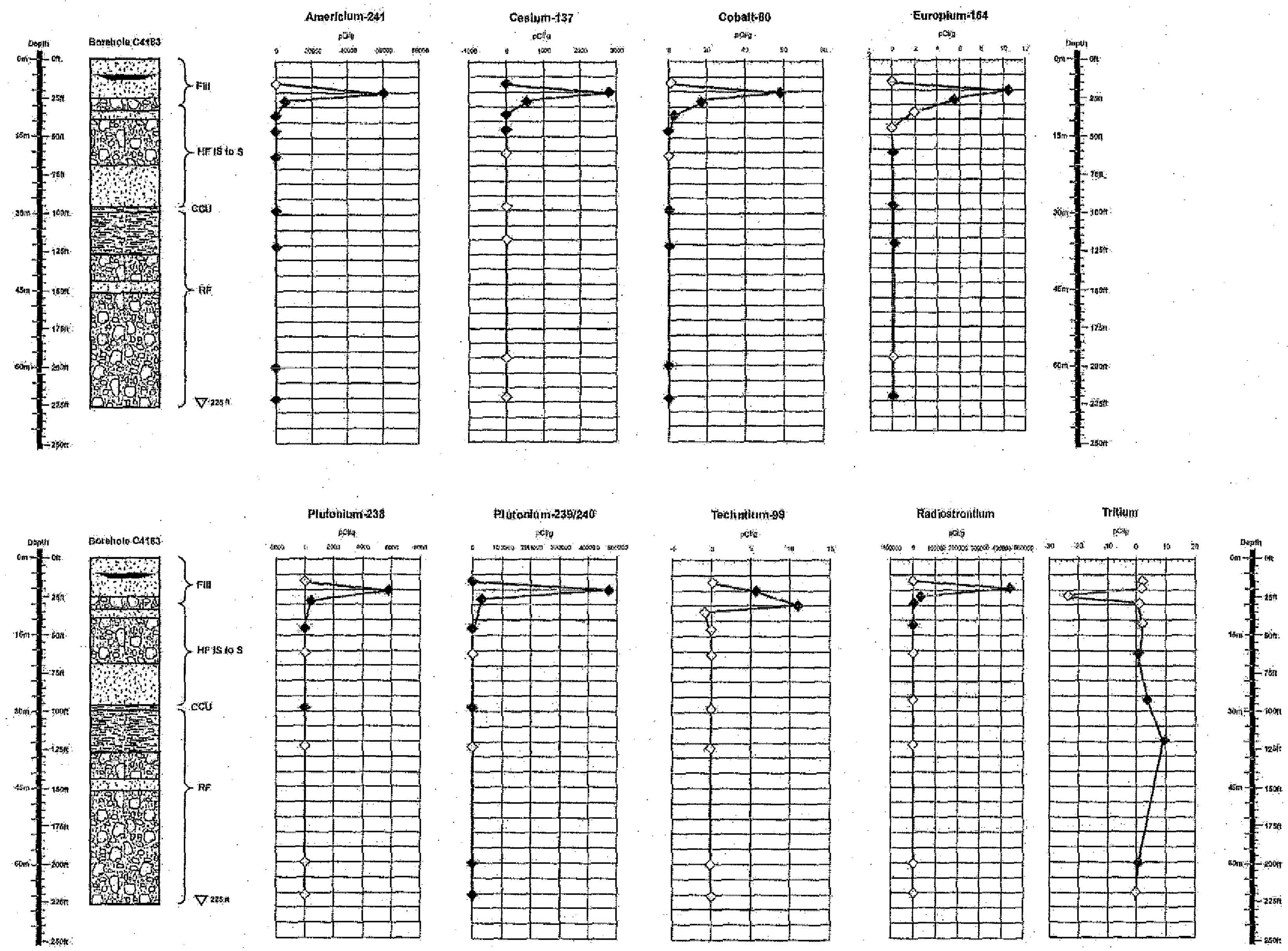
Constituent Legend

- Highest Concentration
- ≥ background or PAL
- < background or PAL
- Detected (no background or PAL)
- Sample Depth
- Depth of Crib
- Water Table

(PAL - Preliminary Action Level)

FG916.12 11/8/05

Figure 3-16. Vertical Profile Plots of Contaminants for the 216-Z-7 Crib. (2 Pages)



216-Z-7 Crib - Borehole C4183

F - Fill
HFGD - Hanford formation Gravel Dominated
HFSD - Hanford formation Sand Dominated
HF IS to S - Hanford formation, interbedded Sand to Silt
RF - Ringold Formation
CCU - Cold Creek Unit
U - R - Upper - Ringold

Concentration Legend

Analyte	Background	Analyte	Background	Analyte	Background
Thorium-228	1.32 pCi/g	Beryllium	1.51 mg/kg	Uranium	3.21 mg/kg
Thorium-232	1.32 pCi/g	Chromium	18.5 mg/kg	Ammonium ion as N	9.23 mg/kg
Uranium-233/234	1.10 pCi/g	Copper	22 mg/kg	Ammonia as N	9.23 mg/kg
Uranium-235	0.109 pCi/g	Lead	10.2 mg/kg	Fluoride	2.81 mg/kg
Uranium-238	1.06 pCi/g	Mercury	0.33 mg/kg	Nitrate as N	12 mg/kg
Arsenic	6.47 mg/kg	Nickel	19.1 mg/kg	Phosphate	0.785 mg/kg
Barium	132 mg/kg	Silver	0.73 mg/kg		

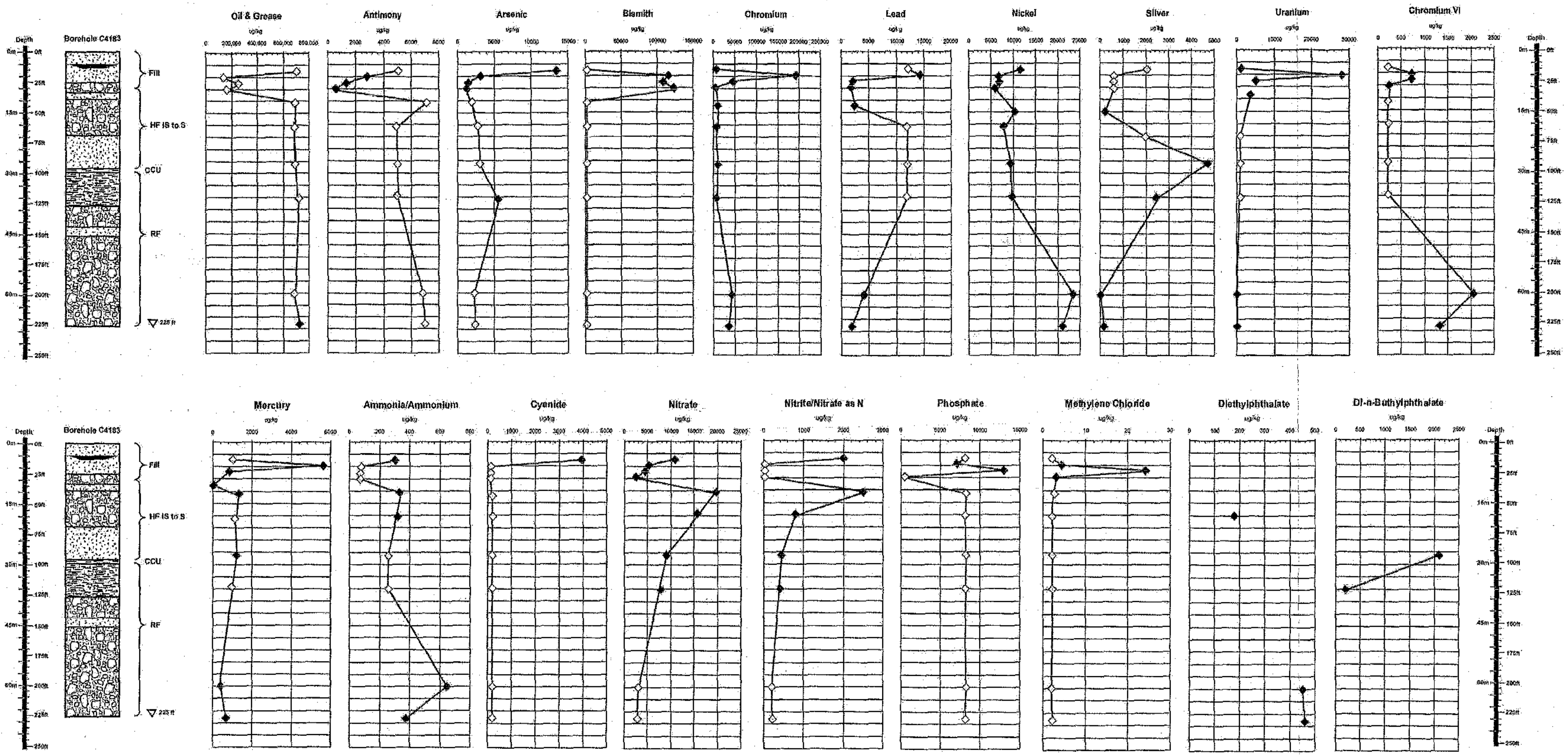
Borehole Legend

Sand, Gravel, Silty Sand, Sandy Silt/Silt, Caliche

▽ Water Table ◆ Positive Detect ◇ Non-detect

FG916.7
11/8/05

Figure 3-16. Vertical Profile Plots of Contaminants for the 216-Z-7 Crib. (2 Pages)



216-Z-7 Crib - Borehole C4183

F - Fill
HFGD - Hanford formation Gravel Dominated
HFSD - Hanford formation Sand Dominated
HF IS to S - Hanford formation, Interbedded Sand to Silt
RF - Ringold Formation
CCU - Cold Creek Unit
U - R - Upper - Ringold

Concentration Legend

Analyte	Background	Analyte	Background	Analyte	Background
Thorium-228	1.32 pCi/g	Beryllium	1.51 mg/kg	Uranium	3.21 mg/kg
Thorium-232	1.32 pCi/g	Chromium	18.5 mg/kg	Ammonium ion as N	9.23 mg/kg
Uranium-233/234	1.10 pCi/g	Copper	22 mg/kg	Ammonia as N	9.23 mg/kg
Uranium-235	0.109 pCi/g	Lead	10.2 mg/kg	Fluoride	2.81 mg/kg
Uranium-238	1.06 pCi/g	Mercury	0.33 mg/kg	Nitrate as N	12 mg/kg
Arsenic	6.47 mg/kg	Nickel	19.1 mg/kg	Phosphate	0.785 mg/kg
Barium	132 mg/kg	Silver	0.73 mg/kg		

Borehole Legend

Sand
Silty Sand
Caliche
Gravel
Sandy Silt/Silt

▽ Water Table ◆ Positive Detect ◇ Non-detect

FG916.8
11/8/05

Figure 3-17. Nonradiological Contamination in Groundwater in the 200 East Area (2001 Data, from DOE/RL-2000-60, Rev. 1).

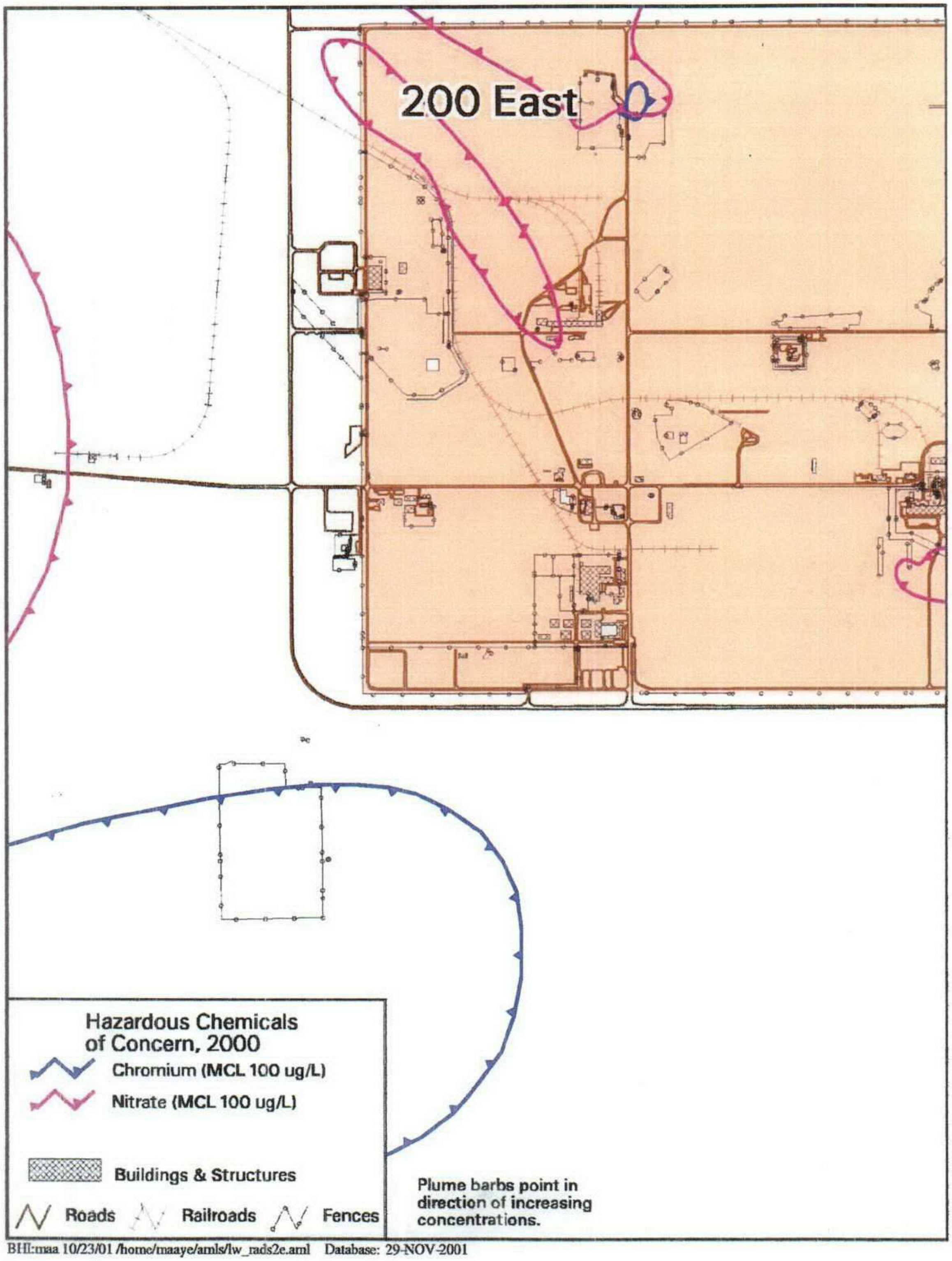


Figure 3-18. Radiological Contamination in Groundwater in the 200 East Area (2001 Data, from DOE/RL-2000-60, Rev. 1).

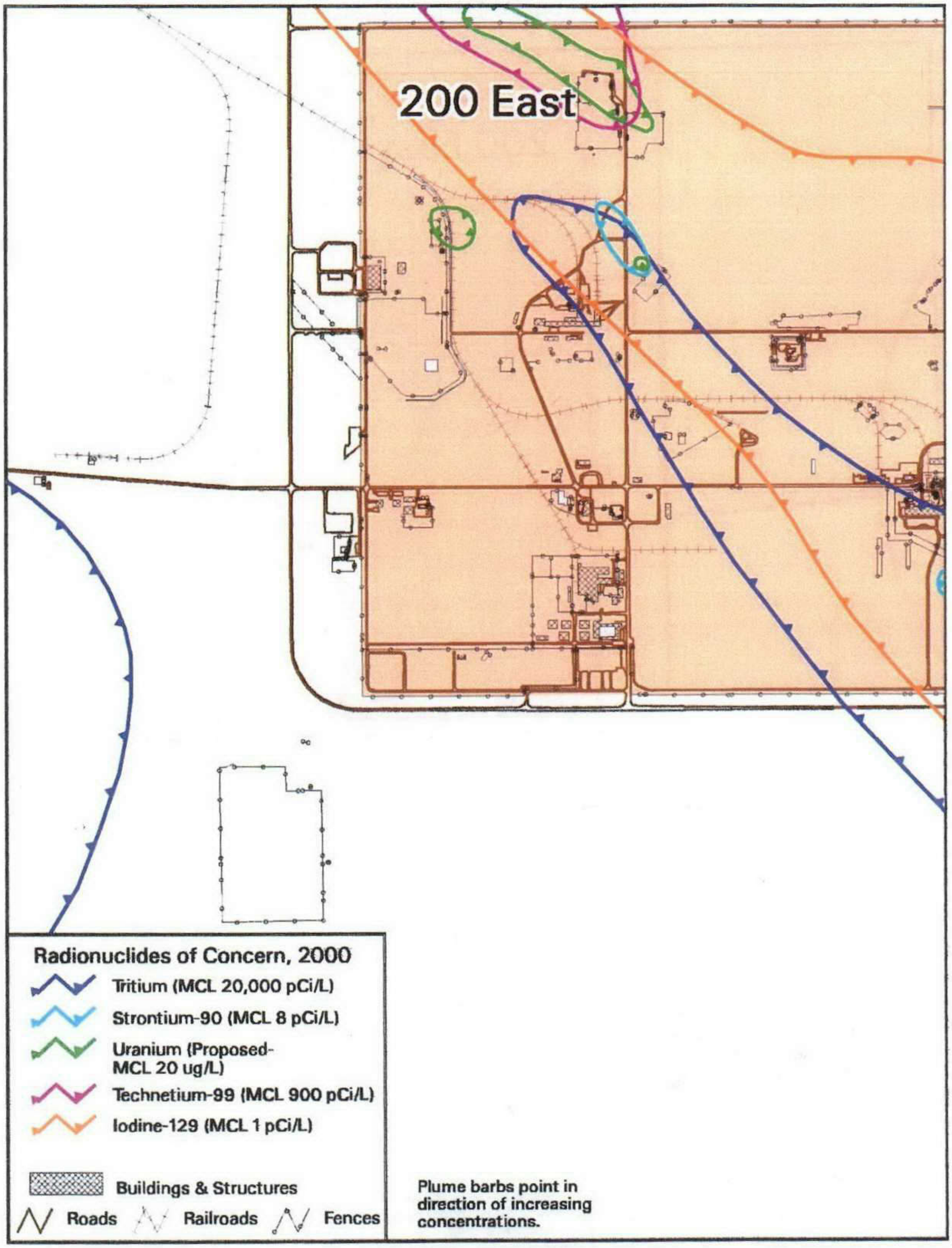


Figure 3-19. Nonradiological Contamination in Groundwater in the 200 West Area (2001 Data, from DOE/RL-2000-60, Rev. 1).

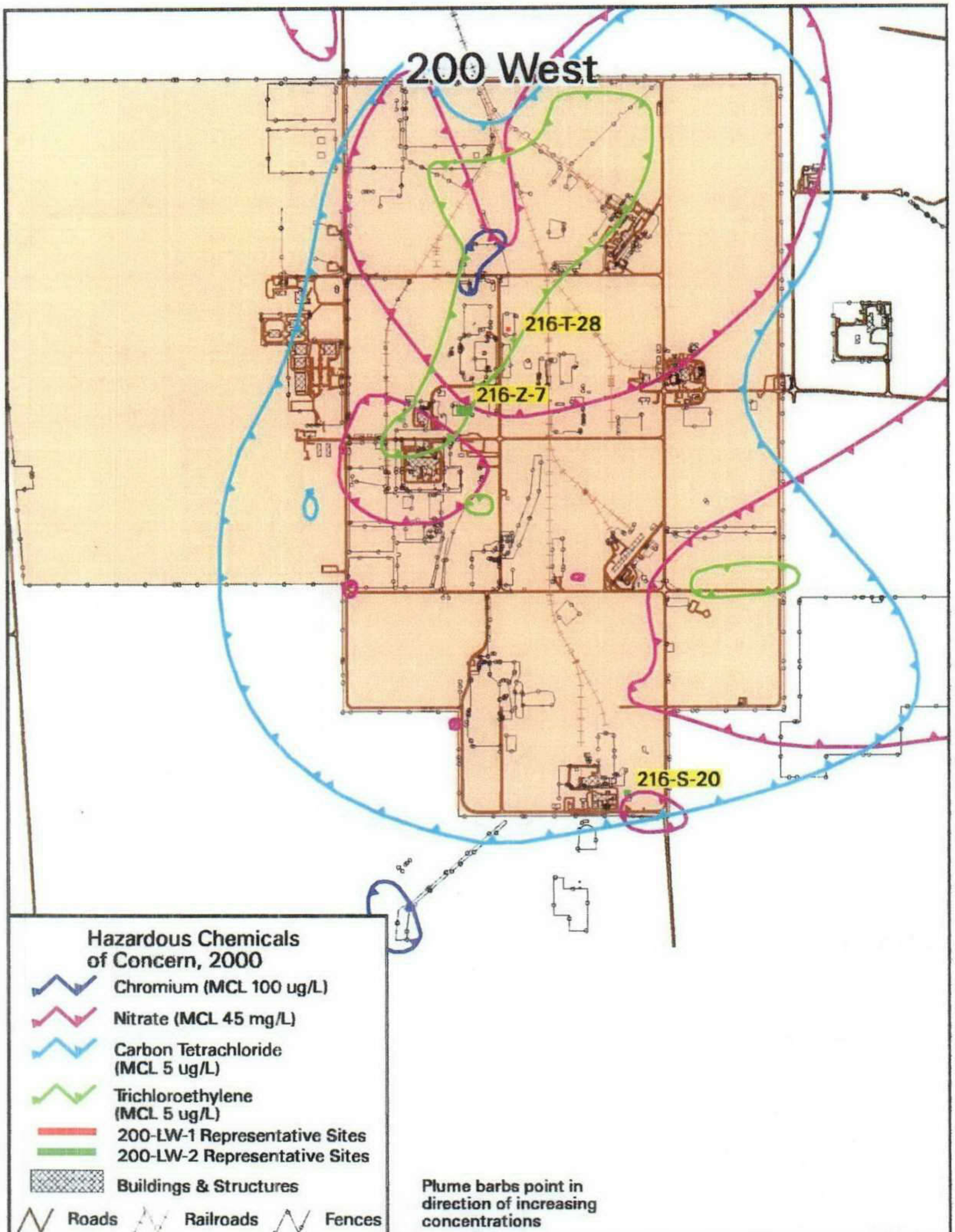


Figure 3-20. Radiological Contamination in Groundwater in the 200 West Area (2001 Data, from DOE/RL-2000-60, Rev. 1).

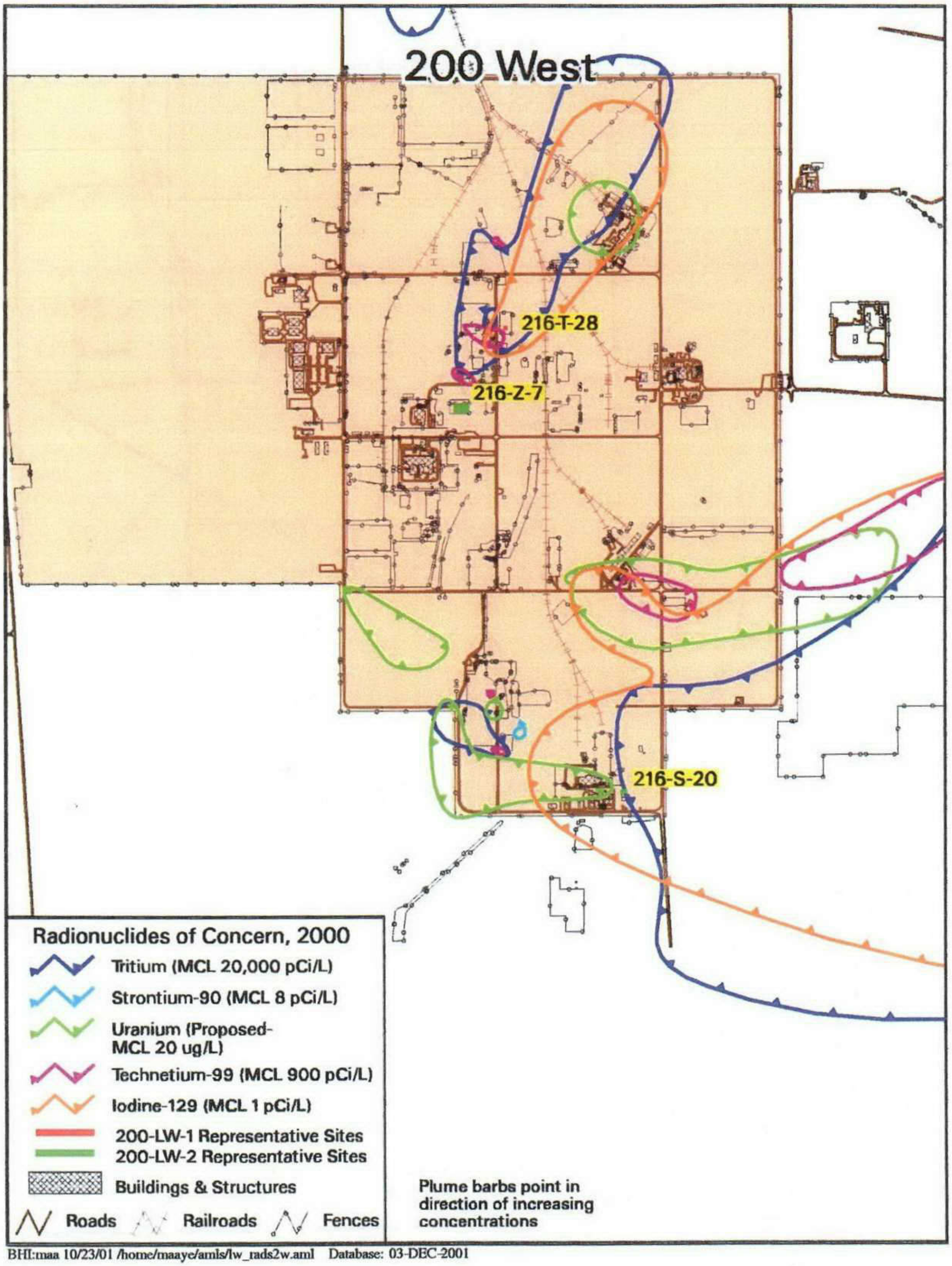


Table 3-1. Soil Physical Property Results.

Sample Number	Sample Depth (ft bgs)	Formation[a]	Particle Size Distribution (Units)			Moisture Content (%)	Bulk Density (g/cm^3)
			Gravel (%)	Sand (%)	Silt/Clay (%)		
216-T-28 Crib (C4175)							
B191C1	32.5 - 35	Hanford, sand dominant	1.8	95.2	3.0	2.9	1.83
B191C2	67.5 - 70	Hanford, sand dominant	1.6	92.2	6.2	3.8	1.81
B191C3	90 – 92.5	Cold Creek unit	1.6	77.5	20.9	12.9	1.83
B19441	197.5 – 200	Ringold Unit E	30.5	38.9	30.6	3.2	1.83
216-S-20 Crib (C4176)							
B19443	72 – 74.5	Hanford, sand dominant	0	87.3	12.7	2.9	1.88
B19444	151.5 – 154	Cold Creek unit	0	1.5	98.5	19.7	2.08
B19445	191.5 - 194	Upper Ringold	47.0	38.8	14.1	6.0	2.29
B19446	238 – 240.5	Upper Ringold	1.5	93.0	5.4	3.7	1.59
216-Z-7 Crib (C4183)							
B19435	57.5 – 60	Hanford, sand dominant	2.9	92.0	5.1	3.3	1.93
B19436	95 – 97.5	Hanford, sand dominant	0.8	86.9	12.3	4.8	1.84
B19437	197.5 – 200	Ringold	6.7	52.6	40.7	2.2	1.98

[a] Descriptions are based on DOE/RL-2002-39, *Standardized Stratigraphic Nomenclature for Post-Ringold-Formation Sediments Within the Central Pasco Basin.*

Table 3-2. Comparison of Selected Radionuclide Data for the 216-Z-7 Crib.

Location	Parameter	Cs-137	Co-60	Eu-154
Borehole C4183	**Max conc. (pCi/g)**	**23,000**	**35**	**29**
	Depth range detected (ft)	12-48	13-124	13-28
	Depth of max conc. (ft)	17	19	19
Direct-push hole C4177	**Max conc. (pCi/g)**	**15,000**	**28**	**60**
	Depth range detected (ft)	1-3 & 13-49	14-49	13-47
	Depth of max conc. (ft)	17	23	18
Direct-push hole C4178	**Max conc. (pCi/g)**	**7**	**Near MDL of 0.1**	**ND**
	Depth range detected (ft)	14-19	17-52	ND
	Depth of max conc. (ft)	17	--	ND
Direct-push hole C4179	**Max conc. (pCi/g)**	**100,000**	**23**	**14**
	Depth range detected (ft)	15-51	14-50	15-28 & 40-44
	Depth of max conc. (ft)	19	23	23
Direct-push hole C4180	**Max conc. (pCi/g)**	**0.3**	**2**	**ND**
	Depth range detected (ft)	14.5	30-52.5	ND
	Depth of max conc. (ft)	14.5	31.5	ND
Direct-push hole C4181	**Max conc. (pCi/g)**	**100,000**	**35**	**18**
	Depth range detected (ft)	13-48	13-48	14-43
	Depth of max conc. (ft)	17	23	15
Direct-push hole C4182	**Max conc. (pCi/g)**	**60,000**	**28**	**14**
	Depth range detected (ft)	1-5 & 12-49	14-52	12-24 & 34
	Depth of max conc. (ft)	16	23	9

-- = data were not reported or are unavailable.
ND = not detected.
SGL = spectral gamma logging.

4.0 VADOSE ZONE CONTAMINANT FATE AND TRANSPORT MODELING

4.1 INTRODUCTION AND BACKGROUND

Groundwater impacts were evaluated at the three representative waste sites in the 200-LW-1 and 200-LW-2 OUs. The evaluations were conducted to identify contaminants that pose a future risk to groundwater, based on data collected during the RI and on existing data. The modeling evaluates whether the contaminants migrating from the waste sites will reach groundwater before decaying or attenuating and estimates potential future concentrations in groundwater. The results of the impact evaluations will support the evaluation of remedial alternatives and closure options that will be included in the group-specific FS.

Transport modeling is conducted over a time period of 0 to 1,000 years. The 1,000-year time period was selected based on guidance established in WDOH/320-015, *Hanford Guidance for Radiological Cleanup*, Rev. 1, which adopted a dose-based guidance for the remediation of radiologically contaminated soil, groundwater, materials, and structures at the Hanford Site for 1,000 years after completion of the cleanup. Additionally, this time period often is used in DOE analyses. DOE M 435.1-1, *Radioactive Waste Management Manual*, requires 1,000 years for low-level waste performance assessments. DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, discusses 1,000 years as a relevant time period for uranium tailing stabilization, and several proposed EPA rules use 1,000 years. Hanford Site CERCLA closures frequently use a 1,000-year analytical period. However, transport simulations were extended to 10,000 years when migration characteristics of long-lived radionuclides were being evaluated. The results of the groundwater impact evaluation will be used in developing remedial alternatives and closure options that will be included in the group-specific FS.

4.2 MODELING METHODOLOGY

Potential groundwater impacts were evaluated using different methodologies for nonradioactive and radioactive contaminants. Detailed process modeling of flow and transport, using a code developed by the Pacific Northwest National Laboratory (PNNL-11217, *STOMP - Subsurface Transport Over Multiple Phases: Theory Guide*) (STOMP), was not deemed necessary for this investigation. Modeling conducted previously at 200 Areas sites (DOE/RL-2002-42, *Remedial Investigation Report for the 200-TW-1 and 200-TW-2 Operable Units (includes the 200-PW-5 Operable Unit))* for nonradioactive constituents has consistently indicated breakthrough to the water table for constituents with soil-water partition distribution coefficients (K_d) of zero. The Pacific Northwest National Laboratory has documented that constituents with K_ds of 40 L/kg or greater are effectively immobile in the vadose zone and groundwater (PNNL-11800, *Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site*). For the contaminants that exceeded groundwater thresholds in the screening phase, additional modeling only would have served to restate the finding that eventually the contaminant will reach groundwater. These contaminants will be considered further in the FS. For other contaminants, the original concentrations were sufficiently small that, although they may eventually reach groundwater, the concentrations would be far below levels of concern and, therefore, no benefit would be derived from further modeling. The contaminants anticipated to reach groundwater are discussed in the following sections.

4.2.1 Nonradioactive Contaminants

For nonradioactive contaminants, maximum contaminant concentrations at any depth in the vadose zone (the deep-zone soil column extending from the surface to groundwater) were compared to the Hanford Site lognormal 90th percentile background values identified in Summary Table 2 of DOE/RL-92-24. The comparison between each maximum detected contaminant concentration, at each waste site, and its background values are presented in Table 4-1. Shaded rows indicate that the maximum detected concentration of an inorganic contaminant exceeds its background screening value or had no available background values.

Background criteria have not been developed for organic chemicals in Hanford Site soils; therefore, background screening was not conducted for these contaminants.

Inorganic contaminants with maximum detected concentrations exceeding background screening values or with no available background values, and the maximum concentration of organic chemicals detected in one or more samples at any depth in the vadose zone, then were screened using the soil screening criteria calculated from the fixed-parameter three-phase partitioning model described in WAC 173-340-747, "Deriving Soil Concentrations for Ground Water Protection." Groundwater cleanup levels and constituent-specific chemical properties used in the calculation of the soil cleanup levels were obtained from the most recent version available at the time of Ecology 94-145, *Cleanup Levels and Risk Calculations under the Model Toxics Control Act Cleanup Regulation; CLARC, Version 3.1* (CLARC) (updated on 10-21-04).

The fixed-parameter (default values) variant of the three-phase equilibrium-partitioning model (WAC 173-340-747) was used for calculating soil cleanup levels for groundwater protection as described below. This model calculates soil-screening values for groundwater protection using the following equation:

$$C_s = C_w (UCF) DF \left[K_d + \frac{(\theta_w + \theta_a H_{cc})}{\rho_b} \right]$$

where

C_s = soil concentration (mg/kg)

C_w = groundwater cleanup level (μg/L)

UCF = unit conversion factor (1 mg/1,000 μg)

DF = dilution factor (20)

K_d = distribution coefficient (L/kg)

θ_w = water-filled soil porosity (0.3)

θ_a = air-filled soil porosity (0.13)

H_{cc} = Henry's law constant

ρ_b = dry bulk soil density (1.5 kg/L).

Chemical-specific K_ds and groundwater cleanup values used in the calculation of soil-screening criteria for groundwater impacts are provided in Tables 4-2, 4-3, and 4-4. Unless otherwise specified, the groundwater cleanup levels are from WAC 173-340-740, "Unrestricted Land Use Soil Cleanup Standards," and the K_d and Henry's law constant (H_{cc}) values are default values from CLARC Version 3.1 (Ecology 94-145).

The key variables in the fixed-parameter three-phase partitioning model, when applying this model to the 200 Areas sites in this report, are the dilution factor and K_d values. Generic K_d values obtained in CLARC Version 3.1 may not correspond to values estimated or measured in Hanford Site soils. The dilution factor in the fixed-parameter three-phase partitioning model is calculated as the sum of the volumetric infiltration and groundwater flow rates (m^3/yr) divided by the volumetric infiltration flow rate (m^3/yr). The default value of 20 implies that groundwater flow volume beneath a site is about 20 times greater than the volume of vadose zone water. Considering aquifer flow rates and recharge rates for the 200 Areas, the RESRAD default value of 20 is a minimum value for dilution for these sites.

Tables 4-2, 4-3, and 4-4 show the comparison of the maximum detected concentrations of nonradioactive contaminants, from each representative waste site, at any depth in the vadose zone to its protection-of-groundwater screening level. A shaded set of cells indicates that the maximum detected concentration of a contaminant exceeds the screening level for that contaminant.

4.2.2 Radioactive Contaminants

For radioactive contaminants, maximum contaminant concentrations at any depth in the vadose zone (the deep-zone soil column extending from the surface to groundwater) were compared to the Hanford Site lognormal 90th percentile radionuclide background values identified in Table 5-1 of DOE/RL-96-12.

Summary statistics also are provided in Table 5-1 of DOE/RL-96-12 for several fallout radionuclides. Background data for fallout radionuclides pertain only to undisturbed surface soil. Therefore, background comparisons will not be performed for fallout radionuclides, because the waste sites evaluated in this RI report do not have undisturbed surface soils and because all site data have been collected from vadose zone soils that are not associated with deposition of fallout radionuclides.

The comparison between each maximum detected radioactive contaminant concentration, at each waste site, and its background values are presented in Table 4-5. Shaded rows indicate that the maximum detected concentration of a radioactive contaminant exceeds its background screening value or had no available background values.

Radioactive contaminants with maximum detected concentrations exceeding background screening values or that had no available background values at any depth in the vadose zone were evaluated for potential groundwater impacts using the RESRAD computer model.

RESRAD Version 6.21 was used for this evaluation (ANL 2002). Implementation of the RESRAD model followed guidance described in ANL/EAD-4, *User's Manual for RESRAD, Version 6*,. Groundwater impacts were evaluated based on leaching of radionuclides from the contaminated zone, followed by infiltration through the vadose zone to groundwater, where exposure may occur via a hypothetical groundwater well.

In RESRAD, leaching of radionuclides from the contaminated zone is described by a sorption-desorption model that incorporates inputs such as precipitation and irrigation rates, evapotranspiration rate, K_d values of the individual radionuclides, and physical characteristics of the contaminated zone such as area, thickness, soil density, and moisture content. Site- and/or 200 Areas-specific information generally was used to establish appropriate values for these inputs to the leaching model. The irrigation rate was set to zero in the RESRAD simulations.

RESRAD employs a one-dimensional simplification of infiltration through the vadose zone from the bottom of the contaminated zone to the water table. Site-specific data were used to characterize the vadose zone, under the model constraint of a maximum of five geologic strata. Parameters employed in the infiltration model include soil porosity and density, moisture content, field capacity, hydraulic conductivity, and thickness for each geologic stratum. The time at which a radionuclide reaches groundwater and the rate at which it enters groundwater are calculated in RESRAD as a function of these parameters.

RESRAD contains two models that are used to calculate the time at which groundwater radionuclide concentrations reach their maximum and the dilution factor between water infiltrating from the vadose zone and groundwater at a hypothetical well. For sites less than 1,000 m^2, ANL/EAD-4 recommends using the RESRAD mass-balance model. In this model, all radionuclides released from the contaminated area are assumed to be withdrawn from the theoretical well, as might be the case if the well were located in the middle of a small site. For larger sites, greater than 1,000 m^2, ANL/EAD-4 recommends use of the nondispersion model, which allows for vertical mixing in the saturated zone and considers the location of the theoretical well to be at the downgradient edge of the site. The sizes of the three representative waste sites in the 200-LW-1 and 200-LW-2 OUs are less than 1,000 m^2; therefore, the mass-balance model was used for all three sites in this RI report.

The RESRAD transport models provide protective evaluations of potential groundwater impacts. By ignoring lateral dispersivity in both the unsaturated and the saturated zones, the quantity of radionuclides leached from the contaminated zone that might reach a hypothetical well is maximized.

Radionuclide concentrations at the hypothetical groundwater well at the time of maximum concentrations were identified as the output of the RESRAD evaluation of groundwater impacts. Derivation of hydrogeological input parameter values for the RESRAD evaluation of groundwater impacts at each site and the modeling results are discussed in further sections.

4.3 GROUNDWATER PATHWAY MODELING USING RESRAD VERSION 6.21

Radionuclides with maximum detected concentrations exceeding background values or that had no available background values were evaluated for potential impact to groundwater. The computer code RESRAD Version 6.21 (ANL 2002) was used to model transport of the radionuclides from designated contamination zones to the groundwater. The depth of the contamination zones was defined based on the contaminant distribution models in the Work Plan (DOE/RL-2001-66) and refined by the contaminant distribution in the vertical cross sections beneath the cribs as determined from analytical data collected during the RI investigation. Figures 3-10, 3-13, and 3-16 of this RI report present the contaminant distribution models for each borehole located at the three representative sites.

Based on contaminant distribution in the vertical cross sections beneath the cribs, there are three distinct zones of contamination at the 216-T-28 Crib, the 216-S-20 Crib, and the 216-Z-7 Crib. The zones of contamination in the 216-T-28 Crib, as shown in Figure 4-1, are defined as follows:

- Shallow contamination-transport zone to a depth of 15 m (49.2 ft), related to low mobility contaminants
- Intermediate contamination-transport zone to a depth of 30 m (98.4 ft), related to moderate mobility contaminants
- Deep contamination-transport zone to a depth of 69 m (226.4 ft), related to high mobility contaminants.

The zones of contamination in the 216-S-20 Crib, as shown in Figure 4-2, are defined as follows:

- Shallow contamination-transport zone to a depth of 15 m (49.2 ft), related to low mobility contaminants
- Intermediate contamination-transport zone to a depth of 50 m (164 ft), related to moderate mobility contaminants
- Deep contamination-transport zone to a depth of 73 m (239.5 ft), related to high mobility contaminants.

The zones of contamination in the 216-Z-7 Crib (Figure 4-3), are defined as follows:

- Shallow contamination-transport zone to a depth of 18 m (59.1 ft), related to low mobility contaminants
- Intermediate contamination-transport zone to a depth of 35 m (114.8 ft), related to moderate mobility contaminants
- Deep contamination-transport zone to a depth of 66 m (216.5 ft), related to high mobility contaminants.

4.3.1 Site Hydrogeologic Data for RESRAD Modeling

The RESRAD computer code requires information about the flow and transport characteristics of the vadose zone and saturated zone to estimate the movement of radionuclides from a contaminated zone through the soil to the groundwater. Requirements also include information about the site meteorology, surface-water hydrology, and erosion, because these processes also may influence contaminant migration. Parameters related to flow will be discussed in Section 4.3.1.1, and those related to transport will be discussed in Section 4.3.1.2.

4.3.1.1 RESRAD Flow Parameters

For the water pathways, RESRAD requires information for the cover and contaminated zone, the uncontaminated vadose zone, and the saturated zone. A number of these inputs for the water pathway depend on the characteristics of the geologic material. To assign these properties correctly, the stratigraphy of each site needed to be approximated by layers in the RESRAD model. RESRAD allows seven layers that include a contaminated zone layer, up to five vadose zone layers, and a saturated zone layer. A number of the soil categories associated with the 200 Areas soils and their hydraulic properties are presented in DOE/RL-2002-42. These soil categories are specific to the 216-T-28 Crib, 216-S-20 Crib, and 216-Z-7 Crib boreholes, because the sites analyzed in DOE/RL-2002-42 are located in the vicinity of the three cribs. These categories were used as the basis for identifying layers for RESRAD from stratigraphic and lithologic descriptions in borehole logs from the three sites evaluated in this RI report. The stratigraphic layer thicknesses for the 216-T-28 Crib, the 216-S-20 Crib, and the 216-Z-7 Crib are presented in Table 4-6 and Figures 4-1, 4-2, and 4-3. The associated hydraulic property categories for each stratigraphic layer within each borehole at the three sites are presented in Tables 4-7, 4-8, and 4-9.

Values for bulk densities and the RESRAD texture parameter 'b' were obtained for each category from DOE/RL-2004-17, *Remedial Investigation Report for the 200-CS-1 Chemical Sewer Group Operable Unit*. The bulk densities and the RESRAD texture parameters 'b' for stratigraphic units 5, 7, and 8 were assumed to be identical to the stratigraphic unit 3 soil category, because these units are similar and a soil category was not available for these units.

Parameters required for the saturated zone are the hydraulic gradient, water-table drop rate, well-pump intake depth, and the well pumping rate. Parameter values used for the well pumping rate and water-table drop rate were RESRAD default values. The hydraulic gradient varied between sites, and the values used were obtained from DOE/RL-2001-66. The value used for the well-pump intake depth was a typical well-screen depth for the Hanford Site (DOE/RL-2002-42).

Additional meteorological parameters required are the evaporation coefficient, precipitation, wind speed, and humidity in the air (for tritium only). The evaporation coefficient for the Hanford Site was obtained from WDOH/320-015. Mean annual precipitation for the Hanford Site was based on a 51-year average from DOE/RL-98-28. Mean annual wind speed was obtained from 200 Areas data (PNNL-13033, *Recharge Data Package for the Immobilized Low-Activity Waste 2001 Performance Assessment*), and humidity in the air was set to the

RESRAD default. Surface water parameters, the runoff coefficient, and the watershed area also were set to the RESRAD default values.

4.3.1.2 RESRAD Transport Parameters

Parameters required for modeling transport include the area of the contaminant zone, the cover and contaminant transport-zone thicknesses, and the length of the contaminant zone parallel to the aquifer flow. Site-specific areas of contaminant zones and the cover were obtained from Table 2-1 of the Work Plan (DOE/RL-2001-66). The thickness of the contaminant transport zone was based on the contaminant distribution as discussed in Section 4.3.

The values of the effective and total porosities and bulk densities of the geologic material composing the cover, contaminated zone, uncontaminated vadose zone, and the aquifer layers are required. The values of effective porosity were obtained by using the mean effective porosity from DOE/RL-2002-42 for the hydraulic property category associated with a given layer. The values for bulk densities were obtained for each category from DOE/RL-2004-17. Estimates of the erosion rate for the cover and contaminated zones are also required and were set to the RESRAD default values.

Distribution coefficient parameters that specify the concentration ratio of the adsorbed radionuclide to the radionuclide in solution are required for each element modeled. Isotopes of an element are assumed to have the same K_d. The K_ds were obtained from PNNL-11800, Appendix E. The K_ds were defined based on the K_d zone category and source category. Three K_d zone categories were defined in PNNL-11800, Appendix E, Table E.3. These zones are high impact, intermediate impact, and groundwater. The K_d categories were defined in Appendix E, Table E.4, for each K_d zone category and each source category. The 216-T-28 Crib, 216-S-20 Crib, and 216-Z-7 Crib fall into the "low organic/low salts/near neutral" source category. The K_d category for this source category is "F" for all three K_d zone categories. The K_d of each radionuclide of concern was specified based on the corresponding conservative value for the category F (Appendix E, Table E.10). The best-estimate values were provided for comparison only. The same values were used for the contaminated zone, unsaturated zone, and saturated zone, because they fall into the same K_d zone category.

A complete tabulation of RESRAD input-parameter values and input data that are not cross-section specific or radionuclide specific for the 216-T-28 Crib are summarized in Tables 4-10, 4-11, and 4-12; the values and data for the 216-S-20 Crib are summarized in Tables 4-13, 4-14, and 4-15, and the values and data for the 216-Z-7 Crib are summarized in Tables 4-16, 4-17, and 4-18.

4.4 SUMMARY EVALUATION OF FATE AND TRANSPORT

This section provides the evaluation of the constituents that potentially exceed groundwater RBCs. This section also evaluates whether added modeling beyond that presented will provide information required to assess whether degradation of the groundwater has occurred.

4.4.1 216-T-28 Crib Nonradioactive Contaminants of Potential Concern

The inorganic contaminants that are present at maximum concentrations greater than background or that do not have an applicable background value and exceed groundwater protection screening standards include the following:

- Arsenic
- Bismuth
- Fluoride
- Mercury
- Nitrate
- Uranium.

The RBC is not available for bismuth. Consequently, the corresponding soil concentration of bismuth was not calculated. However, the maximum concentration of bismuth is relatively high, and bismuth was included on the list of COPCs for further consideration.

The RBCs and other constituent-related parameters are not available for the three following organic constituents:

- Eicosane
- n-Hexanoic Acid
- Hexadecanoic acid (9Cl)
- Methylene chloride.

All four of these constituents were detected in very low concentrations (less than 1 mg/kg). It is suspected that the detection of these constituents is caused by sample contamination in the laboratory. Consequently, none of these constituents were included on the list of COPCs for further consideration.

The WAC 173-340-747 three-phase model does not address transport through uncontaminated vadose zone soils beneath the contaminated site. An additional screening evaluation for potential groundwater impacts was applied based on the Pacific Northwest National Laboratory report (PNNL-11800) that indicated that a K_d value of 40 L/kg is a reasonable metric for considering transport from the vadose zone to groundwater. This screening supplements the comparison to the soil-screening criteria by identifying those constituents that are effectively immobile in the vadose zone and, therefore, are highly unlikely to reach groundwater.

The following two constituents have a K_d greater than 40 L/kg:

- Mercury (K_d = 52 L/kg)
- Bismuth (K_d = 100 L/kg).

Uranium has a low K_d. However, uranium transport in the vadose zone considered in the radioactive contaminant analysis showed that none of the uranium isotopes reach groundwater in 1,000 years.

The vertical distributions of arsenic, mercury, and uranium are shown in Figure 3-10. The depths of the peak concentrations of arsenic and mercury are roughly proportional to the inverse ratio of their K_ds, as was expected. The depth of the maximum arsenic concentration is 3.7 times greater than the depth of the maximum mercury concentration, while the arsenic K_d is 1.8 times smaller than the mercury K_d. Uranium peak concentration is only 1.5 m (5 ft) below the mercury peak concentration. This suggests that the uranium K_d is significantly higher than was assumed in the radioactive contaminant analysis, indicating that this analysis was very conservative. Also, the simple mass balance calculations show that 367 kg of uranium (or 97 percent of the amount disposed of) are located within the contaminated soil column that extends to the depth of about 32 m (105 ft). One reason for uranium to have a larger K_d than expected would be the reducing of U^{6+} to U^{3+}. The latter has significantly lower solubility and consequently lower mobility (greater apparent K_d). Therefore, the only COPCs remaining on the list are arsenic, fluoride, and nitrate.

The arsenic potential to reach the groundwater in 1,000 years was evaluated using RESRAD Version 6.21 (ANL 2002). Uranium-238 was selected to emulate the arsenic behavior in the vadose zone, because its half-life is very large, and a negligible portion of its mass is lost by decay within 1,000 years. The U-238 K_d was specified as equal to 29 L/kg, which is the assumed arsenic K_d (Table 4-2). The RESRAD parameters that are not vertical cross-section specific and constituent specific are defined in Table 4-10. The cross-section-specific parameters are defined in Table 4-12, assuming the total depth of the contaminated zone to be equal to 50.3 m (165 ft). Based on the RESRAD calculations, it is concluded that a nondecaying constituent with the K_d equal to 29 L/kg will not reach groundwater within 1,000 years, assuming that the current depth of the contaminated zone extends to about 50 m (164 ft). Based on this conclusion, arsenic is excluded from the list of COPCs.

The remaining COPCs are fluoride and nitrate. The vertical distributions of these constituents are shown in Figure 3-10. In this figure, the concentrations of both constituents increase with depth. This means either that the peak concentration occurs very close to the water table or that the peak discharges to the groundwater already have occurred.

Based on DOE/RL-2001-66, the total amount of nitrate discharged into the 216-T-28 Crib was 10,000 kg. Simplified calculations of the nitrate mass within the contaminated soil column extending to the groundwater table using conservative assumptions about nitrate concentrations shows that the maximum nitrate mass currently stored in this column is about 6,200 kg. This means that about 38 percent or more of the nitrate mass has discharged into the aquifer. This is consistent with the fact that nitrate has a K_d equal to 0 and travels with the same velocity as the groundwater. As discussed in DOE/RL-2001-66, based on the total amount of effluents discharged in the 216-T-28 Crib and the volume of soil column beneath the crib, the waste water already could have reached the aquifer (DOE/RL-2001-66). The fluoride K_d is 0 as well, suggesting that the same conclusions can be made about this constituent.

The fact that the nondecaying constituent with a K_d equal to zero reaches groundwater within 1,000 years is consistent with the previous modeling (DOE/RL 2002-42; and DOE/RL-2003-11, *Remedial Investigation for the 200-CW-5 U Pond/ Z Ditches Cooling Water Group, the 200-CW-2 S Pond and Ditches Cooling Water Group, the 200-CW-4 T Pond and Ditches Cooling Water Group, and the 200-CS-1 Steam Condensate Group Operable Units*) and with the existence of the known groundwater plumes (DOE/RL-2001-66) within the 200 Areas. Therefore, an additional modeling of nitrate and fluoride will not be of a specific value. Fluoride and nitrate are the only two constituents detected in the vadose zone beneath the 216-T-28 Crib that exceed background concentrations, exceed the WAC-173-340, "Model Toxics Control Act -- Cleanup," groundwater protection screening standards, and reach the groundwater aquifer in less than 1,000 years.

4.4.2 216-T-28 Radioactive Contaminants of Potential Concern

Hanford Site 90th- percentile background values from DOE/RL-96-12, Table 5-1, were used to identify potentially site-related contaminants in the background screening. The results of the background screening are presented in Table 4-5. The radionuclides that are no longer retained for further evaluation based on the background screening are K-40, Ra-226, Ra-228, Th-230, and Th-232.

Radionuclide-specific parameters and contamination-depth-specific parameters used in the RESRAD model are presented in Tables 4-11 and 4-12.

4.4.2.1 Shallow Contaminant-Transport Zone - 15 Meters

The radionuclides selected for the shallow contaminant-transport zone modeling were defined based on the analysis of the contaminant distribution in the vertical cross section. These radionuclides are Sb-125, Cs-134, Cs-137, Np-237, Pu-238, Pu-239/240, Sr-90, Th-228, U-233/234, U-235, and U-238. The concentrations of these radionuclides (except for Sr-90, which had only one data point) versus depth are shown in Figure 3-10. As seen in this figure, these radionuclides are located within the upper 15 m (49.2 ft) of the cross section. The only exception is Sr-90. Only one depth interval (5.3 to 6 m [17.4 to 19.7 ft]) was available for Sr-90. Strontium detected in this interval was considered to be at the maximum concentration. The contaminant zone depth was assumed to be 15 m (49.2 ft).

None of the radionuclides selected for the shallow contaminant-transport zone modeling reach the groundwater in 1,000 years. Neptunium and plutonium (all isotopes) reach the hypothetical groundwater well, with the maximum doses ranging from 4×10^{-5} to 1.7×10^{-2} mrem/yr at 10,000 years. Uranium (all isotopes) reaches the hypothetical groundwater well with the maximum dose of 105 mrem/yr at 6,000 years.

4.4.2.2 Intermediate Contaminant-Transport Zone - 30 Meters

The radionuclides selected for the intermediate contaminant-transport zone modeling were defined based on the analysis of the contaminant distribution in the vertical cross section. These radionuclides are C-14, Co-60, Eu-152, Eu-154, Eu-155, and Ni-63. The concentrations of these radionuclides versus depth are shown in Figure 3-10. As seen in this figure, these radionuclides are located within the upper 30 m (98.4 ft) of the cross section.

None of radionuclides selected for the intermediate contaminant-transport zone modeling reach groundwater in 1,000 years. Carbon-14 reaches the hypothetical groundwater well with the maximum dose of 0.032 mrem/yr at 3,500 years. The other radionuclides do not reach the hypothetical groundwater well in 10,000 years.

4.4.2.3 Deep Contaminant-Transport Zone - 68.5 Meters

The radionuclides selected for the deep contaminant-transport zone modeling were defined based on the analysis of the contaminant distribution in the vertical cross section. These radionuclides are Am-241, Tc-99, and tritium. The concentrations of these radionuclides versus depth are shown in Figure 3-10. As seen in this figure, these radionuclides are located within the entire vadose zone. It was assumed that the contaminant depth in this case is 68.5 m (224.7 ft), which is 0.5 m (1.6 ft) above the groundwater table. This assumption was made to enable the use of RESRAD calculations.

Two contaminants, Tc-99 and tritium, reach groundwater in a very short time (4.5 years), with maximum dose rates of 0.1 mrem/yr and 41 mrem/yr respectively.

4.4.3 216-S-20 Crib Nonradioactive Contaminants of Potential Concern

The inorganic contaminants that are present at maximum concentrations greater than background or that do not have an applicable background value and exceed groundwater protection screening standards include the following:

- Arsenic
- Bismuth
- Mercury
- Uranium.

The RBC is not available for bismuth. Consequently, the corresponding soil concentration of bismuth was not calculated. However, the maximum concentration of bismuth is relatively high, and bismuth was included on the list of COPCs for further consideration.

The WAC 173-340-747 three-phase model does not address transport through uncontaminated vadose zone soils beneath the contaminated site. An additional screening evaluation for potential groundwater impacts was applied based on the Pacific Northwest National Laboratory report (PNNL-11800) that indicated that a K_d value of 40 L/kg is a reasonable metric for considering transport from the vadose zone to groundwater. This screening supplements the comparison to the soil screening criteria by identifying those constituents that are effectively immobile in the vadose zone and that, therefore, are highly unlikely to reach groundwater.

The following two constituents have a K_d greater than 40 L/kg:

- Mercury (K_d = 52 L/kg)
- Bismuth (K_d = 100 L/kg).

Uranium has a low K_d. However, uranium transport in the vadose zone considered in the radioactive contaminant analysis showed that none of the uranium isotopes reach groundwater in 1,000 years.

The vertical distributions of arsenic and mercury are shown in Figure 3-13. The depths of the peak concentrations of arsenic and mercury are roughly proportional to the inverse ratio of their K_ds, as was expected. The depth of the maximum arsenic concentration is 3.1 times greater than the depth of maximum mercury concentration, while the arsenic K_d is 1.8 times smaller than the depth of the mercury K_d. Note that a very similar relationship was observed for the 216-T-28 Crib.

The arsenic potential to reach the groundwater in 1,000 years was evaluated using RESRAD Version 6.21 (ANL 2002). Uranium-238 was selected to emulate the arsenic behavior in the vadose zone, because its half-life is very large, and a negligible portion of its mass is lost by decay within 1,000 years. The U-238 K_d was specified as equal to 29 L/kg, which is the assumed arsenic K_d (Table 4-3). The RESRAD parameters that are not vertical-cross-section specific and constituent specific were defined in Table 4-13. The cross-section-specific parameters were defined in Table 4-15, assuming the total depth of the contaminated zone to be equal to 50.3 m (165 ft). Based on the RESRAD calculations, it is concluded that a nondecaying constituent with the K_d equal to 29 L/kg will not reach groundwater within 1,000 years, assuming that the current depth of the contaminated zone extends to about 50 m (164 ft). Based on this conclusion, arsenic can be excluded from the list of COPCs.

None of the nonradioactive contaminants detected in the vadose zone beneath the 216-S-20 Crib should be retained on the list of COPCs regarding groundwater protection. This conclusion is based on the analysis of the background concentrations, screening against the WAC-173-340 groundwater protection screening standards, and evaluation of potentials for reaching the groundwater aquifer in less than 1,000 years.

4.4.4 216-S-20 Radioactive Contaminants of Potential Concern

Hanford Site 90th- percentile background values from DOE/RL-96-12, Table 5-1, were used to identify potentially site-related contaminants in the background screening. The radionuclides that are present at maximum concentrations greater than background or that do not have an applicable background value are shown in bold in Table 4-5. The radionuclides that are no longer retained for further evaluation based on the background screening are Sb-125, Cs-134, Eu-152, K-40, Ra-226, Ra-228, and Th-230.

Radionuclide-specific parameters and contamination-depth-specific parameters used in the RESRAD model are presented in Tables 4-14 and 4-15.

4.4.4.1 Shallow Contaminant-Transport Zone - 15 Meters

The radionuclides selected for the shallow contaminant-transport zone modeling were defined based on the analysis of the contaminant distribution in the vertical cross section. These radionuclides are C-14, Cs-137, Co-60, Ni-63, Np-237, Sr-90, Tc-99, Th-228, Th-232, U-233/234, U-235, and U-238. The concentrations of these radionuclides (except Np-237, Sr-90, and Tc-99, which had only a few data points each) versus depth are shown in Figure 3-13. As seen in this figure, these radionuclides are located within the upper 15 m (49.2 ft) of the cross section.

None of radionuclides except Tc-99 reach groundwater in 1,000 years. Technetium-99 reaches groundwater with the maximum concentration at 1,000 years. However, its dose (2×10^{-4} mrem/yr) is significantly lower than the corresponding regulatory limits of 4 mrem/yr. Carbon-14 reaches the hypothetical groundwater well with the maximum dose of 0.06 mrem/yr at 6,000 years (maximum excess cancer risk is 6×10^{-8}). Uranium reaches the hypothetical groundwater well with the maximum dose of 2,830 mrem/yr at 6,000 years. Neptunium-237 dose is 8.46×10^{-4} mrem/yr.

4.4.4.2 Intermediate Contaminant-Transport Zone - 50 Meters

The radionuclides selected for the intermediate contaminant-transport zone modeling were defined based on the analysis of the contaminant distribution in the vertical cross section. These radionuclides are Eu-154, Eu-155, Pu-238, and Pu-239/240. The concentrations of these radionuclides versus depth are shown in Figure 3-13. As seen in this figure, these radionuclides are located within the upper 50 m (164.0 ft) of the cross section.

None of the radionuclides reach groundwater in 1,000 years. Plutonium (its daughters) reaches the hypothetical groundwater well with the total maximum dose of 0.012 mrem/yr at 6,300 years. The other radionuclides do not reach the hypothetical groundwater well in 10,000 years.

4.4.4.3 Deep Contaminant-Transport Zone - 73 Meters

The radionuclides selected for the deep contaminant-transport zone modeling were defined based on the analysis of the contaminant distribution in the vertical cross section. These radionuclides are Am-241 and tritium. The concentrations of these radionuclides versus depth are shown in Figure 3-13. As seen in this figure, these radionuclides are located within the entire vadose zone to the depth of 73 m (239.5 ft). The groundwater table was at 74 m (242.8 ft) bgs.

Only one radionuclide, tritium, cannot be screened out because it reaches groundwater in a very short time, and its excess cancer risk is above the groundwater protection limit. However, after 44 years, the excess cancer risk associated with tritium falls below the groundwater protection limit.

4.4.5 216-Z-7 Crib Nonradioactive Contaminants of Potential Concern

The inorganic contaminants that are present at maximum concentrations greater than background or that do not have an applicable background value and exceed groundwater protection screening standards are as follows:

- Arsenic
- Bismuth

- Cyanide
- Mercury
- Uranium
- Methylene chloride
- Nonadecane.

The RBCs are not available for bismuth and nonadecane. Consequently, the corresponding soil concentrations of bismuth and nonadecane were not calculated. However, the maximum concentration of bismuth is relatively high, and bismuth was included on the list of COPCs for further consideration.

Nonadecane and methylene chloride were detected in very low concentrations in only one sample. It is suspected that the detection of these constituents is from sample contamination in the laboratory. Consequently, nonadecane and methylene chloride were not included on the list of COPCs for further consideration.

The WAC 173-340-747 three-phase model does not address transport through uncontaminated vadose zone soils beneath the contaminated site. An additional screening evaluation for potential groundwater impacts was applied based on the Pacific Northwest National Laboratory report (PNNL-11800) that indicated that a K_d value of 40 L/kg is a reasonable metric for considering transport from the vadose zone to groundwater. This screening supplements the comparison to the soil screening criteria by identifying those constituents that are effectively immobile in the vadose zone and that, therefore, are highly unlikely to reach groundwater.

The following two constituents have a K_d greater than 40 L/kg and may be excluded from the list of the potential contaminants of concern:

- Mercury (K_d = 52 L/kg)
- Bismuth (K_d = 100 L/kg).

Uranium has a low K_d. However, uranium transport in the vadose zone considered in the radioactive contaminant analysis showed that none of the uranium isotopes reach groundwater in 1,000 years. Therefore, the only COPCs remaining on the list are arsenic and cyanide.

The arsenic potential to reach the groundwater in 1,000 years was evaluated using RESRAD Version 6.21 (ANL 2002). Uranium-238 was selected to emulate the arsenic behavior in the vadose zone, because its half-life is very large, and a negligible portion of its mass is lost by decay within 1,000 years. The U-238 K_d was specified as equal to 29 L/kg, which is the arsenic K_d (Table 4-4). The RESRAD parameters that are not vertical-cross-section specific and constituent specific were defined in Table 4-16. The cross-section-specific parameters were defined in Table 4-18. The total depth of the contaminated zone was assumed to be equal to 4.5 m (14.8 ft). This is the depth of the only sample in which arsenic was detected. Based on these calculations, it is concluded that arsenic does not reach groundwater in 1,000 years and can be excluded from the list of the COPCs.

The cyanide potential to reach the groundwater in 1,000 years was evaluated using RESRAD Version 6.21. Uranium-238 was selected to emulate the cyanide behavior in the vadose zone, because its half-life is very large, and a negligible portion of its mass is lost by decay within

1,000 years. The U-238 K_d was specified as equal to 0 L/kg, which is the cyanide K_d (Table 4-4). The RESRAD parameters that are not vertical-cross-section specific and constituent specific were defined in Table 4-16. The cross-section-specific parameters were defined in Table 4-18. Cyanide was detected in only one sample from the depth of 4.5 m (14.8 ft). Consequently, the total depth of the contaminated zone was specified at this depth. The concentration of uranium was specified as equal to the concentration of cyanide (3.95 mg/kg). This concentration was converted to pCi/g (6.32×10^{-11} pCi/g). The uranium (cyanide) reaches the groundwater within 1,000 years, with the maximum concentration at 700 years. The maximum concentration is 3.3×10^{-13} pCi/L, which is the equivalent of 0.21 μg/L. The maximum contaminant level (MCL) for cyanide is 200 μg/L. Consequently, even though cyanide is likely to reach the groundwater within the 1,000-year time period, its maximum concentration will be significantly below the MCL. Based on this evaluation, cyanide is excluded from the list of the potential contaminants.

None of the organic and inorganic constituents detected in the vadose zone beneath the 216-Z-7 Crib should be retained as a COPC.

4.4.6 216-Z-7 Radioactive Contaminants of Potential Concern

Hanford Site 90th percentile background values from DOE/RL-96-12, Table 5-1, were used to identify potentially site-related contaminants in the background screening. The radionuclides that are present at maximum concentrations greater than background or that do not have an applicable background value are shown in bold in Table 4-5. The radionuclides no longer retained for further evaluation based on the background screening are Sb-125, C-14, Cs-134, Eu-152, Ni-63, K-40, Ra-226, Ra-228, Th-228, Th-230, Th-232, U-233/234, U-235, and U-238.

Radionuclide-specific parameters and contamination-depth-specific parameters used in the RESRAD model are presented in Tables 4-17 and 4-18.

4.4.6.1 Shallow Contaminant-Transport Zone - 18 Meters

The radionuclides selected for the shallow contaminant-transport zone modeling were defined based on the analysis of the contaminant distribution in the vertical cross section. These radionuclides are Cs-137, Np-237, Sr-90, and Tc-99. The concentrations of these radionuclides (except Sr-90, which had only a few data points) versus depth are shown in Figure 3-16. As seen in this figure, these radionuclides are located within the upper 18 m (59.1 ft) of the cross section.

None of the radionuclides except Tc-99 reach groundwater in 1,000 years. Technetium-99 reaches groundwater in about 500 years. Its peak dose is 8.5 mrem/yr, which is above the 4 mrem/yr regulatory limit. Consequently, Tc-99 is the only radionuclide of potential concern.

4.4.6.2 Intermediate Contaminant-Transport Zone - 35 Meters

The radionuclides selected for the intermediate contaminant-transport zone modeling were defined based on the analysis of the contaminant distribution in the vertical cross section. These radionuclides are Pu-238 and Pu-239/240. The concentrations of these radionuclides versus depth are shown in Figure 3-16. As seen in this figure, these radionuclides are located within the upper 35 m (114.8 ft) of the cross section. None of radionuclides reach groundwater in 1,000 years.

4.4.6.3 Deep Contaminant-Transport Zone - 66 Meters

The radionuclides selected for the deep contaminant-transport zone modeling were defined based on the analysis of the contaminant distribution in the vertical cross section. These radionuclides are Am-241, tritium, Co-60, Eu-154, and Eu-155. The concentrations of these radionuclides versus depth are shown in Figure 3-16. As seen in this figure, these radionuclides are located within the entire vadose zone. It was assumed that the contaminant depth in this case is 65.8 m (215.9 ft), which is 0.5 m (1.6 ft) above the groundwater table. This was assumed to enable the use of the RESRAD calculations.

Americium-241 and tritium reach groundwater within the 1,000-year period. The total dose during this time period is below 0.3 mrem/yr. Taking into account the fact that the concentration of Am-241 at the depths greater than 50 m (164 ft) is only 10 pCi/g (see Figure 3-16), which is significantly lower than the concentration of 60,600 pCi/g used in the modeling, that the dose associated with Am-241 is insignificant, and the excess cancer risk is just slightly above the regulatory limit, Am-241 can be excluded from the list of COPCs.

4.5 CONCLUSIONS

4.5.1 216-T-28 Crib

Fluoride and nitrate are the only two nonradioactive constituents detected in the vadose zone beneath the 216-T-28 Crib that exceed background concentrations, exceed the WAC-173-340 groundwater protection screening standards, and reach the groundwater aquifer in less than 1,000 years.

The only two radioactive contaminants of concern are Tc-99 and tritium. Both of them reach the hypothetical groundwater well in a very short time (4.5 years), and their dose and/or excess cancer risk are above the groundwater protection limits.

4.5.2 216-S-20 Crib

None of the nonradioactive contaminants detected in the vadose zone beneath the 216-S-20 Crib should be retained on the list of COPCs with regard to groundwater protection.

The only radioactive contaminant of concern is tritium. Tritium reaches the groundwater in a very short time, and its excess cancer risk is above the groundwater protection limit.

4.5.3 216-Z-7 Crib

None of the nonradioactive constituents detected in the vadose zone beneath the 216-Z-7 Crib should be retained as COPCs.

The only two radioactive contaminants of concern are Tc-99 and tritium. Both of them reach the hypothetical groundwater well within the 1,000-year time period. While the peak doses associated with these radionuclides are below the regulatory limit, their excess cancer risk values are above the groundwater protection limits.

Figure 4-1. Contaminant Transport Zone Representation of the 216-T-28 Crib.

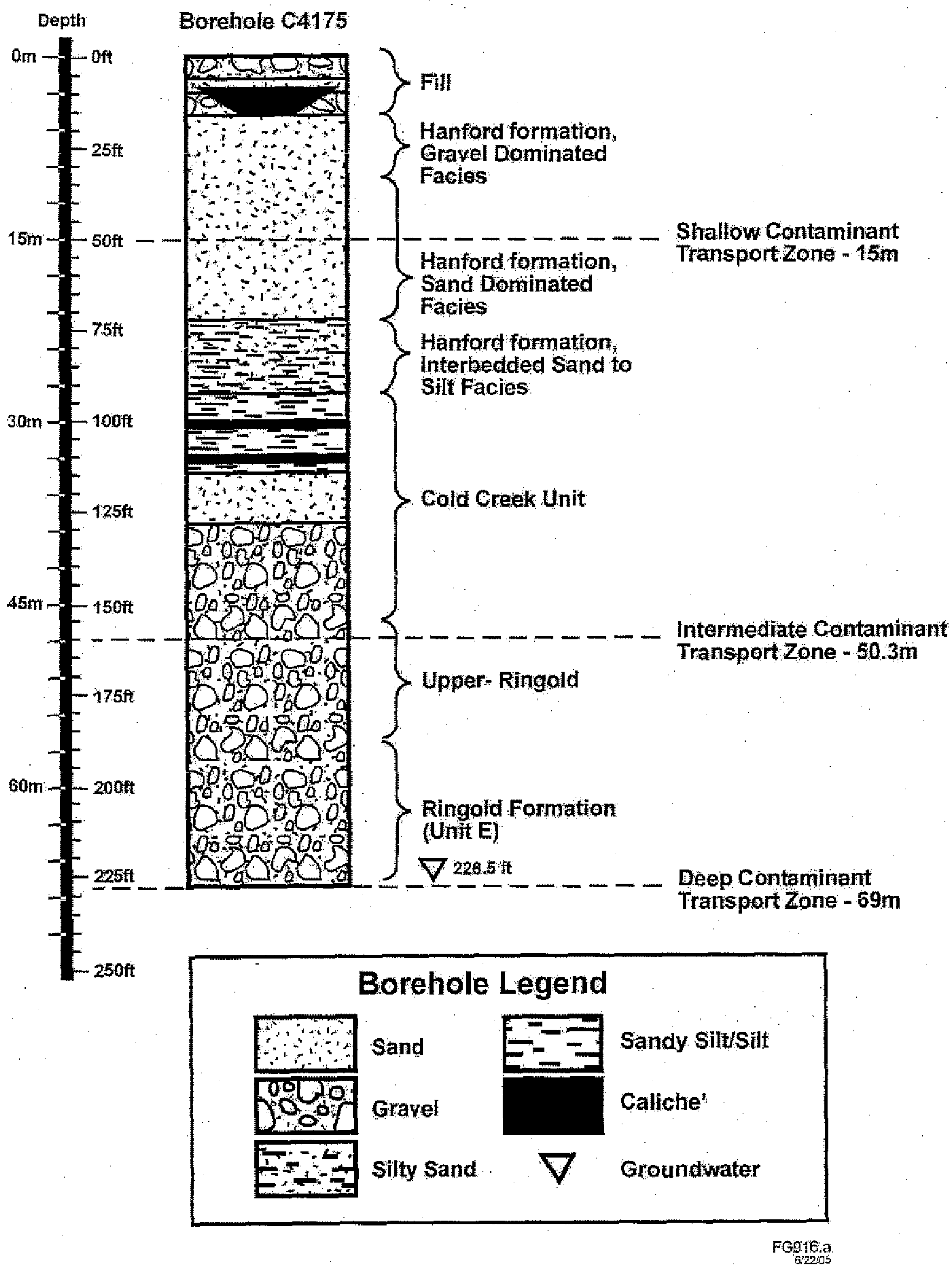


Figure 4-2. Contaminant Transport Zone Representation of the 216-S-20 Crib.

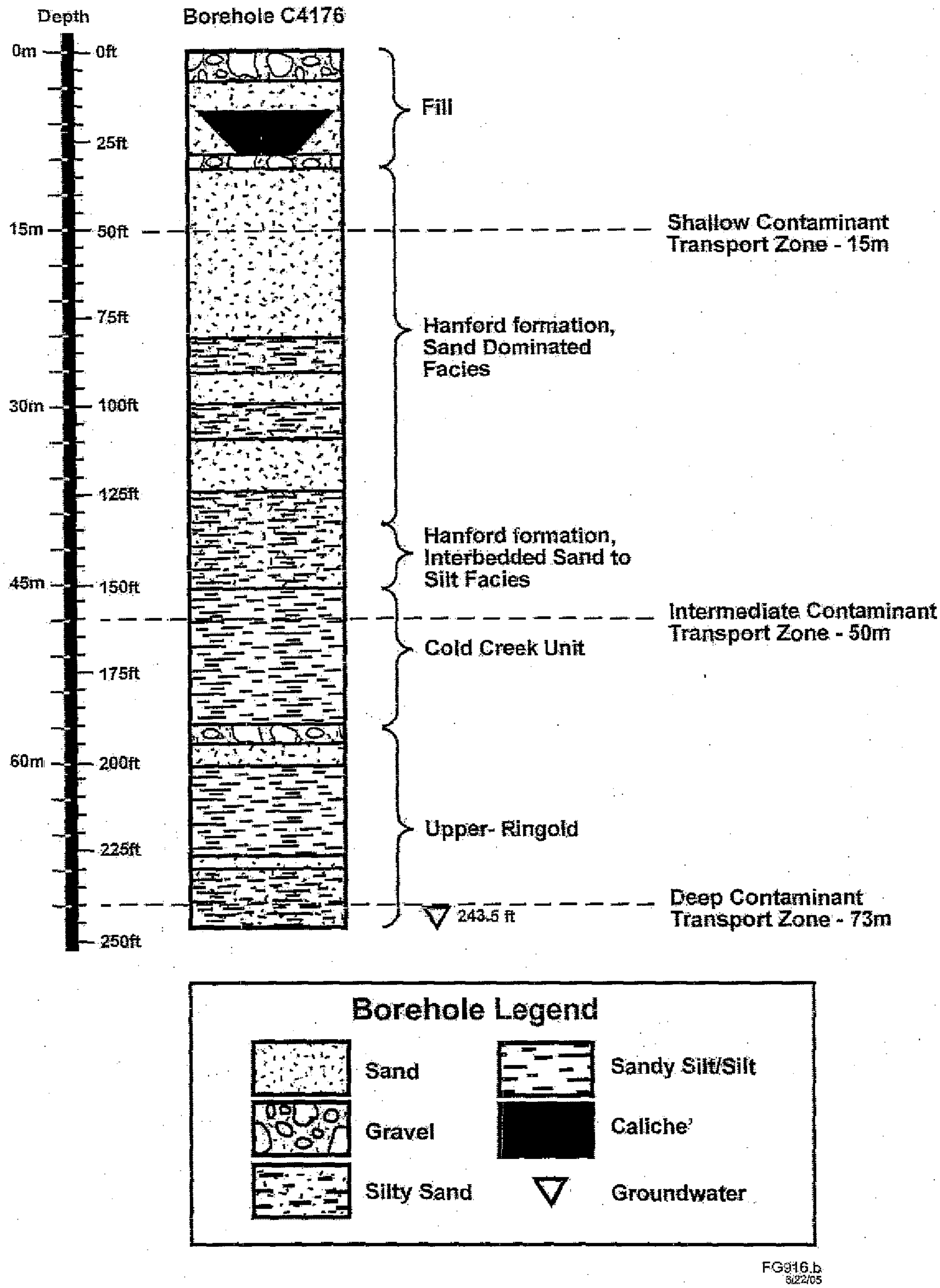


Figure 4-3. Contaminant Transport Zone Representation of the 216-Z-7 Crib.

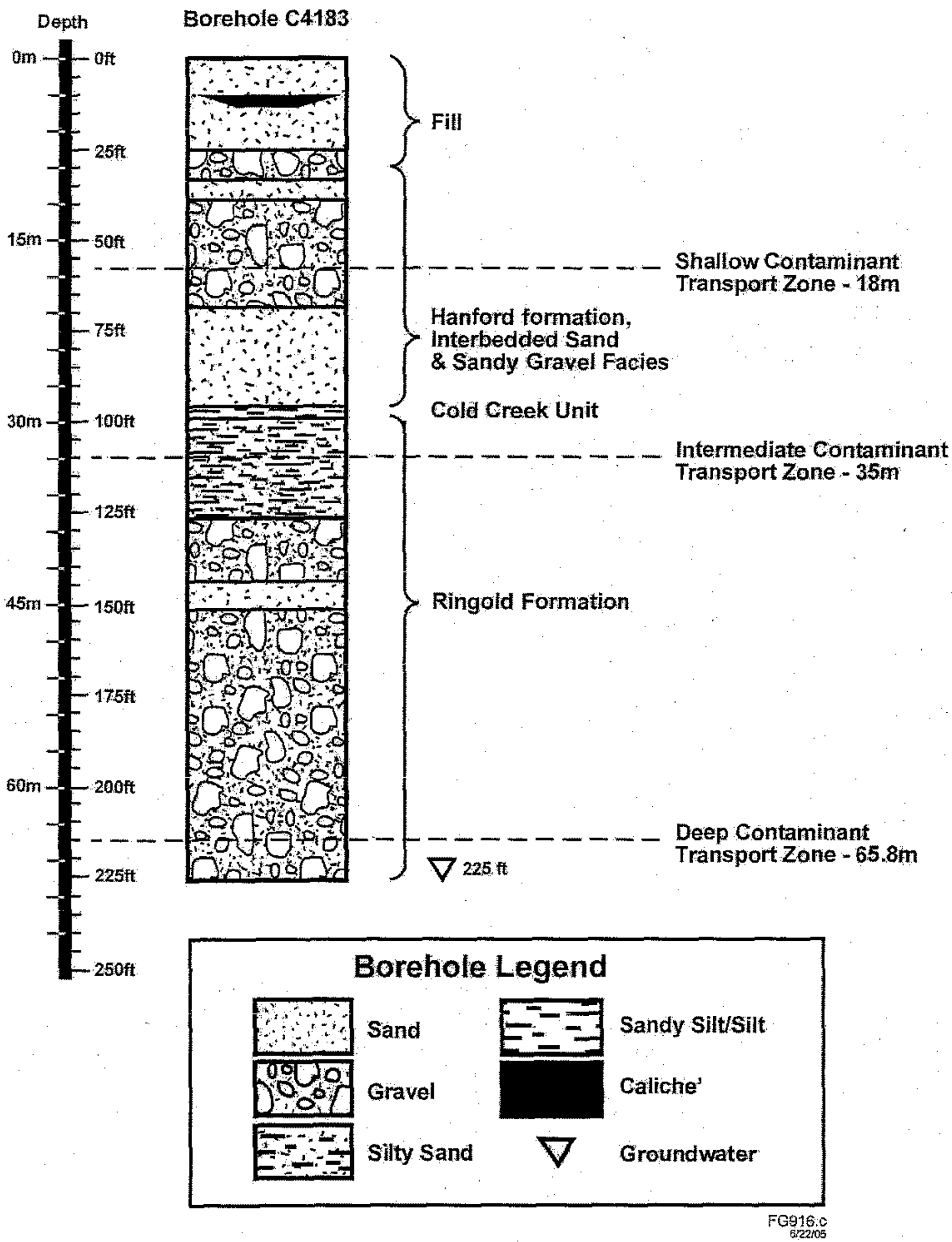


Table 4-1. Background Comparisons for Inorganic Nonradioactive Contaminants of Potential Concern. (3 Pages)

Constituent Class	Constituent	90th Percentile Background Concentration[a] (mg/kg)	Vadose Zone Maximum Concentration (mg/kg)	Sample Interval - Vadose Zone Maximum (ft)	Does Maximum Concentration Exceed Background?
216-T-28 Crib					
GENCHEM	Ammonia as NH_3	9.23	14.5	22.5-25	Yes
GENCHEM	Ammonium Ion	--	24.7	67.5-70	No Background
GENCHEM	Chloride	100	13.3	22.5-25	No
GENCHEM	Cyanide	--	ND	-	No
GENCHEM	Fluoride	2.81	39.6	90-92.5	Yes
GENCHEM	Nitrate as N	12	245	90-92.5	Yes
GENCHEM	Nitrite as N	--	2.53	17.5-20	No Background
GENCHEM	Nitrogen in Nitrite and Nitrate	--	45.8	90-92.5	No Background
GENCHEM	Phosphate	0.785	59.1	22.5-25	Yes
GENCHEM	Sulfate	237	57.2	157.5-160	No
GENCHEM	Sulfide	--	ND	-	No
METAL	Antimony	--	5.03	197.5-200	No Background
METAL	Arsenic	6.47	9.29	90-92.5	Yes
METAL	Barium	132	110	157.5-160	No
METAL	Beryllium	1.51	0.912	47.5-50	No
METAL	Bismuth	--	202	22.5-25	No Background
METAL	Boron	--	ND	-	No Background
METAL	Cadmium	0.81	0.204	157.5-160	No
METAL	Chromium	18.5	81.7	22.5-25	Yes
METAL	Copper	22	19.9	27.5-30	No
METAL	Hexavalent Chromium	--	1.5	90-92.5	No Background
METAL	Lead	10.2	34.4	197.5-200	Yes
METAL	Mercury	0.33	6.84	22.5-25	Yes
METAL	Nickel	19.1	52.7	22.5-25	Yes
METAL	Selenium	--	0.869	157.5-160	No Background
METAL	Silver	0.73	4.98	67.5-70	Yes
METAL	Uranium	3.21 E-03	113	27.5-30	Yes

Table 4-1. Background Comparisons for Inorganic Nonradioactive Contaminants of Potential Concern. (3 Pages)

Constituent Class	Constituent	90th Percentile Background Concentration[a] (mg/kg)	Vadose Zone Maximum Concentration (mg/kg)	Sample Interval - Vadose Zone Maximum (ft)	Does Maximum Concentration Exceed Background?
216-S-20 Crib					
GENCHEM	Ammonia as NH_3	9.23	ND	-	No
GENCHEM	Ammonium Ion	--	2.87	47.5-50	No Background
GENCHEM	Chloride	100	15.7	32.5-35	No
GENCHEM	Cyanide	--	ND	-	No
GENCHEM	Fluoride	2.81	6.51	29.5-32	Yes
GENCHEM	Nitrate as N	12	18.6	29.5-32	Yes
GENCHEM	Nitrite as N	--	ND	-	No Background
GENCHEM	Nitrogen as Nitrite and Nitrate	--	3.4	32.5-35	No Background
GENCHEM	Phosphate	0.785	ND	-	No
GENCHEM	Sulfate	237	16.7	191.5-194	No
GENCHEM	Sulfide	--	23.9	29.5-32	No Background
METAL	Antimony	--	2.9	29.5-32	No Background
METAL	Arsenic	6.5	9.16	97-99.5	Yes
METAL	Barium	132	136	32.5-35	Yes
METAL	Beryllium	1.51	2.7	32.5-35	Yes
METAL	Bismuth	--	202	29.5-32	No Background
METAL	Boron	--	13.5	29.5-32	No Background
METAL	Cadmium	0.81	0.28	29.5-32	No
METAL	Chromium	18.5	259	29.5-32	Yes
METAL	Copper	22	122	29.5-32	Yes
METAL	Hexavalent Chromium	--	1.28	32.5-35	No Background
METAL	Lead	10.2	489	29.5-32	Yes
METAL	Mercury	0.33	69.2	29.5-32	Yes
METAL	Nickel	19.1	55	29.5-32	Yes
METAL	Selenium	--	ND	-	No
METAL	Silver	0.73	6.0	29.5-32	Yes
METAL	Uranium	3.21 E-03	818	32.5-35	Yes

Table 4-1. Background Comparisons for Inorganic Nonradioactive Contaminants of Potential Concern. (3 Pages)

Constituent Class	Constituent	90th Percentile Background Concentration[a] (mg/kg)	Vadose Zone Maximum Concentration (mg/kg)	Sample Interval - Vadose Zone Maximum (ft)	Does Maximum Concentration Exceed Background?
216-Z-7 Crib					
GENCHEM	Ammonia as NH_3	9.23	ND	-	No
GENCHEM	Ammonium Ion	--	0.649	197.5-200	No Background
GENCHEM	Chloride	100	5.34	197.5-200	No
GENCHEM	Cyanide	--	ND	12.5-15	No
GENCHEM	Fluoride	2.81	0.26	22.5-25	No
GENCHEM	Nitrate as N	12	197.44	40-42.5	Yes
GENCHEM	Nitrite as N	--	ND	-	No
GENCHEM	Nitrogen as Nitrite and Nitrate	--	2.5	40-42.5	No Background
GENCHEM	Phosphate	0.785	13.0	22.5-25	Yes
GENCHEM	Sulfate	237	5.62	220-222.5	No
METAL	Antimony	--	2.8	17.5-20	No Background
METAL	Arsenic	6.5	13.4	12.5-15	Yes
METAL	Barium	132	80.5	96.5-99	No
METAL	Beryllium	1.51	0.38	40-42.5	No
METAL	Bismuth	--	123	27.5-30	No Background
METAL	Boron	--	3.1	27.5-30	No Background
METAL	Cadmium	0.81	0.321	40-42.5	No
METAL	Chromium	18.5	193	17.5-20	Yes
METAL	Copper	22	18.2	22.5-25	No
METAL	Hexavalent Chromium	--	2.05	197.5-200	No Background
METAL	Lead	10.2	14.3	17.5-20	Yes
METAL	Mercury	0.33	5.6	17.5-20	Yes
METAL	Nickel	19.1	23.4	197.5-200	Yes
METAL	Selenium	--	ND	-	No Background
METAL	Silver	0.73	4.7	96.5-99	Yes
METAL	Uranium	3.21 E-03	27.9	40-42.5	Yes

Shaded cells indicate constituents that exceed background values or which are detected but have no background values.

GENCHEM = General Chemistry.
METAL = Metals suite.
ND = not detected.
-- = no background value available.

Table 4-2. Parameters and Results of Screening to WAC 173-340 Groundwater Protection Screening Standards, 216-T-28 Crib. (3 Pages)

Chemical Name	Groundwater RBC (µg/L)	Distribution Coefficient (K_d) (L/kg)	K_d Source	Henry's Law Constant (H_{cc}) (Dimensionless)	H_{cc} Source	Protection of GW Screening Level (mg/kg)	Max. Detected Concentration in Soil (mg/kg)	Is Max. Concentration Greater than Screening Level?
2-Butoxyethanol	4.00 E+03[a]	0	Conservative assumption[c]	0	Conservative	16.00	0.15	No
4-Chloro-3-methylphenol	800[a]	0	Conservative assumption[c]	0	Conservative	3.20	0.023	No
Acetone	7.20 E+03[a]	5.75 E-04	CLARC 3.1[h]	1.59 E-03	CLARC 3.1	28.90	0.008	No
Ammonia as NH_3	N/A	N/A	N/A	N/A	N/A	N/A	14.5	Not Regulated
Ammonium Ion	N/A	N/A	N/A	N/A	N/A	N/A	24.7	Not Regulated
Antimony	6.0[b]	45	CLARC 3.1	0	CLARC 3.1	5.40	5.03	No
Aroclor-1254*	0.32[a]	75.6	RAIS database[d]	1.16 E-02	RAIS database[d]	0.49	0.24	No
Arsenic	5.8 E-02[a]	29	CLARC 3.1	0	CLARC 3.1	0.0342	9.29	Yes
Bismuth	NA	100	ANL/EAIS-8[e]	NA	NA	NA	202	No Screening Value
Bis(2-ethylhexyl)phthalate	6[b]	111.1	CLARC 3.1	0	CLARC 3.1	13.9	0.700	No
Chromium (total)	1.00 E+02[a]	1,000	CLARC 3.1	0	CLARC 3.1	2,000	81.7	No
Diethylphthalate	1.28 E+04[a]	0.082	CLARC 3.1	1.85 E-05	CLARC 3.1	72.19	0.73	No
Di-n-butylphthalate	1.60 E+03[a]	1.57	CLARC 3.1	3.85 E-08	CLARC 3.1	56.64	1.7	No
Eicosane	NA	NA	NA	NA	NA	NA	0.97	No Screening Value
Fluoride	4,000[b]	1.43 E-02	RAIS database[d]	1	RAIS database[d]	24.1	39.6	Yes
Hexadecanoic acid (9Cl)	NA	NA	NA	NA	NA	NA	0.18	No Screening Value
Hexavalent Chromium	48[a]	19	CLARC 3.1	0	CLARC 3.1	18.43	1.5	No
Lead	15[b]	900	CLARC 3.1	1	CLARC 3.1	270	34.4	No
Mercury	2.0[b]	52	CLARC 3.1	0.47	CLARC 3.1	2.09	6.84	Yes
Methylene chloride	5[b]	1.00 E-02	CLARC 3.1	8.98 E-02	CLARC 3.1	0.0218	0.025	Yes

Table 4-2. Parameters and Results of Screening to WAC 173-340 Groundwater Protection Screening Standards, 216-T-28 Crib. (3 Pages)

Chemical Name	Groundwater RBC (µg/L)	Distribution Coefficient (K_d) (L/kg)	K_d Source	Henry's Law Constant (H_{cc}) (Dimensionless)	H_{cc} Source	Protection of GW Screening Level (mg/kg)	Max. Detected Concentration in Soil (mg/kg)	Is Max. Concentration Greater than Screening Level?
n-Hexanoic Acid	NA	NA	NA	NA	NA	NA	0.57	No Screening Value
Nickel	100[f]	65	CLARC 3.1	0	CLARC 3.1	130.40	52.7	No
Nitrate	1.00E+04 [b]	0	Conservative assumption[c]	0	Conservative	40.0	245	Yes
Nitrite	1.00E+03 [b]	0	Conservative assumption[c]	0	Conservative	4.0	2.53	No
Nitrogen in Nitrate and Nitrite	used parameters and screening values for nitrite							
Phenol	4.8 E+03 [a]	2.88 E-02	CLARC 3.1	1.63 E-05	CLARC 3.1	21.96	0.024	No
Phosphate	N/A	N/A	N/A	N/A	N/A	N/A	59.1	Not Regulated
Pyrene	480 [a]	68	CLARC 3.1	4.51 E-04	CLARC 3.1	654.72	0.021	No
Selenium	50 [b]	5	CLARC 3.1	0	CLARC 3.1	5.20	0.869	No
Silver	80 [a]	8.3	CLARC 3.1	0	CLARC 3.1	13.60	4.98	No
Toluene	1.0 E+03 [b]	1.4 E-01	CLARC 3.1	2.72 E-01	CLARC 3.1	7.27	0.0049	No
Uranium	30 [b]	0.6	PNNL-11800[g]	0	CLARC 3.1	0.48	113	Yes
Oil and grease	NA	NA	NA	NA	Method A	2,000	1,080	No
Total petroleum hydrocarbons - diesel range	NA	NA	NA	NA	Method A	2,000	13	No
Total petroleum hydrocarbons – kerosene range	NA	NA	NA	NA	NA	NA	13	No Screening Level

Table 4-2. Parameters and Results of Screening to WAC 173-340 Groundwater Protection Screening Standards, 216-T-28 Crib. (3 Pages)

Chemical Name	Groundwater RBC (µg/L)	Distribution Coefficient (K_d) (L/kg)	K_d Source	Henry's Law Constant (H_{cc}) (Dimensionless)	H_{cc} Source	Protection of GW Screening Level (mg/kg)	Max. Detected Concentration in Soil (mg/kg)	Is Max. Concentration Greater than Screening Level?

Shaded cells indicate that the maximum detected concentration exceeds the groundwater screening levels.

*Aroclor is an expired trademark.
[a]WAC 173-340-720(4), "Ground Water Cleanup Standards," "Method B Cleanup Levels for Potable Ground Water."
[b]Maximum contaminant level.
[c]Assumption that K_d=0 indicates that contaminant is not retarded from migrating through soil, which provides more conservative value for screening of groundwater.
[d]*Risk Assessment Information System* (RAIS) database at http://risk.lsd.ornl.gov/ .
[e]ANL/EAIS-8, *Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil.*
[f]WAC 246-290-310, "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)."
[g]PNNL-11800, *Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site.*
[h]CLARC 3.1 = Ecology 94-145, *Model Toxics Control Act Cleanup Levels & Risk Calculations (CLARC) Version 3.1.*

GW = groundwater.
H_{cc} = Henry's law constant.
K_d = distribution coefficient.
Method A = WAC 173-340-720(3), "Ground Water Cleanup Standards," "Method A Cleanup Levels for Potable Ground Water."
N/A = not applicable.
NA = not available.
RAIS = *Risk Assessment Information System.*
RBC = risk-based concentration.
WAC = *Washington Administrative Code.*

Table 4-3. Parameters and Results of Screening to WAC 173-340 Groundwater Protection Screening Standards, 216-S-20 Crib. (2 Pages)

Chemical Name	Groundwater RBC (µg/L)	Distribution Coefficient (K_d) (L/kg)	K_d Source	Henry Law Constant (H_{cc}) (Dimensionless)	H_{cc} Source	Protection of GW Screening Level (mg/kg)	Max. Detected Concentration in Soil (mg/kg)	Is Max. Concentration Greater than Screening Level?
Ammonium Ion	N/A	N/A	N/A	N/A	N/A	—	2.87	Not regulated
Antimony	6.0[b]	45	CLARC 3.1	0	CLARC 3.1	5.40	2.9	No
Aroclor 1254*	0.32[a]	75.6	RAIS database[d]	1.16 E-02	RAIS database[d]	0.49	0.17	No
Arsenic	5.83 E-02[a]	29	CLARC 3.1	0	CLARC 3.1	0.0342	9.16	Yes
Barium	1.12 E+03[a]	41	CLARC 3.1	0	CLARC 3.1	922.88	136	No
Beryllium	4[b]	790	CLARC 3.1	0	CLARC 3.1	63.2	2.7	No
Bismuth	NA	100	ANL/EAIS-8[e]	NA	NA	NA	202	No Screening Value
Boron	3.20 E+03	3	RAIS database[d]	1	RAIS database[d]	210.35	13.5	No
Chromium	100[a]	1000	CLARC 3.1	0	CLARC 3.1	2,000	259	No
Copper	5.92 E+02[a]	22	CLARC 3.1	0	CLARC 3.1	262.85	122	No
Di-n-butylphthalate	1.60 E+03[a]	1.57	CLARC 3.1	3.85 E-08	CLARC 3.1	56.64	1.2	No
Fluoride	4.00 E+03[b]	1.43 E-02	RAIS database[d]	1	RAIS database[d]	24.1	6.51	No
Hexavalent Chromium	48[a]	19	CLARC 3.1	0	CLARC 3.1	18.43	1.28	No
Lead	15[b]	900	CLARC 3.1	0	CLARC 3.1	270	489	Yes
Mercury	2.0[b]	52	CLARC 3.1	0.47	CLARC 3.1	2.09	69.2	Yes
Methylene chloride	5.00	1.00E-02	CLARC 3.1	8.98E-02	CLARC 3.1	0.0218	0.0047	No
Nickel	100[f]	65	CLARC 3.1	0	CLARC 3.1	130.40	6	No
Nitrate	1.00E+04[b]	0	Conservative assumption[c]	0	Conservative	40.0	18.6	No

Table 4-3. Parameters and Results of Screening to WAC 173-340 Groundwater Protection Screening Standards, 216-S-20 Crib. (2 Pages)

Chemical Name	Groundwater RBC (µg/L)	Distribution Coefficient (K_d) (L/kg)	K_d Source	Henry Law Constant (H_{cc}) (Dimensionless)	H_{cc} Source	Protection of GW Screening Level (mg/kg)	Max. Detected Concentration in Soil (mg/kg)	Is Max. Concentration Greater than Screening Level?
Nitrogen in Nitrate and Nitrite	Used parameters and screening values for nitrite (see Table 4-2)							
Silver	8.00 E+01 [a]	8.3	CLARC 3.1	0	CLARC 3.1	13.60	6	No
Sulfide	2.50 E+05 [b]	0	Conservative assumption [c]	0	Conservative	1000.00	23.9	No
Uranium	30 [b]	0.6	PNNL-11800	0	CLARC 3.1	0.48	652	Yes

Shaded cells indicate the maximum detected concentration exceeds the groundwater screening levels.
*Aroclor is an expired trademark.
PNNL-11800, *Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site.*
[a]WAC 173-340-720(4), "Ground Water Cleanup Standards," "Method B Cleanup Levels for Potable Ground Water."
[b]Maximum Contaminant Level.
[c]Assumption that K_d=0 indicates that contaminant is not retarded from migrating through soil, which provides more conservative value for screening of groundwater.
[d]*Risk Assessment Information System* (RAIS) database at http://risk.lsd.ornl.gov/ .
[e]ANL-EAIS-8, *Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil.*
[f]WAC 246-290-310, "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)."

CLARC 3.1 = Ecology 94-145, *Model Toxics Control Act Cleanup Levels & Risk Calculations (CLARC) Version 3.1.*
GW = groundwater
H_{cc} = Henry's law constant.
K_d = distribution coefficient.
N/A = not applicable.
NA = not available.
RAIS = *Risk Assessment Information System.*
RBC = risk-based concentration.
WAC = *Washington Administrative Code.*

Table 4-4. Parameters and Results of Screening to WAC 173-340 Groundwater Protection Screening Standards, 216-Z-7 Crib. (2 Pages)

Chemical Name	Groundwater RBC (µg/L)	Distribution Coefficient (K_d) (L/kg)	K_d Source	Henry Law Constant (H_{cc}) (Dimension -less)	H_{cc} Source	Protection of GW Screening Level (mg/kg)	Max. Detected Concen- tration in Soil (mg/kg)	Is Max. Concentration Greater than Screening Level?
Ammonium Ion	N/A	N/A	N/A	N/A	N/A	N/A	0.649	Not Regulated
Antimony	6.0[b]	45	CLARC 3.1	0	CLARC 3.1	5.40	2.8	No
Arsenic	5.83 E-02[a]	29	CLARC 3.1	0	CLARC 3.1	0.0342	13.4	Yes
Bismuth	NA	100	ANL/EAIS-8[e]	NA	NA	NA	123	No Screening Value
Boron	3.20 E+03[b]	3	RAIS database[d]	1	RAIS database[d]	210.35	3.1	No
Chromium	100[b]	1000	CLARC 3.1	0	CLARC 3.1	2,000	193	No
Cyanide	2.00 E+02[b]	0	Conservative assumption[c]	0	Conservative	0.80	3.95	Yes
Carbon Disulfide	8.00 E+02[a]	4.57 E-02	CLARC 3.1	1.24	CLARC 3.1	5.65	0.0011	No
Diethylphthalate	12800[a]	0.082	CLARC 3.1	1.85 E-05	CLARC 3.1	72.19	0.46	No
Di-n-butylphthalate	1.60 E+03[a]	1.57	CLARC 3.1	3.85 E-08	CLARC 3.1	56.64	2.1	No
Hexavalent Chromium	48[a]	19	CLARC 3.1	0	CLARC 3.1	18.43	2.05	No
Ethyl Acetate	1.44 E+04[a]	6.13 E-03	RAIS database[d]	5.48 E-03	RAIS database[d]	59.50	0.0055	No
Lead	15[b]	900	CLARC 3.1	0	CLARC 3.1	270	14.3	No
Mercury	2.0[b]	52	CLARC 3.1	0.47	CLARC 3.1	2.09	5.6	Yes
Methylene Chloride	5[b]	0.01	CLARC 3.1	0.0898	CLARC 3.1	0.0218	0.024	Yes
Nickel	100[f]	65	CLARC 3.1	0	CLARC 3.1	130.40	4.7	No
Nitrate	1.00 E+04[b]	0	Conservative assumption[c]	0	Conservative	40	19.744	No
Nitrogen in Nitrate and Nitrite	Used parameters and screening values for nitrite (see Table 4-2)							

Table 4-4. Parameters and Results of Screening to WAC 173-340 Groundwater Protection Screening Standards, 216-Z-7 Crib. (2 Pages)

Chemical Name	Groundwater RBC (µg/L)	Distribution Coefficient (K_d) (L/kg)	K_d Source	Henry Law Constant (H_{cc}) (Dimension-less)	H_{cc} Source	Protection of GW Screening Level (mg/kg)	Max. Detected Concen-tration in Soil (mg/kg)	Is Max. Concentration Greater than Screening Level?
Nonadecane	NA	NA	NA	NA	NA	NA	1.5	No Screening Value
Oil and grease	NA	NA	NA	NA	Method A	2,000	727	No
Phosphate	N/A	N/A	N/A	N/A	N/A	N/A	13.0	Not Regulated
Silver	8.00 E+01 [a]	8.3	CLARC 3.1	0	CLARC 3.1	13.60	4.7	No
Trichloroethene	3.98 [a]	9.40 E-02	CLARC 3.1	4.22 E-01	CLARC 3.1	0.0263	0.002	No
Trichlorobenzene(1,2,4)	8.00 E+01 [b]	1.66	CLARC 3.1	5.82 E-02	CLARC 3.1	2.98	0.0075	No
Uranium	30 [b]	0.6	PNNL-11800	0	CLARC 3.1	0.48	2.67	Yes

Shaded cells indicated the maximum detected concentration exceeds the groundwater screening level.
PNNL-11800, *Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site*.
[a]WAC 173-340-720(4), "Ground Water Cleanup Standards," "Method B Cleanup Levels for Potable Ground Water."
[b]Maximum contaminant level.
[c]Assumption that K_d=0 indicates that contaminant is not retarded from migrating through soil, which provides more conservative value for screening of groundwater.
[d]*Risk Assessment Information System* (RAIS) database at http://risk.lsd.ornl.gov/ .
[e]ANL-EAIS-8, *Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil.*
[f]WAC 246-290-310, "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)"

CLARC 3.1 = Ecology 94-145, *Model Toxics Control Act Cleanup Levels & Risk Calculations (CLARC) Version 3.1.*
GW = groundwater.
H_{cc} = Henry's law constant.
K_d = distribution coefficient.
Method A = WAC 173-340-720(3), "Ground Water Cleanup Standards," "Method A Cleanup Levels for Potable Ground Water."
N/A = not applicable.
NA = not available.
RAIS = *Risk Assessment Information System.*
RBC = risk-based concentration.
WAC = *Washington Administrative Code.*

Table 4-5. Background Comparisons for Radioactive Contaminants of Potential Concern. (3 Pages)

Constituent	90th Percentile Background Concentration[a]	Vadose Zone Maximum Concentration (pCi/g)	Sample Interval - Vadose Zone Maximum (ft)	Does Maximum Concentration Exceed Background?
216-T-28				
Americium-241	--	802	17.5-20	No Background
Antimony-125	--	2.39	27.5-30	No Background
Carbon-14	--	4.52	90-92.5	No Background
Cesium-134	--	456	17.5-20	No Background
Cesium-137	1.05	3,100,000	17.5-20	Yes
Cobalt-60	0.00842	1,180	17.5-20	Yes
Europium-152	--	0.733	90-92.5	No Background
Europium-154	0.0334	43	90-92.5	Yes
Europium-155	0.0539	19.9	90-92.5	Yes
Neptunium-237	--	0.011	47.5-50	No Background
Nickel-63	--	843	17.5-20	No Background
Plutonium-238	0.00378	84.5	17.5-20	Yes
Plutonium-239/240	0.0248	1,110	17.5-20	Yes
Potassium-40	16.6	15	22.5-25	No
Radium-226[d]	0.815	0.523	90-92.5	No
Radium-228	1.32	0.974	90-92.5	No
Technetium-99	--	1.61	197.5-200	No Background
Thorium-228[d]	1.32	2.69	22.5-25	Yes
Thorium-230[d]	1.1	0.932	27.5-30	No
Thorium-232	1.32	1.09	47.5-50	No
Strontium-90	0.178	642,000	17.5-20	Yes
Tritium	--	19,000	90-92.5	No Background
Uranium-233/234[b]	1.1	59.4	22.5-25	Yes
Uranium-234	1.1	59.4	22.5-25	Yes
Uranium-235	0.109	3.44	22.5-25	Yes
Uranium-238	1.06	35.1	22.5-25	Yes
216-S-20				
Americium-241	--	5800	29.5-32	No Background
Antimony-125	--	ND	-	No
Carbon-14	--	35.6	29.5-32	No Background
Cesium-134	--	ND	-	No

Table 4-5. Background Comparisons for Radioactive Contaminants of Potential Concern. (3 Pages)

Constituent	90th Percentile Background Concentration[a]	Vadose Zone Maximum Concentration (pCi/g)	Sample Interval - Vadose Zone Maximum (ft)	Does Maximum Concentration Exceed Background?
Cesium-137	1.05	95600	29.5-32	Yes
Cobalt-60	0.00842	104	29.5-32	Yes
Europium-152	--	ND	-	No
Europium-154	0.0334	70.8	29.5-32	Yes
Europium-155	0.0539	0.144	151.5-154	Yes
Neptunium-237	--	0.084	32.5-35	No Background
Nickel-63	--	4580	29.5-32	No Background
Plutonium-238	0.00378	2.6	32.5-35	Yes
Plutonium-239/240	0.0248	78	32.5-35	Yes
Potassium-40	16.6	13.8	151.5-154	No
Radium-226	0.815	0.594	40-42.5	No
Radium-228	1.32	0.687	40-42.5	No
Technetium-99	--	9.18	29.5-32	No Background
Thorium-228	1.32	15.9	29.5-32	Yes
Thorium-230	1.1	1.03	97-99.5	No
Thorium-232	1.32	1.41	32.5-35	Yes
Strontium-90	0.178	96,300	29.5-32	Yes
Tritium	--	63.1	29.5-32	No Background
Uranium-233/234	1.1	250	32.5-35	Yes
Uranium-235	0.109	26.4	32.5-35	Yes
Uranium-238	1.06	270	32.5-35	Yes
216-Z-7				
Americium-241	--	60600	17.5-20	No Background
Antimony-125	--	ND	-	No
Carbon-14	--	ND	-	No
Cesium-134	--	ND	-	No
Cesium-137	1.05	2800	17.5-20	Yes
Cobalt-60	0.00842	58.3	17.5-20	Yes
Europium-152	--	ND	-	No
Europium-154	0.0334	10.5	17.5-20	Yes
Europium-155	0.0539	0.0829	57.5-60	Yes
Neptunium-237	--	0.059	17.5-20	No Background
Nickel-63	--	ND	-	No

Table 4-5. Background Comparisons for Radioactive Contaminants of Potential Concern. (3 Pages)

Constituent	90th Percentile Background Concentration[a]	Vadose Zone Maximum Concentration (pCi/g)	Sample Interval - Vadose Zone Maximum (ft)	Does Maximum Concentration Exceed Background?
Plutonium-238	0.00378	5770	17.5-20	Yes
Plutonium-239/240	0.0248	472,000	17.5-20	Yes
Potassium-40	16.6	14.9	57.5-60	No
Radium-226	0.815	0.807	117.5-120	No
Radium-228	1.32	0.729	96.5-99	No
Technetium-99	--	11	22.5-25	No Background
Thorium-228	1.32	1.18	57.5-60	No
Thorium-230	1.1	1.03	12.5-15	No
Thorium-232	1.32	1.22	57.5-60	No
Strontium-90	0.178	437,000	17.5-20	Yes
Tritium	--	9.54	117.5-120	No Background
Uranium-233/234	1.1	0.506	12.5-15	No
Uranium-235	0.109	0.053	197.5-200	No
Uranium-238	1.06	0.696	12.5-15	No

Shaded cells indicate nuclide exceeds background values or has a detect but no background value.

-- = no background value.

ND = not detected.

Table 4-6. Stratigraphic Representation of the Boreholes Vertical Cross Sections within the 216-T-28 Crib, the 216-S-20 Crib, and the 216-Z-7 Crib.

Stratigrapic Description	Name of Unit Assigned to Stratigraphic Layer	Thickness (m)
216-T-28 Crib		
Soil backfill	Cover	2.2
Gravel backfill	unit 1	2.4
H1 Sandy Gravel		4.6
H2 Sand	unit 2	18.3
Cold Creek Unit and Upper Ringold sand to silty sand	unit 3	9.1
Upper Ringold silty sandy gravel	unit 4	3
Ringold sand	unit 5	1.5
Ringold silty sandy gravel to silty gravel	unit 4	16.8
Ringold sand	unit 5	1.8
Ringold silty sandy gravel	unit 4	9.3
Total thickness		**69**
216-S-20 Crib		
Soil backfill	Cover	11.0
Gravel backfill/crib	unit 1	3.0
H1 Sandy Gravel		
H2 Sand	unit 2	34
Cold Creek Unit and Upper Ringold sand to silty sand	unit 3	22
Upper Ringold silty sandy gravel	unit 4	4
Total thickness		**74**
216-Z-7 Crib		
Cover/unit 2	Cover	2.33
Gravely Sand to Silty Sand	unit 2	0.67
H1 Sandy Gravel	unit 1	9.5
H2 Silty Sand and Sand	unit 7	16
Cold Creek Unit and Upper Ringold silty to silty sand	unit 8	6.9
Ringold silty sandy gravel	unit 4	7.9
Ringold sand	unit 5	1.5
Ringold silty sandy gravel	unit 4	21.8
Total thickness		**66.3**

Table 4-7. Stratigraphic Unit Properties Used in RESRAD Modeling, 216-T-28 Crib.

Stratigraphic Unit	Unit Adopted for 216-T-28 Crib Modeling[a]	Soil Category[b]	Alpha (1/cm)	Van Genuchten parameter (n) (Dimension-less)	Saturated Moisture Content (Dimension-less)	Residual Moisture Content (Dimension-less)	Saturated Hydraulic Conductivity (m/yr)	Bulk Density[c] (g/cm^3)	RESRAD Parameter b[c]
Cover	N/A	SS					75.69	1.48	
Unit 1	Hanford sandy gravel	SG1	0.083	1.66	0.166	0.023	39420.00	1.96	4.05
Unit 2	Hanford sand	S	0.104	2.15	0.346	0.027	394.20	1.59	4.05
Unit 3	Ringold/Cold Creek Unit silty sand	SS	0.009	1.851	0.435	0.067	75.69	1.48	4.38
Unit 4	Ringold silty sandy gravel	SSG	0.01	1.772	0.262	0.044	551.88	1.96	4.05
Unit 5	Ringold gravely sand to sand	N/A	0.021	1.845	0.304	0.066	788.4	1.48	4.38

[a]Unit definition from Table 4-1 of DOE/RL-2002-42, *Remedial Investigation Report for the 200-TW-1 and 200-TW-2 Operable Units (Includes the 200-PW-5 Operable Unit).*
[b]Soil category as defined in WHC-EP-0883, *Variability and Scaling of Hydraulic Properties for 200 Area Soils, Hanford Site.*
[c]From Tables 5-1 (soil categories) and 4.19 (bulk densities/b) of DOE/RL-2004-17, *Remedial Investigation Report for the 200-CS-1 Chemical Sewer Group Operable Unit.*

Soil Categories:
S – sand.
SG1 - sandy gravel with more than 60% gravel.
SS - sand mixed with finer fraction.
SSG - sand and gravel mixed with finer fraction.

N/A = not applicable.

Table 4-8. Stratigraphic Unit Properties Used in RESRAD Modeling, 216-S-20 Crib.

Strati-graphic Unit	Unit Adopted for 216-S-20 Crib Modeling[a]	Soil Category[b]	Alpha, 1/cm	van Genuchten parameter (n) (Dimensionless)	Saturated Moisture Content (Dimension-less)	Residual Moisture Content (Dimensionless)	Saturated Hydraulic Conductivity (m/yr)	Bulk Density[c] (g/cm^3)	RESRAD Parameter b[c]
Cover	N/A	SS					75.69	1.48	
Unit 1	Hanford sandy gravel	SG1	0.083	1.66	0.166	0.023	39420.00	1.96	4.05
Unit 2	Hanford sand	S	0.104	2.15	0.346	0.027	394.20	1.59	4.05
Unit 3	Ringold/PPU silty sand	SS	0.009	1.851	0.435	0.067	75.69	1.48	4.38
Unit 4	Ringold silty sandy gravel	SSG	0.01	1.772	0.262	0.044	551.88	1.96	4.05

[a]Unit definition from Table 4-1 of DOE/RL-2002-42, *Remedial Investigation Report for the 200-TW-1 and 200-TW-2 Operable Units (Includes the 200-PW-5 Operable Unit).*
[b]Soil category as defined in WHC-EP-0883, *Variability and Scaling of Hydraulic Properties for 200 Area Soils, Hanford Site.*
[c]From Tables 5-1 (soil categories) and 4.19 (bulk densities/b) of DOE/RL-2004-17, *Remedial Investigation Report for the 200-CS-1 Chemical Sewer Group Operable Unit.*

N/A = not applicable.
PPU = Plio-Pleistocene unit.

Soil Categories:
S – sand.
SG1 - sandy gravel with more than 60% of gravel.
SS - sand mixed with finer fraction.
SSG - sand and gravel mixed with finer fraction.

Table 4-9. Stratigraphic Unit Properties Used in RESRAD Modeling, 216-Z-7 Crib.

Stratigraphic Unit	Unit Adopted for 216-Z-7 Crib Modeling[a]	Soil Category[b]	Alpha (1/cm)	van Genuchten parameter (n) (Dimension-less)	Saturated Moisture Content (Dimension-less)	Residual Moisture Content (Dimension-less)	Saturated Hydraulic Conductivity (m/yr)	Bulk Density[c] (g/cm^3)	RESRAD Parameter b[c]
Cover	N/A	SS					75.69	1.48	
Unit 1	Hanford sandy gravel	SG1	0.083	1.66	0.166	0.023	39420.00	1.96	4.05
Unit 2	Hanford sand	S	0.104	2.15	0.346	0.027	394.20	1.59	4.05
Unit 4	Ringold silty sandy gravel	SSG	0.01	1.772	0.262	0.044	551.88	1.96	4.05
Unit 5	Ringold gravely sand to sand	N/A	0.021	1.845	0.304	0.066	788.4	1.48	4.38
Unit 7	Ringold gravely sand to sand	N/A	0.011	1.923	0.448	0.07800	1102.3	1.48	4.38
Unit 8	Ringold gravely sand to sand	N/A	0.005	2.067	0.424	0.041	47.45	1.48	4.38

[a]Unit definition from Table 4-1 of DOE/RL-2002-42, *Remedial Investigation Report for the 200-TW-1 and 200-TW-2 Operable Units (Includes the 200-PW-5 Operable Unit).*
[b]Soil category as defined in WHC-EP-0883, *Variability and Scaling of Hydraulic Properties for 200 Area Soils, Hanford Site.*
[c]From Tables 5-1 (soil categories) and 4.19 (bulk densities/b) of DOE/RL-2004-17, *Remedial Investigation Report for the 200-CS-1 Chemical Sewer Group Operable Unit.*
N/A = not applicable.

Soil Categories:
S – sand.
SG1 - sandy gravel with more than 60% of gravel.
SS - sand mixed with finer fraction.
SSG - sand and gravel mixed with finer fraction.

Table 4-10. RESRAD Parameters that are not Either Radionuclide Specific or Vertical Cross Section Specific, 216-T-28 Crib.

Parameter Name	Units	Value	Source
Contaminated area	m^2	83.6	DOE/RL-2001-66, Figure 2-16 and Table 2-1
Hydraulic Gradient		0.0015385	DOE/RL-2001-66, Figure 2-2*
Cover erosion rate	m/yr	0.001	RESRAD default
Contaminated zone erosion rate	m/yr	0.001	RESRAD default
Evapotranspiration coefficient	-	0.91	WDOH/320-015
Wind speed	m/s	3.4	PNNL-13033
Precipitation	m/yr	0.173	Based on 51year average, DOE/RL-98-28
Runoff coefficient	-	0.2	RESRAD default
Irrigation	m/yr	0	Site-specific assumption
Watershed area	m^2	1,000,000	RESRAD default
Water table drop rate	m/yr	0.001	RESRAD default
Well pumping intake depth below water table	m	4.6	Typical RCRA well screen length, DOE/RL-2002-42
Well pumping rate	m^3/yr	250	RESRAD default

*Calculated from Figure 2-2.

ANL, 2002, *RESRAD for Windows*.

DOE/RL-98-28, *200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program*.

DOE/RL-2001-66, *Chemical Laboratory Waste Group Operable Units RI/FS Work Plan, Includes: 200-LW-1 and 200-LW-2 Operable Units*.

DOE/RL-2002-42, *Remedial Investigation Report for the 200-TW-1 and 200-TW-2 Operable Units (Includes the 200-PW-5 Operable Unit)*.

PNNL-13033, *Recharge Data Package for the Immobilized Low-Activity Waste 2001 Performance Assessment*.

WDOH/320-015, *Hanford Guidance for Radiological Cleanup*.

RCRA = *Resource Conservation and Recovery Act of 1976*.

RESRAD = RESidual RADioactivity (dose model) (ANL, 2002).

Table 4-11. Radionuclide-Specific Data, 216-T-28 Crib. (2 Pages)

Radionuclides	Contaminant Zone Concentration (pCi/g)	K_d (mL/g)	
		Conservative	Best Estimate
Shallow Contaminant Transport Zone			
Sb-125	2.39	45*	45*
Cs-134	456	540	1,500
Cs-137[b]	3,100,000	540	1,500
Np-237	0.011	10	15
Pu-238	84.5	80	200
Pu-239/240	1110	80	200
Sr-90	642,000	8	20
Th-228	2.69	40	1,000
U-233/234	59.4	0.6	3
U-235	3.44	0.6	3
U-238[a]	35.1	0.6	3
Daughters			
Ac-227	0	100	300
Pa-231	0	10	15
Pb-210	0	2,000	6,000
Ra-226[a]	0	8	20
Ra-228	0	8	20
Th-229	0	40	1,000
Th-230	0	40	1,000
Th-232[a]	0	40	1,000
U-236	0	0.6	3
Intermediate Contaminant Transport Zone			
C-14	4.52	0.5	5
Co-60[b]	1,180	1,200	1,200
Eu-152	0.733	100	350
Eu-154	43	100	350
Eu-155	19.9	100	350
Ni-63	843	50	300
Daughters			
Gd-152	0	100	350
Deep Contaminant Transport Zone			
Am-241[a]	802	100	350
Tc-99[a]	1.61	0	0
H-3[a]	19,000	0	0
Daughters			
Np-237	0	10	15

Table 4-11. Radionuclide-Specific Data, 216-T-28 Crib. (2 Pages)

Radionuclides	Contaminant Zone Concentration (pCi/g)	K_d (mL/g)	
		Conservative	Best Estimate
Th-229	0	40	1,000
U-233	0	0.6	3

* The value for Sb-125 is from EPA/530/D-98/001B, *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities*, Vol. 2.

[a] Radioisotopes are alpha emitters.

[b] Radioisotopes are beta emitters.

Table 4-12. Modeling Representation of the Cover, Contaminated Area, Uncontaminated, and Unsaturated Zone, 216-T-28 Crib. (2 Pages)

Modeling Unit	Assigned Property Category	Assigned Thickness (m)	Saturated Moisture Content (Dimensionless)	Residual Moisture Content (Dimensionless)	Saturated Hydraulic Conductivity (m/yr)	Bulk Density (g/cm^3)	RESRAD Parameter b
Shallow Contaminant Transport Zone Depth - 15 m							
Cover	cover	2.2	-	-	-	1.48	-
Contaminated zone	weighted average of unit 1 and unit 2	12.8	0.249	0.025	845.3*	1.79	4.05**
Unsaturated zone layer 1	unit 2	12.5	0.346	0.027	394.2	1.59	4.05
Unsaturated zone layer 2	unit 3	9.1	0.435	0.067	75.7	1.48	4.38
Unsaturated zone layer 3	unit 4	3	0.262	0.044	551.9	1.96	4.05
Unsaturated zone layer 4	unit 5	1.5	0.304	0.066	788	1.48	4.38
Unsaturated zone layer 5	unit 4	27.9	0.262	0.044	551.9	1.96	4.05
Saturated zone	unit 4	-	0.262	-	551.9	1.96	4.05
Intermediate Contaminant Transport Zone Depth - 30 m							
Cover	cover	2.2	-	-	-	1.48	-
Contaminated zone	weighted average of unit 1, unit 2, and unit 3	27.8	0.308	0.030	348.8*	1.67	4.05**
Unsaturated zone layer 1	unit 3	6.6	0.435	0.067	75.7	1.48	4.38
Unsaturated zone layer 2	unit 4	3	0.262	0.044	551.9	1.96	4.05
Unsaturated zone layer 3	unit 5	1.5	0.304	0.066	788	1.48	4.38
Unsaturated zone layer 4	unit 4	27.9	0.262	0.044	551.9	1.96	4.05

Table 4-12. Modeling Representation of the Cover, Contaminated Area, Uncontaminated, and Unsaturated Zone, 216-T-28 Crib. (2 Pages)

Modeling Unit	Assigned Property Category	Assigned Thickness (m)	Saturated Moisture Content (Dimension-less)	Residual Moisture Content (Dimension-less)	Saturated Hydraulic Conductivity (m/yr)	Bulk Density (g/cm^3)	RESRAD Parameter b
Saturated zone	unit 4	-	0.262	0.044	551.9	1.96	4.05
Deep Contaminant Transport Zone Depth – 69 m							
Cover	cover	2.2	-	-	-	1.48	-
Contaminated zone	weighted average of unit 1, unit 2, unit 3, unit 4, and unit 5	66.3	0.303	0.042	253.4	1.78	4.05
Unsaturated zone layer 1	unit 4	0.5	0.262	0.044	551.9	1.96	4.05
Saturated Zone	unit 4	-	0.262	0.044	551.9	1.96	4.05
Saturated Zone	unit 4	-	0.262	0.044	551.9	1.96	4.05

*Weighted average hydraulic conductivity is weighted geometric mean value.
Average parameter **b is equal to the parameter **b** of the unit that has a greatest thickness within the contaminated zone.

Table 4-13. RESRAD Parameters That Are Not Either Radionuclide Specific or Vertical Cross Section Specific, 216-S-20 Crib. (2 Pages)

Parameter Name	Units	Value	Source
Contaminated Area	m^2	334.5	DOE/RL-2001-66, Figure 2-17 and Table 2-1
Hydraulic Gradient		0.000133	DOE/RL-2001-66, Figure 2-2*
Cover erosion rate	M/yr	0.001	RESRAD default
Contaminated zone erosion rate	M/yr	0.001	RESRAD default
Evapotranspiration coefficient	-	0.91	WDOH/320-015
Wind speed	m/s	3.4	PNNL-13033
Precipitation	M/yr	0.173	Based on 51year average, DOE/RL-98-28
Runoff coefficient	-	0.2	RESRAD default
Irrigation	m/yr	0	Site-specific assumption
Watershed area	m^2	1000000	RESRAD default
Water table drop rate	m/yr	0.001	RESRAD default
Well pumping intake depth below water table	m	4.6	Typical RCRA well screen length, DOE/RL-2002-42
Well pumping rate	m^3/yr	250	RESRAD default

Table 4-13. RESRAD Parameters That Are Not Either Radionuclide Specific or Vertical Cross Section Specific, 216-S-20 Crib. (2 Pages)

Parameter Name	Units	Value	Source

*Calculated from Figure 2-2.
ANL, 2002, *RESRAD for Windows*.
DOE/RL-98-28, *200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program*.
DOE/RL-2001-66, *Chemical Laboratory Waste Group Operable Units RI/FS Work Plan, Includes: 200-LW-1 and 200-LW-2 Operable Units*.
DOE/RL-2002-42, *Remedial Investigation Report for the 200-TW-1 and 200-TW-2 Operable Units (Includes the 200-PW-5 Operable Unit)*.
PNNL-13033, *Recharge Data Package for the Immobilized Low-Activity Waste 2001 Performance Assessment*.
WDOH/320-015, *Hanford Guidance for Radiological Cleanup*.
RCRA = *Resource Conservation and Recovery Act of 1976*.
RESRAD = RESidual RADioactivity (dose model) (ANL, 2002).

Table 4-14. Radionuclide-Specific Data, 216-S-20 Crib. (2 Pages)

Radionuclides	Contaminant Zone Concentration (pCi/g)	K_d (mL/g)	
		Conservative	Best Estimate
Shallow Contaminant Transport Zone			
C-14	35.6	.5	5
Cs-137	95,600	540	1500
Co-60	104	1200	1200
Ni-63	4580	50	300
Np-237	0.084	10	15
Sr-90	96,300	8	20
Tc-99	9.18	0	0
Th-228	15.9	40	1000
Th-232	1.41	40	1000
U-233/234	250	0.6	3
U-235	26.4	0.6	3
U-238	270	0.6	3
Daughters			
Ac-227	0	100	300
Pa-231	0	10	15
Pb-210	0	2000	6000
Ra-226[a]	0	8	20
Ra-228	0	8	20
Th-229	0	40	1000
Th-230	0	40	1000
Intermediate Contaminant Transport Zone			
Eu-154	70.8	100	350

Table 4-14. Radionuclide-Specific Data, 216-S-20 Crib. (2 Pages)

Radionuclides	Contaminant Zone Concentration (pCi/g)	K_d (mL/g)	
		Conservative	Best Estimate
Eu-155	0.144	100	350
Pu-238	2.6	80	200
Pu-239/240	78.0	80	200
Daughters			
Ac-227	0	100	300
Pa-231	0	10	15
Pb-210	0	2000	6000
Ra-226[a]	0	8	20
Ra-228	0	8	20
Th-228	0	40	1000
Th-232	0	40	1000
U-234	0	0.6	3
U-235	0	0.6	3
U-236	0	0.6	3
Deep Contaminant Transport Zone			
Am-241[a]	5800	100	350
H-3[a]	63.1	0	0
Daughters			
Np-237	0	10	15
Th-229	0	40	1000
U-233	0	0.6	3

Table 4-15. Modeling Representation of the Cover, Contaminated Area, Unsaturated Zone, and Saturated Zone 216-S-20 Crib.

Modeling Unit	Assigned Property Category	Assigned Thickness (m)	Saturated Moisture Content	Residual Moisture Content	Saturated Hydraulic Conductivity (m/yr)	Bulk Density (g/cm³)	RESRAD Parameter b
Shallow Contaminant Transport Zone Depth - 15 m							
Cover	cover	11	-	-	-	1.48	-
Contaminated zone	weighted average of unit 1 and unit 2	4	0.211	0.024	1530.9	1.87	4.05**
Unsaturated zone layer 1	unit 2	33	0.346	0.027	394.2	1.59	4.05
Unsaturated zone layer 2	unit 3	22	0.435	0.067	75.7	1.48	4.38
Unsaturated zone layer 3	unit 4	4	0.262	0.044	551.9	1.96	4.05
Saturated zone	unit 4	-	0.262	-	551.9	1.96	4.05
Intermediate Contaminant Transport Zone Depth - 50m							
Cover	cover	11	-	-	-	1.48	-
Contaminated zone	weighted average of unit 1, unit 2, unit 3, and unit 4	39	0.337	0.023	345.8*	1.61	4.05**
Unsaturated Zone layer 1	unit 3	20	0.435	0.067	75.6	1.48	4.38
Unsaturated Zone layer 2	unit 4	4	0.262	0.044	551.9	1.96	4.05
Saturated Zone	Unit 4	-	0.262	0.044	551.9	1.96	4.05
Deep Contaminant Transport Zone Depth - 73m							
Cover	cover	11	-	-	-	1.48	-
Contaminated zone	weighted average of unit 1, unit 2, unit 3, unit 4, and unit 5	62	0.365	0.042	161.9	1.59	4.05
Unsaturated zone layer 1	unit 4	1	0.262	0.044	551.9	1.96	4.05
Saturated Zone	unit 4	-	0.262	0.044	551.9	1.96	4.05

*Weighted average hydraulic conductivity is weighted geometric mean value.
Average parameter **b is equal to the parameter **b** of the unit that has a greatest thickness within the contaminated zone.

Table 4-16. RESRAD Parameters that are not Either Radionuclide Specific or Vertical Cross Section Specific, 216-Z-7 Crib.

Parameter Name	Units	Value	Source
Contaminated Area	m^2	765	DOE/RL-2001-66, Figure 2-18 and Table 2-1
Hydraulic Gradient		0.0015385	DOE/RL-2001-66, Figure 2-2*
Cover erosion rate	m/yr	0.001	RESRAD default
Contaminated zone erosion rate	m/yr	0.001	RESRAD default
Evapotranspiration coefficient	-	0.91	WDOH/320-015
Wind speed	m/s	3.4	PNNL-13033
Precipitation	m/yr	0.173	Based on 51year average, DOE/RL-98-28
Runoff coefficient	-	0.2	RESRAD default
Irrigation	m/yr	0	Site-specific assumption
Watershed area	m^2	1,000,000	RESRAD default
Water table drop rate	m/yr	0.001	RESRAD default
Well pumping intake depth below water table	m	4.6	Typical RCRA well screen length, DOE/RL-2002-42
Well pumping rate	m^3/yr	250	RESRAD default

- calculated from Figure 2-2.

ANL, 2002, *RESRAD for Windows.*

DOE/RL-98-28, *200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program.*

DOE/RL-2001-66, *Chemical Laboratory Waste Group Operable Units RI/FS Work Plan, Includes: 200-LW-1 and 200-LW-2 Operable Units.*

DOE/RL-2002-42, *Remedial Investigation Report for the 200-TW-1 and 200-TW-2 Operable Units (Includes the 200-PW-5 Operable Unit).*

PNNL-13033, *Recharge Data Package for the Immobilized Low-Activity Waste 2001 Performance Assessment.*

WDOH/320-015, *Hanford Guidance for Radiological Cleanup.*

RCRA = *Resource Conservation and Recovery Act of 1976.*

RESRAD = RESidual RADioactivity (dose model) (ANL, 2002).

Table 4-17. Radionuclide-Specific Data, 216-Z-7 Crib.

Radionuclides	Contaminant Zone Concentration (pCi/g)	K_d (mL/g)	
		Conservative	Best Estimate
Shallow Contaminant Transport Zone			
Cs-137[b]	2800	45*	45*
Np-237	0.059	540	1500
Sr-90	437,000	8	20
Tc-99[a]	11	540	1500
Daughters			
Th-229	0	40	1000
U-233	0	0.6	3
Intermediate Contaminant Transport Zone			
Pu-238	5770	80	200
Pu-239/240	472000	80	200
Daughters			
Ac-227	0	100	300
Pa-231	0	10	15
Pb-210	0	2000	6000
Ra-226[a]	0	8	20
Ra-228	0	8	20
Th-238	0	40	1000
Th-230	0	40	1000
Th-232[a]	0	40	1000
U-234	0	0.6	3
U-235	0	0.6	3
U-236	0	0.6	3
Deep Contaminant Transport Zone			
Am-241[a]	60,600	100	350
H-3[a]	9.54	0	0
Co-60[b]	58.3	1200	1200
Eu-154	10.5	100	350
Eu-155	0.0829	100	350
Daughters			
Np-237	0	10	15
Th-229	0	40	1000
U-233	0	0.6	3

Table 4-18. Modeling Representation of the Cover, Contaminated Area, and Unsaturated Zone, and Saturated Zone 216-Z-7 Crib.

Modeling Unit	Assigned Property Category	Assigned Thickness (m)	Saturated Moisture Content	Residual Moisture Content	Saturated Hydraulic Conductivity (m/yr)	Bulk Density (g/cm^3)	RESRAD Parameter b
Shallow Contaminant-Transport Zone Depth - 18 m							
Cover	cover	2.33	-	-	-	1.48	-
Contaminated zone	weighted average of unit 1, 2, and 7	15.67	0.278	0.044	2178.3*	1.767	4.05**
Unsaturated zone layer 1	unit 7	10.2	0.448	0.078	1102.3	1.48	4.38
Unsaturated zone layer 2	unit 8	6.9	0.424	0.041	47.45	1.48	4.38
Unsaturated zone layer 3	unit 4	7.9	0.262	0.044	551.9	1.96	4.05
Unsaturated zone layer 4	unit 5	1.5	0.304	0.066	788	1.48	4.38
Unsaturated zone layer 5	unit 4	21.8	0.262	0.044	551.9	1.96	4.05
Saturated Zone	Unit 4	-	0.262	-	551.9	1.96	4.05
Intermediate Contaminant-Transport Zone Depth - 30 m							
Cover	cover	2.33	-	-	-	1.48	-
Contaminated zone	weighted average of unit 1, unit 2, 7 and 8	32.67	0.363	0.054	201.8*	1.622	4.38**
Unsaturated Zone layer 1	unit 4	7.9	0.262	0.044	551.9	1.96	4.05
Unsaturated Zone layer 2	unit 5	1.5	0.304	0.066	788	1.48	4.38
Unsaturated Zone layer 3	unit 4	21.8	0.262	0.044	551.9	1.96	4.05
Saturated zone	unit 4	-	0.262	0.044	551.9	1.96	4.05
Deep Contaminant-Transport Zone Depth – 65.8 m							
Cover	cover	2.33	-	-	-	1.48	-
Contaminated zone	weighted average of unit 1, 2, 7, 8, 4 and 5	63.47	0.323	0.05	292.9	1.603	4.05
Unsaturated zone layer 1	unit 4	0.5	0.262	0.044	551.9	1.96	4.05
Saturated zone	unit 4	-	0.262	0.044	551.9	1.96	4.05

*Weighted average hydraulic conductivity is weighted geometric mean value.

Average parameter **b is equal to the parameter **b** of the unit that has a greatest thickness within the contaminated zone.

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5.0 RISK ASSESSMENT

5.1 INTRODUCTION

This chapter presents the results of the human-health risk assessment (HHRA), including the HHRA for nonradionuclides and the RESRAD modeling for radionuclides (ANL 2002). This evaluation provides a characterization of site risks to determine if remedial actions are warranted and to support evaluation of remedial alternatives in the FS. This chapter also compares the ecological risk screening of contaminants in the 200-LW-1 and 200-LW-2 OUs against screening concentrations in WAC 173-340-900, Table 749-3, for nonradionuclides and calculated screening levels using DOE/EH-0676, *RESRAD-BIOTA: A Tool for Implementing a Graded Approach to Biota Dose Evaluation*, to implement DOE-STD-1153-2002 for radionuclides (Section 4.5). DOE-STD-1153-2002 was prepared for the DOE by the Biota Dose Assessment Committee (BDAC) and presents a method for developing screening levels (BCG) for radionuclides, as well as a methodology for conducting ecological risk assessments for radionuclides. DOE/RL-2001-54 contains additional details on the BDAC document.

This assessment was conducted to determine the potential for risk to human health and the environment under current and reasonably anticipated future use conditions. The results of the assessment will be used, in part, to determine whether remedial action may need further evaluation. This risk assessment consists of the following components:

- **Site Conceptual Model**. Identifies the pathways by which human and ecological exposures could occur
- **Human Health Risk Assessment.** Provides the results of the COPC selection process, human exposure assessment, toxicity assessment, and risk characterization
- **Screening-Level Ecological Risk Assessment**. Provides the results of the ecological risk assessment screening evaluation.

5.2 SITE CONCEPTUAL MODEL

The site conceptual model provides a current understanding of the physical and ecological setting, sources of contamination, and current and future land use and identifies potentially complete human and ecological exposure pathways for the 200-LW-1 and LW-2 OUs. Information generated during the development of the RI has been incorporated into this site conceptual model to identify potential exposure scenarios.

5.2.1 Physical Setting

The sites sampled and evaluated in this risk assessment are the three representative sites for the 200-LW-1 and LW-2 OUs. The waste sites are described in greater detail in Chapters 1.0 and

3.0 of the RI report. These sites are situated on the Central Plateau in and near industrial areas. The areas proximal to these representative sites have been disturbed by operations for several decades. Wildlife habitats on the Central Plateau are described in Section 4.2.2. The Hanford Site climate is classified as mid-latitude semiarid or mid-latitude desert, depending on the climatological classification scheme. Most precipitation occurs during late autumn and winter with more than half of the annual amount occurring from November through February (PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization*). Normal annual precipitation is 17.7 cm (6.98 in.). The prevailing wind direction is from the northwest, particularly in the winter and summer. Wind speeds are lowest in the winter, averaging 9.7 kilometers per hour (km/h) (6 to 7 miles per hour [mi/h]), and highest in the summer, averaging 12.9 to 14.5 km/h (8 to 9 mi/h), with frequent gusts to 48.3 km/h (30 mi/h). Summertime temperatures can exceed 37.8 °C (100 °F), and winter temperatures may drop below -17.8 °C (0 °F) (DOE/RL-2001-54).

The Central Plateau is located between the ridges of Gable Mountain and the lower altitude area of dunes. The 200 Areas lie on a prominent geologic flood bar, the Cold Creek bar, which trends generally east-west with elevations between 197 m and 225 m (647 and 740 ft) above mean sea level. The plateau drops off rather steeply to the north and northwest into a former flood channel where differences in elevation are between 15 m and 30 m (50 and 100 ft). The plateau decreases more gently in elevation to the south into the Cold Creek valley and to the east toward the Columbia River. Most of the 200 West Area and the southern half of the 200 East Area are situated on the Cold Creek Bar, while the northern half of the 200 East Area is located within the former flood channel. A secondary flood channel running south from the main channel bisects the 200 West Area. A generalized stratigraphic column and descriptions of the geologic strata are presented is Section 3.2.1. Currently, much of the 200 Areas are covered with industrial facilities associated with current and past operations.

5.2.2 Ecological Setting

The broad classification for the ecology of the Hanford Site area is shrub-steppe, though this broad classification can be refined into a number of separate types of communities found within the shrub-steppe classification. The 200 Area representative sites consist mainly of highly disturbed areas with little vegetative cover because of past industrial and remedial activities. The sites have been stabilized with a substantial gravel cover, further impeding reestablishment of any of the surrounding habitats. In addition, some nearby areas, particularly by the 200 West Area sites, were burned in the 2000 range fire. However, these representative sites and their contamination can be accessed by species from the surrounding habitats; these species are considered to be the potential receptors for which this screening with generalized receptors was conducted. In the absence of future activities, any of the surrounding habitats could potentially occur on or near the representative sites. The surrounding plant communities and the available census data on plant, bird, and mammal species are described in depth in DOE/RL-2001-54 and are only summarized here. In general, aside from the highly disturbed areas, four plant communities occur in the vicinity of the 200 Areas: sagebrush-dominated communities, gray rabbitbrush-cheatgrass communities, bunchgrass communities, and cheatgrass-dominated communities. Characteristic vegetation and the percent cover of each plant species associated with each habitat type are described in detail in DOE/RL-2001-54.

Reptiles found in the Central Plateau include gopher snakes (*Pituophis melanoleucus*) and side-blotched lizards (*Uta stansburiana*). Rattlesnakes (*Crotalus viridis*) also have been observed. Observations of reptiles were not widespread, with only 23 observations of side-blotched lizards at 316 sites surveyed in 2001 (DOE/RL-2001-54).

Numerous species of birds and mammals occupy habitats surrounding the 200 Areas. Based on the results of bird point counts, the species of bird observed at the largest number of stations in the 200 East Area are the American robin (*Turdus migratus*), the European starling (*Sturnus vulgaris*), and the western meadowlark (*Sturnella neglecta*). The species of bird observed at the largest number of stations in the 200 West Area are the western meadowlark (*Sturnella neglecta*), the sage sparrow (*Amphispiza belli*), the lark sparrow (*Chondestes grammacus*), and the loggerhead shrike (*Lanius ludovicianus*). Mammal species in these surrounding habitats consist primarily of small rodents including the Great Basin Pocket Mouse (*Perognathus parvus*) and deer mice (*Peromyscus maniculatus*). Other small mammals such as the pocket gopher (*Thomomys talpoides*) could potentially occur in less disturbed surrounding habitat. The surrounding habitat is also home to black-tailed jackrabbits (*Lepus californicus*), mountain cottontails (*Sylvilagus nutalli*), badgers (*Taxidiea taxus*), coyotes (*Canis latrans*), mule deer (*Odocoileus hemionus*), and an occasional elk (*Cervus elaphus*) (DOE/RL-2001-54). This SLERA compares soil media concentrations against concentrations that are known to have no observable adverse effects. Target receptors are designed to be broadly representatives of groups of mammals and birds that include the species occurring at the 200 Area sites.

Three of the most common groups of insects found at the Hanford Site are darkling beetles, grasshoppers, and ants. Darkling beetles are a dominant part of the insect community in the 200 Areas, where they occur with very little seasonal restriction but exhibit dramatic changes in abundance from year to year (PNL-2253, *Ecology of the 200 Area Plateau Waste Management Environs: A Status Report*). Grasshoppers are herbivorous insects common to the Central Plateau. This SLERA compares soil media concentrations against concentrations that are known to have no observable adverse effects. Target receptors are designed to be broadly representatives of insects and other soil invertebrates such as earthworms that include the invertebrate species occurring at the 200 Area sites. Ants tunnel underground and move soil to the surface; however, their ability to move contaminants to the surface at the Hanford Site is not well documented. Biota samples in conjunction with soil samples would be helpful in understanding the completeness of this exposure pathway. The role of soil invertebrate species in transport of contaminants from the subsurface is discussed in more detail in Section 5.2.5.3.

5.2.2.1 Sensitive Habitat

Sensitive habitats are those identified in DOE/RL-96-32, *Hanford Site Biological Resources Management Plan*, as rare or wetlands (riparian) habitat. The Federal and state governments protect wetlands. Rare habitats are those that have a low availability but are important for plant, fish, and wildlife species (DOE/RL-96-32). On the Central Plateau, the only identified rare habitat areas, rated as Level IV in DOE/RL-96-32, are located in proximity of the basalt ridges of

Gable Butte and Gable Mountain. These basalt outcrops have limited availability, are associated with rare plant communities, and are easily disturbed. No waste sites are near these rare habitats.

On the Central Plateau, man-made ponds and ditches, including the B Pond Complex located near the 200 East Area, once were present and were sources of riparian habitat. In 1995, all contaminated effluent discharges to liquid waste sites were ceased. All riparian habitats within the fence line have been eliminated, except for a small riparian area that was identified in the 200 East Area during the 2001 survey. This may be a seasonal wetland; the value of this small riparian area has not been evaluated. No wetland habitat was located in the 200 West Area.

Vernal pools, such as those on Gable Butte and Gable Mountain, are temporary and are considered seasonally flooded wetlands. Approximately twenty vernal pools were located on the eastern end of Umtanum Ridge, near the central part of Gable Butte, and on the eastern end of Gable Mountain. None of these pools are near waste sites in the Central Plateau (TNC 1999, *Biodiversity Inventory and Analysis of the Hanford Site, Final Report 1994-1999*).

5.2.2.2 Endangered, Threatened, and Sensitive Species

Two federally protected species have been observed at the Hanford Site: the Aleutian Canada Goose (*Branta canadensis leucopareia*) and the bald eagle (*Haliaeetus leucocephalus*). Both depend on the river corridor and rarely are seen in the Central Plateau. As migratory birds, these species are protected under the *Migratory Bird Treaty Act* (1918).

No plants, invertebrates, amphibians, reptiles, or mammals on the US Fish and Wildlife Service or State of Washington threatened and endangered species lists are known to inhabit the Central Plateau. Sensitive species include threatened and endangered species that are protected by Federal and state laws. Washington State defines sensitive species as "any wildlife species native to the State of Washington that is vulnerable or declining and is likely to become endangered or threatened throughout a significant portion of its range within the state without cooperative management or removal of threats" (WAC 232-12-297, "Endangered, Threatened, and Sensitive Wildlife Species Classification").

5.2.2.3 Rare Plants

Rare plant species are vascular plant species listed by the Washington Natural Heritage Program (WNHP 1998, *Washington Rare Plant Species by County*) as endangered, threatened, or sensitive in the State of Washington. The Nature Conservancy survey discovered 112 populations of 28 rare plant taxa on the Hanford Site (TNC 1999). Although rare plants were found dispersed throughout the Site, the highest densities occurred on the east end of the Umtanum Ridge, the basalt-derived sands near Gable Mountain, the White Bluffs, Rattlesnake Mountain, and the Yakima Ridge.

5.2.2.4 Mammals of Concern

The state has classified the pygmy rabbit (*Brachylagus idahoensis*) as a candidate endangered species. None have been observed to date in the Central Plateau. The pygmy rabbit depends on sagebrush, primarily big sagebrush *(Artemisia tridentata)*, and usually is found in areas where big sagebrush grows in very dense stands.

5.2.2.5 New-to-Science Species

The Nature Conservancy conducted a biodiversity survey of plants, mammals, reptiles and amphibians, birds, and insects at the Hanford Site between 1994 and 1998 (TNC 1999). This survey found two species and one variety of plants and 41 species and two subspecies of insects that had not been known to science. The new plant and insect species are listed at http://www.pnl.gov/ecology/ecosystem/Species/Species.html.

Insects were dispersed throughout the Hanford Site, with the new species found in shrub-steppe, areas around the basalt talus, springs, and upland areas. The size, diversity, and relatively undisturbed nature of the Hanford Site shrub-steppe habitat has provided for a large and diverse insect population, of which the new-to-science species are a part. The U.S. Fish and Wildlife Service and the State of Washington have not yet determined the protective status of these new-to-science species (i.e., are they considered threatened or endangered). The habitat-based management plan at the Hanford Site will offer protection to most of these species. With the exception of some of the insects, none of these new-to-science species are anticipated near the 200-LW-1 and 200-LW-2 OU waste sites. Habitat protection will be primary to preserving the insect diversity at the Hanford Site.

5.2.2.6 Suitability of Habitat

It should be noted that while there is habitat within the waste areas, the land has been classified as industrial and has been since establishment of the Hanford Site. These habitats are low to poor quality, but nevertheless have the potential to be used by wildlife at the site. There are other higher quality habitat areas adjacent to but outside the waste areas. It is more likely that local wildlife will use these higher quality habitats preferentially to the habitat found in the 200-LW-1 and 200-LW-2 OUs.

5.2.2.7 Characterization of Land Use

The land-use boundary around the 200 East and 200 West Areas has been designated as industrial-exclusive in DOE/EIS-0222-F, *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*. Based on standards in specific sections of DOE/EIS-0222-F and the associated 64 FR 61615, industrial-exclusive land use is defined as "preserving DOE control of the continuing remediation activities and use of the existing compatible infrastructure required to support activities such as dangerous waste, radioactive waste, and mixed waste treatment, storage, and disposal facilities" (DOE/EIS-0222-F). With the exception of the 216-S-19 Pond and the 216-S-26 Crib, all of the waste sites associated with the 200-LW-1 and 200-LW-2 OUs are located within this industrial-exclusive land-use boundary. Sites 216-S-19 Pond and 216-S-26 Crib are outside the industrial exclusive use land boundary (DOE/EIS-02220F) but within the Core Zone (Klein et al., 2002).

5.2.3 Groundwater Beneficial Use

Local groundwater is not a current source of drinking water at the 200-LW-1 and 200-LW-2 OU waste sites. In addition, groundwater beneath the waste sites is not anticipated to become a source of drinking water until at least groundwater cleanup levels are met. Under current conditions, no complete human exposure pathways to groundwater are assumed at the waste sites. Risks associated with current contamination in the groundwater were not evaluated in this RI. Contaminated groundwater in the vicinity of the waste areas is being and will continue to be addressed under the 200-UP-1 Groundwater OU.

The potential for contaminants to migrate from the soil to groundwater, however, was examined in this RI. Concentrations in soil were compared to groundwater protection cleanup levels for the nonradiological contaminants. For radiological contaminants, a tiered approach was used to evaluate the protection-of-groundwater pathway. The first tier used the RESRAD model (ANL 2002) to identify contaminants that should move forward into the second tier which uses the STOMP model (PNNL-12034, *STOMP, Subsurface Transport Over Multiple Phases, Version 2.0, User's Guide*). The RESRAD model is used to identify radiological contaminants that could potentially affect groundwater as it calculates the "cumulative" effective dose that is compared to 4 mrem/yr. RESRAD sums the effective dose of all contaminants, rather than comparing individual groundwater concentrations to the dose limit of 4 mrem/yr. Typically, contaminants identified by RESRAD as potentially affecting groundwater are then carried forward into the STOMP model, which incorporates extensive site-specific parameters to predict the concentration of the contaminant at the groundwater table. For this activity, additional STOMP modeling was not considered necessary, because modeling conducted previously at 200 Areas sites (DOE/RL-2002-42) for nonradioactive contaminants consistently has indicated breakthrough to the water table for contaminants with soil-water partition K_ds of zero, and additional modeling only would have served to restate the finding that eventually the contaminant will reach groundwater. The behavior of the potential contaminants present is well documented from previous modeling. Assumptions based on previous STOMP modeling were subsequently incorporated into the risk model.

The RESRAD output provided current and future simulations of contribution to the risk of groundwater contamination from the movement of contaminants from the vadose zone to groundwater. Fate and transport modeling was approximated using RESRAD and surrogate chemical species to support evaluation of the protection of groundwater. Details of the RESRAD input parameters are discussed in Chapter 4.0. The results of the modeling are summarized in the sections below.

5.2.4 Conceptual Exposure Model for Human Health and the Environment

This section describes the potential exposure pathways from site contaminants, based on currently available waste site information. The conceptual exposure model was formulated following guidance in EPA/540/R-99/005, *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual [Part E, Supplemental Guidance for Dermal Risk Assessment]*.

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

- A source
- A mechanism for chemical release and transport
- An environmental transport medium
- An exposure point
- An exposure route
- A receptor or exposed population.

In the absence of any one of these components, an exposure pathway is considered incomplete and, by definition, no risk or hazard exists. Figure 5-1 presents the conceptual exposure model for the 200-LW-1 and 200-LW-2 OU waste sites.

5.2.4.1 Contaminant Sources

The 200-LW-1 OU is one of two OUs in the chemical laboratory waste category as described in DOE/RL-96-81. The OU received liquid wastes resulting from 300 Area process laboratory operations that supported radiochemistry and metallurgical experiments. The wastes were transferred from the 300 Area to the 200-LW-1 OU waste sites in the 200 Areas for disposal. The other OU in this waste category, the 200-LW-2 200 Area Chemical Laboratory Waste Group OU, received liquid waste resulting mainly from 200 Area laboratory operations that supported the major chemical processing facilities and equipment decontamination from T Plant. Some 200-LW-2 sites, however, are known to have also received waste from 300 Area laboratories.

The 200-LW-1 and 200-LW-2 OUs fall within the chemical laboratory waste category. This category is composed of waste sites that received liquid waste streams from 200 and 300 Area laboratory facilities. Experiments conducted in these laboratories were associated with the major processing facilities in the 200 Areas (e.g., T and B Plants, Plutonium-Uranium Extraction [PUREX] Facility, Reduction-Oxidation [REDOX] Facility).

Detailed descriptions and histories of the three representative waste sites, the 216-T-28, 216-S-20, and 216-Z-7 Cribs, can be found in Section 1.4 of this report.

5.2.4.2 Release Mechanisms and Environmental Transport Media

The primary release and transport mechanisms for COPCs from the source via environmental media to potentially contaminated media are as follows:

- Surface and subsurface liquid discharge, followed by deposition on surface and subsurface soils

- Infiltration, percolation, and leaching contaminants from waste sites to subsurface soils and groundwater

- Generation of dust emanating from shallow-zone soil to ambient air from wind or during maintenance or construction activities at the release site
- Volatilization of chemicals emanating from shallow-zone soil to ambient air at the release site.

5.2.5 Potentially Complete Human Exposure Pathways and Receptors

The most plausible exposure pathways considered for characterizing human health risks were determined on the basis of the current understanding of land-use conditions at and near the site. The pathways are shown in Figure 5-1 and are described in the following sections.

The point of compliance for shallow-zone soils is defined as 0 m to 4.6 m (0 to 15 ft) bgs. This soil depth is associated with potential exposure under unrestricted land use in WAC 173-340-740(6)(d), "Point of Compliance," as follows:

> *"For soil cleanup levels based on human exposure via direct contact or other exposure pathways where contact with the soil is required to complete the pathway, the point of compliance shall be established in the soils throughout the site from the ground surface to fifteen feet below the ground surface. This represents a reasonable estimate of the depth of soil that could be excavated and distributed at the soil surface as a result of site development activities."*

The point of compliance to evaluate the protection of groundwater is defined as those samples collected throughout the soil profile (0 m [0 ft] to groundwater).

Evaluation of radiological contaminants in shallow-zone soil (for the direct-contact exposure pathways) was conducted using two different methods. The first evaluation method, the "cover" alternative, is considered representative of current site conditions because it accounts for existing clean cover over the waste site. The shielding effects of the clean cover directly influence the resulting dose and risk estimates. The second evaluation method, the "no cover" alternative is considered representative of worst-case conditions; it assumes that existing cover is removed from the representative waste site (i.e., the exposure point concentration [EPC] is representative of the entire shallow zone).

5.2.5.1 Industrial Land-Use Scenario

Under current and likely future site conditions, onsite industrial workers could potentially be exposed to shallow-zone soils from the waste site during construction or maintenance activities.

The industrial land-use scenario assumes that no groundwater from the waste site will be used for drinking purposes. Soil screening levels for nonradiological contaminants consider exposure through direct-contact pathways (incidental soil ingestion and dermal contact) and inhalation of dust and vapors in ambient air. For radiological contaminants, potential routes of exposure to shallow-zone soil include external gamma radiation, incidental soil ingestion, and inhalation of dust particulates.

5.2.5.2 Protection of Groundwater

Although groundwater beneath the 200 Areas is not likely to be used as a drinking water source, contaminants were evaluated for protection of groundwater for decision-making purposes. Potential impacts to groundwater for nonradionuclides were screened by comparing the maximum detected soil concentration at any depth in the vadose zone to WAC 173-340-747 soil screening values. The exposure parameters, chemical properties, and toxicity values used as the basis of these groundwater screening values are discussed throughout Section 5.3. Potential groundwater impacts of radionuclide COPCs were evaluated within the RESRAD modeling framework, as discussed in Chapter 4.0.

5.2.5.3 Potentially Complete Ecological Exposure Pathways and Receptors

The following ecological exposures potentially associated with the OUs will be considered for characterizing ecological risks:

- Potential current or future direct contact with or ingestion of surface soil by invertebrates (e.g., beetles)
- Direct contact with or ingestion of surface soil by avian (e.g., western meadowlark) and terrestrial (e.g., coyote) wildlife that may use the waste sites
- Bioaccumulation through ingestion of food items (e.g., plants, prey) consumed by wildlife that may forage at the waste sites.

The major pathways of exposure expected at the representative sites in the 200-LW-1 and 200-LW-2 OUs are direct ingestion of contaminated soil and ingestion of food items that have taken up contaminants from soil. These pathways are the same pathways that were used to develop the screening levels for soil. Although some standing water could potentially remain after precipitation events, these sites contain no permanent bodies of water. Therefore, only pathways associated with exposure to contaminated soil are considered to be complete at this site. Potential species potentially at the site include both surface-dwelling species and burrowing species. Both plants and burrowing species may move contamination from the subsurface to the surface, potentially exposing other species to these contaminants. The contribution by terrestrial invertebrates is not well documented at the Hanford Site, but may not be insignificant.

The exposure pathways used to develop the ecological screening levels consist of all complete exposure pathways except for inhalation and dermal exposure. Although these pathways contribute to the dose of contaminants of potential ecological concern received by animals, it is expected that the contribution from these pathways is relatively small and does not contribute significantly to receptor exposure (EPA 2003, *Guidance for Developing Ecological Soil Screening Levels*, OSWER Directive 9285.7-55). Inhalation is viewed to be an insignificant pathway for contaminated soil in areas where plants cover the contaminated ground surface or where much of the contamination is buried. Dermal exposure to wildlife is mitigated by the fur or feathers that cover the bodies of most vertebrates. In addition, the incidental consumption of soil during grooming is assumed to be included in the direct soil ingestion estimates. Based on EPA guidance that suggests that the ingestion route is most important to terrestrial animals (EPA/540/R-97/006), dermal contact and inhalation and/or respiration pathways are typically not assessed quantitatively in ecological risk assessments. Even if these pathways are ignored, the exposure scenarios considered in the development of the screening values used for this site are considered to be adequate in modeling the primary exposures for wildlife receptors.

The soil concentrations used to represent the EPCs for contaminants at this site are the maximum detected concentrations seen at any point within the top 4.6 m (15 ft) of the soil column below ground surface. This value was used as the EPC because disturbance of the site through bioturbation or human activities could potentially bring these maximum concentrations of contaminants to the surface where any terrestrial receptor could be exposed to them. Also, the screening levels are based on generalized receptor species, so excluding contaminants based on the burrowing depths of individual species is not appropriate at the level of a screening assessment. However, most biological activity occurs within the topmost 0.61 m (2 ft) of the soil column. The 4.6 m (15-ft) depth provided in the Ecology guidance is deeper than the expected burrowing or rooting depth of species known to occur at the site (DOE/RL-2001-54) and should represent a sufficiently protective section of the soil column for species expected to inhabit these sites both now and in the future.

5.2.5.4 Computation of Exposure Point Concentrations

In the human and ecological risk assessments presented in this report, EPCs at each site are represented by the maximum detected concentration in the 0 m to 4.6 m (0- to 15-ft) shallow-zone soil column. The COPC concentrations in deep-zone soils, which are used to evaluate potential impacts to groundwater, are defined as the maximum detected concentration in the 0 m-to-groundwater deep-zone soil column. The use of maximum detected concentrations results in a protective bias that potentially is much greater than that associated with the use of an upper confidence limit (UCL) on an average concentration, which is the generally recommended approach for estimating an exposure point concentration (EPA 2002). However, the relatively small number of sampling locations at the waste sites evaluated in this report render the use of a maximum concentration appropriate because, in such cases, calculated UCL values may exceed the maximum detected concentration (EPA 2002).

Air concentrations were estimated by modeling particulate or vapor emissions from the soil. Air concentrations from vapor emissions were estimated using a volatilization factor for those contaminants that are considered volatile. Volatile contaminants considered for the inhalation pathway are operationally defined as those contaminants with a Henry's Law Constant greater than 10^{-5} atm-m^3/mole and a molecular weight smaller than 200 g/mole (*Region 9 [Preliminary Remediation Goals] PRGs 2004 Tables*, available on the Internet at: www.epa.gov/region09/waste/sfund/prg/files/02table.pdf [EPA 2004]). Air concentrations from fugitive dust emissions were estimated using a particulate emissions factor for those contaminants that are not volatile. The following equation was used to estimate air concentrations from volatile or particulate emissions:

$$Air\ Concentration = C_s \times \left(\frac{1}{PEF} or \frac{1}{VF} \right)$$

where

C_s = soil concentration (mg/kg)

VF = volatilization factor (chemical-specific) (m^3/kg)

PEF = particulate emissions factor (1.32 x 10^9 m^3/kg).

The volatilization factors for volatile organic compounds identified as COPCs in shallow-zone soil[1] and the particulate emissions factor used to estimate fugitive dust emissions were obtained from EPA/540/R-96/018, *Soil Screening Guidance: Users Guide*, Directive 9355.4-23.
No volatile organic or semivolatile organic compounds were detected in the shallow zone soils at the 216-S-20 Crib or the 216-Z-7 Crib. No data were available for the shallow zone soils for the 216-T-28 Crib on which to calculate risk. As a surrogate, concentrations of organic compounds from deeper in the 216-T-28 Crib were evaluated and compared to established screening levels. Based on that analysis, and because of the chemistry of the compounds, particularly a low partial pressure, it is unlikely that organic compounds remain in the shallow zone soil, having volatized long ago. Subsequently, vapor emissions for the 216-T-28 Crib were not considered a valid exposure pathway, and no particulate emission factor was calculated.

5.3 HUMAN HEALTH RISK EVALUATION FOR NONRADIOLOGICAL CONTAMINANTS

A baseline HHRA, in which potential adverse health effects are evaluated in the absence of any remedial action, generally consists of four steps: data collection and analysis, exposure assessment, toxicity assessment, and risk characterization (EPA/540/1-89/002, *Risk Assessment Guidance for Superfund (RAGS), Volume I -- Human Health Evaluation Manual, (Part A) Interim Final,* OSWER 9285.7-01A). In the first step of the assessment, COPCs are identified on the basis of such criteria as detection status, comparison to background concentrations, and comparison to toxicity-based screening criteria. Exposure pathways associated with the toxicity-based screening criteria were described in Section 5.2.4 of this RI Report. The results of the screening assessment are interpreted in an uncertainty analysis in Section 5.3.3.

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[1] Shallow-zone soils are defined as those collected from 0 to 4.6 m (0 to 15 ft) bgs.

This section presents the HHRA for the 200-LW-1 and LW-2 OU waste sites. This HHRA comprises the following components.

- **Human Health Risk Assessment Guidance.** Lists the guidance documents used for the HHRA.
- **Selection of Chemicals of Potential Concern.** Identifies the contaminants considered to be most important to evaluating human health risk.
- **Human Exposure and Toxicity Assessment.** Identifies the pathways by which potential human exposures could occur; describes how they are evaluated; and evaluates the magnitude, frequency, and duration of these exposures. Identifies the sources of toxicity values used.
- **Risk Assessment Results.** Integrates information from the exposure and toxicity assessments to characterize the risks to human health from potential exposure to contaminants in environmental media.
- **Identification of Major Uncertainties and Assumptions.** Summarizes the basic assumptions used in the RA, as well as limitations of data and methodology.

5.3.1 Human Health Risk Evaluation Guidance Documents

The following guidance was used to conduct the human health evaluation for nonradiological contaminants:

- **Ecology 94-145,** *Cleanup Levels and Risk Calculations under the Model Toxics Control Act Cleanup Regulation; CLARC, Version 3.1.* Provides screening levels for nonradioactive analytes regulated under WAC 173-340-740, WAC 173-340-745, and WAC 173-340-747
- **DOE/RL-92-24,** *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*, Rev. 4. Provides soil backgrounds for nonradioactive analytes
- **OSWER Directive 9285.6-10,** *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites.* Recommends approaches for estimating exposure-point concentrations (EPA 2002)
- **EPA/540/1-89/002,** *Risk Assessment Guidance for Superfund (RAGS), Volume I -- Human Health Evaluation Manual, (Part A) Interim Final,* OSWER 9285.7-01A. Provides guidance on risk assessments and screening criteria

- **OSWER Directive 9285.6-03**, *Risk Assessment Guidance for Superfund, Vol. I Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors, (Interim Final)* (EPA 1991)
- **EPA/600/P-95/002Fa**, *Exposure Factors Handbook*
- **EPA/540/R-99/005,** *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim*
- **EPA/600/P-92/003C**, *Proposed Guidelines for Carcinogen Risk Assessment*
- **OSWER 9285.7-081**, *Supplemental Guidance to RAGS: Calculating the Concentration Term* (EPA 1992).

5.3.2 Contaminants of Potential Concern for Human Health

The COPCs are those chemicals that should be carried through the human health risk quantification process. This component of the HHRA process summarizes those contaminants detected in environmental media and identifies the COPCs for environmental media that are accessible for human exposure. Chemicals of potential concern are those chemicals that pose potentially unacceptable risks to human health. Actions to improve the understanding of COPC distribution and/or migration in the environment or actions to mitigate potential exposures should be evaluated further in the FS. The technical approach for identifying nonradionuclide COPCs is outlined in Figure 5-2.

5.3.2.1 Data Evaluation

All soil data collected under the Work Plan (DOE/RL-2001-66) were considered in the human health evaluation. Soil sampling information, including collection dates, sample identification numbers, depths, and analytical laboratories are summarized in Tables 2-1 through 2-3.

All nonradiological contaminants detected in one or more samples were included in the human health risk evaluation. In accordance with established precedent, the following rules were applied to data for the risk assessment.

- Sample data with estimated concentrations ("B" or "J" qualification flags) were evaluated at the reported concentration in the risk evaluation.
- Rejected ("R"-qualified) data were not used in the risk evaluation.
- If duplicate and/or split sample results were available for a sample, the highest of the reported concentrations was used in the risk evaluation.

Frequency-of-detection criteria were not applied to this data set. All detected contaminants were carried to the next screening step.

The principal distinction for data use in the human health risk evaluation was the sample depth. Maximum detected concentrations from analytical data from samples collected at depths of 4.6 m (15 ft) or less were evaluated for direct contact by comparison to industrial exposure scenario soil screening levels as promulgated under WAC 173-340-745. Maximum detected concentrations from samples collected at all depths were evaluated for potential groundwater impacts by comparing them to soil screening values calculated using the fixed-parameter three-phase partition model as outlined in WAC 173-340. Text and tables throughout this document, including Appendix A, that reference shallow-zone soils refer to the 0 m to 4.6 m (15-ft) layer, whereas references to deep-zone soils are based on data from all depths sampled from 0 m (0 ft) to groundwater. Table 5-1 summarizes the maximum detected concentrations of COPCs in both the shallow zone and the deep zone for all three representative sites.

Detected contaminants in shallow- and deep-soils can be summarized as follows.

- *Shallow-Zone Soils*:
  - **216-T-28 Crib.** Because of low and incomplete sample recovery, analyses were not conducted on this interval, no samples above 6.1 m (20 ft) bgs
  - **216-S-20 Crib.** Ten radionuclides, eight inorganic nonradionuclides, and no organic compounds were detected
  - **216-Z-7 Crib.** Thirteen radionuclides, nine inorganic compounds, and no organic compounds were detected.
- *Deep-Zone Soils*:
  - **216-T-28 Crib.** Twenty-six radionuclides, 24 inorganic compounds, and 17 organic compounds were detected
  - **216-S-20 Crib.** Twenty-one radionuclides, 22 inorganic compounds, and three organic compounds were detected
  - **216-Z-7 Crib.** Twenty radionuclides, 22 inorganic compounds, and eight organic compounds were detected.

A number of organic tentatively identified compounds (TIC) were detected in the samples for the characterized sites. The TICs fall into the following three categories, none of which were included in the human health risk evaluations:

- Products of column bleed from the gas chromatograph that are caused by the analytical process and are likely false positives not site contaminants. These are siloxane-type compounds. These compounds do not appear in the human health or ecological risk evaluation comparisons
- Products from heating acetone during the extraction process, e.g., diacetone alcohols or 2-pentanone 4- hydroxy. These are false positives that are not real site contaminants

- Other TICs that are not calibrated and are estimated and that do not have risk values in the , Version 3.1 tables (Ecology 94-145) are 2,4,6-trimethylpyridine, 3-penten-2-one, 6-tridecene, mesityl oxide, tetramethylpiperidinone, 2-butyl-1,1,3-trimethyl-cyclohexane, decahydro-2 6-dimethyl-naphthalene, n-butylbenzenesulfonamide, bis(2-ethylhexyl)adipate, o-terphenyl, propionic acid, eicosane, n-hexanoic acid, decahexanoic acid octacosane, 1,2,4-trithiolane, 3-methyl 2-cyclohexen-1-one, and cyclohexyl isocyanate.

Tributyl phosphate often is reported as a TIC; however, because of its use at the Hanford Site and because many of the laboratories under contract calibrate for this compound, it was considered during the human health risk evaluations.

5.3.2.2 Identification of Essential Nutrients

Chemicals that are considered essential human nutrients, are toxic only at very high doses. These nutrients are typically present at concentrations only slightly higher than naturally occurring levels and are not generally evaluated in a human health risk assessment (EPA/540/1-89/002). Examples of such chemicals described in Section 5.9.4 of EPA/540/1-89/002, are iron, magnesium, calcium, potassium, and sodium. These essential nutrients were not included in any of the comparisons as part of the human health screening assessment.

5.3.2.3 Background Screening

As shown in Figure 5-2, detected contaminants that are not essential nutrients were screened for consideration in the risk-based evaluation by comparing the maximum detected concentration with background concentrations. With the following three exceptions, Hanford Site lognormal 90^{th} percentile background values were used to identify potentially site-related contaminants in the background screening, as recommended in DOE/RL-92-24. The background values were identified in Summary Table 2 of DOE/RL-92-24.

- DOE/RL-92-24 does not list a background value for cadmium. For cadmium, the 90^{th} percentile background value of 0.81 mg/kg was obtained from Table 7 of Ecology Publication 94-145. The cadmium background value is specific to eastern Washington.

- Organic compounds, semivolatile organic compounds, and PCBs are not naturally occurring in the soils at the Hanford Site; background criteria have not been developed. Therefore, concentrations of these contaminants have been compared to soil screening levels without a prior background screening.

- Site-wide and statewide soil background levels are not available for antimony, selenium, strontium, thallium, titanium, yttrium, Am-241, Co-60, Cm-244, Eu-152, Np-237, Se-79, Tc-99, or U-234. If any of these metals or radionuclides were detected, they were carried forward in the risk assessment process.

- If a toxicity value was not available from a reliable source or an appropriate surrogate could not be identified, the chemical was not included in the risk assessment.

Data collected for representative sites at the 200-LW-1 and 200-LW-2 OUs are summarized in Appendix A, Table A-1, for shallow-zone (0 to 4.6 m [15 ft]) soils, and in Table A-2 for deep-zone (0 m to groundwater) soils. The data summaries contain number of samples, frequency of detects, range of MDA for nondetects, range of results, and depth at which maximum result was found. These data are used for background comparisons. Table 5-1 illustrates the maximum detected concentrations at each representative site.

The results of the background comparison for nonradionuclides are summarized in Table 5-2 for both the shallow-zone and deep-zone soils. At the 216-T-28 Crib, incomplete sample recovery prevented laboratory analyses for the shallow zone. In the deep zone, 16 inorganic contaminants were detected above background or were detected and no background value was available. At the 216-S-20 Crib, three inorganic contaminants in shallow-zone soils and 17 inorganic contaminants in deep-zone soils were detected above background or were detected and no background value was available. At the 216-Z-7 Crib, three inorganic contaminants in shallow-zone soils and ten inorganic contaminants in deep-zone soils were detected above background. The individual comparisons between each maximum detected concentration for each inorganic contaminant and its background value are presented in Table 5-3 for the shallow-zone soil column and in Chapter 4.0, Table 4-1 for the deep-zone soils (the entire soil column down to groundwater). Shaded rows in the tables indicate that the maximum detected concentration of an inorganic contaminant exceeds its background screening value. Contaminants with a maximum detected concentration exceeding background in one or both soil strata are evaluated by comparing their values to soil screening levels in Section 5.3.2.4.

The following contaminants are present in the shallow-zone soils and the deep-zone soils at maximum concentrations greater than background or do not have an applicable background value, and will be evaluated by comparison to WAC 173-340-745 soil screening levels.

Shallow-Zone Soils (0 to 4.6 m [15 ft] bgs)

- **216-T-28 Crib.** Because of incomplete sample recovery, no shallow zone data is available for this representative site
- **216-S-20 Crib.** Arsenic, nitrate and nitrate/nitrite as nitrogen
- **216-Z-7 Crib.** Arsenic, cyanide, nitrate and nitrate/nitrite as nitrogen.

Deep-Zone Soils (0 m bgs to Groundwater)

- **216-T-28 Crib.** Antimony, arsenic, bismuth, total chromium, hexavalent chromium, lead, mercury, nickel, silver, uranium, ammonium ion as N, ammonia as N, fluoride, nitrate as N, nitrite as N, nitrogen as nitrate/nitrite, phosphate

- **216-S-20 Crib.** Antimony, arsenic, barium, beryllium, bismuth, boron, total chromium, hexavalent chromium, copper, lead, mercury, nickel, silver, uranium, fluoride, nitrate as N, nitrogen as nitrate/nitrite, sulfide
- **216-Z-7 Crib.** Antimony, arsenic, bismuth, boron, total chromium, hexavalent chromium, lead, mercury, nickel, silver, uranium, ammonium ion as N, nitrate as N, nitrogen as nitrate/nitrite, phosphate.

5.3.2.4 Screening to WAC 173-340 Soil and Groundwater Protection Screening Levels

Inorganic contaminants with maximum detected concentrations exceeding background screening values and the maximum concentrations of organic chemicals detected in one or more samples were evaluated against WAC 173-340-745 screening levels. The maximum detected concentration in the upper 4.6 m (15 ft) was compared to direct-contact screening levels for industrial land use (WAC 173-340-745 levels). The exposure assumptions used to develop the WAC 173-340-745 levels for direct exposure to soil are summarized in Table 5-4. These exposure assumptions represent a reasonable maximum exposure scenario for an industrial worker. The maximum contaminant concentrations from any depth (the deep-zone soil column extending from the surface to groundwater) were evaluated against WAC 173-340-747 soil screening levels for groundwater protection. The exposure assumptions that were incorporated in the development of the soil screening levels for groundwater protection are provided in Table 5-5. The fixed-parameter (default values) variant of the WAC 173-340-747 three-phase equilibrium model was used to calculate soil screening levels for groundwater protection in Chapter 4.0. Developing screening levels using this model involves considering groundwater RBCs, such as MCLs, as well as the chemical and physical parameters of the chemicals being considered. Table 4-2 provides the groundwater RBC, K_d, and H_{cc} values used to develop the WAC 173-340-747 soil screening levels for groundwater protection. Table 5-6 provides the toxicity values used to develop both these direct-contact screening levels and the soil screening levels for groundwater protection. Direct-exposure screening levels were obtained from CLARC, Version 3.1. The summary of the comparison of nonradionuclides against WAC 173-340-740, WAC 173-340-745, and WAC 173-340-747 screening levels is summarized in Table 5-7.

Table 5-8 provides the comparison of the maximum detected concentration of any organic contaminant in shallow-zone soil to its direct-exposure screening level A shaded set of cells indicates the maximum detected concentration of a contaminant exceeds screening level. No organic contaminants exceeded direct exposure screening levels at two of the three representative sites based on comparison of maximum detected values in the top 4.6 m (15 ft) of soil to WAC 173-340-745 industrial screening values. There are no shallow zone data available for 216-T-28 Crib. As a surrogate, concentrations of organic compounds from deeper in the 216-T-28 Crib were evaluated and compared to established screening levels. Based on that analysis, and because of the chemistry of the compounds, particularly a low partial pressure, it is unlikely that organic compounds remain in the shallow zone soil, having volatized long ago. It should be noted that the 216-T-28 Crib contained a larger concentration of volatile compounds at depth than any of the waste sites in this OU. However, the maximum concentrations in the deep zone soils were quite low. Therefore, this pathway does not appear to present a significant health risk.

Table 5-9 presents a comparison of the maximum detected concentration of any inorganic contaminant in shallow-zone soil that exceeded background screening levels to its direct-soil-exposure screening level. No inorganic contaminants exceeded their direct-soil-exposure screening levels at two of the three representative sites. No shallow zone data are available for the 216-T-28 Crib.

A comparison of the maximum detected concentration of any organic and inorganic contaminant in deep-zone soil to its protection-of-groundwater screening level is provided in Table 4-2. Shaded cells indicate that the maximum detected concentration of a contaminant exceeded groundwater screening levels. For groundwater protection, the following contaminants detected in the deep-zone soils were identified as COPCs:

- **216-T-28 Crib**. Arsenic, bismuth, fluoride, mercury, nitrate as N, hexadecanoic acid, n-hexanoic acid, TPH-Kerosene range organics, uranium
- **216-S-20 Crib**. Arsenic, bismuth, mercury, uranium
- **216-Z-7 Crib**. Arsenic, bismuth, cyanide, methylene chloride, nonadecane, uranium.

Risk screening criteria were available for all inorganic contaminants except bismuth and sulfide. The low concentration of sulfide (23.9 mg/kg) is not considered a potential health risk. Additionally, the regulatory criteria for sulfide are based on secondary aesthetic standards such as taste and odor. Inorganic contaminants that exceeded their screening levels should be evaluated further in the FS. Bismuth was detected at all three waste sites and is discussed in greater detail below.

In addition to the comparison to WAC 173-340-747 groundwater protection screening limits, those contaminants present at concentrations above their screening limits were assessed for potential mobility to groundwater based on their K_d values and is discussed in greater detail in Chapter 4.0.

5.3.3 Uncertainty Analysis

The results of the risk evaluation indicate that no potentially significant health risks are associated with direct soil contact at any of the three representative sites under an industrial land-use scenario. The results of the risk evaluation indicate that no potentially significant health risks are associated with direct soil contact at two of the three representative sites under an industrial land-use scenario. The principal uncertainty associated with this evaluation is the use of maximum detected contaminant concentrations in the top 4.6 m (15 ft) of soil to represent a chronic exposure concentration across the entire site. The use of maximum detected contaminant concentrations almost certainly introduces a conservative bias into the screening evaluation, although the magnitude of the bias cannot be well estimated with existing sample support. Although no shallow data were available for the assessment, similarities in inventory, construction, and future land-use suggest there is a similar lack of risk associated with the 216-T-28 Crib.

The results of soil screening for groundwater protection indicate that a number of soil contaminants may potentially pose groundwater impacts. The finding of potential groundwater impacts for some of these contaminants is, however, implausible because of the nature of the chemical distribution in soils and the site-specific characteristics of the vadose zone. The fixed-parameter three-phase partitioning model is an equilibrium model that does not account for transport through an uncontaminated vadose zone. In the model, soil is assumed to be uniformly contaminated to the top of the aquifer. In fact, for most of the contaminants, a considerable thickness of vadose zone separates contamination from the aquifer. Contaminants with relatively high K_d values (see Section 5.3.2.4), such bismuth, lead, and mercury, are highly unlikely to be able to infiltrate from near the ground surface to the aquifer. Discussion in PNNL-11800 concluded that contaminants with K_d values of 40 mL/g or greater are considered immobile in the vadose zone and groundwater.

5.4 RESRAD MODELING

The RESRAD computer code (ANL 2002) was used to evaluate potential adverse health effects of residual radionuclides in soil at the 216-S-20 Crib, 216-T-28 Crib, and 216-Z-7 Crib. The radiological COPCs identified in Section 5.4.1 were chosen based on detection status and comparison to background concentrations. The input parameter values for the RESRAD modeling and the associated rationale and assumptions are discussed in Section 5.4.2. The results of RESRAD modeling of potential health effects and groundwater impacts associated with radionuclides in shallow- and deep-zone soils are described in Section 5.4.3. Both radiological dose and cancer risk are assessed as health-effects endpoints. An uncertainty analysis for the RESRAD modeling is provided in Section 5.4.4.

5.4.1 Criteria for Selecting Radiological Contaminants of Potential Concern in Shallow-Zone Soil Samples

The COPCs are those radionuclides that pose potentially unacceptable radiological dose and/or cancer risks. Radionuclides identified in this section will be evaluated as COPCs in the RESRAD modeling. If exposure to radionuclide COPCs exceeds dose or risk criteria as determined by the RESRAD modeling, actions to improve the understanding of COPC distribution and/or migration in the environment or actions to mitigate potential exposures should be evaluated further in the FS. The technical approach for identifying radionuclide COPCs is illustrated in Figure 5-3.

5.4.1.1 Data Evaluation

All soil data collected under the Work Plan (DOE/RL-2001-66) were considered in the radiological evaluation. Soil sampling information, including collection dates, sample identification numbers, depths, and analytical laboratories, is summarized in Tables 2-1 through 2-3.

- Sample data with estimated concentrations ("B" or "J" qualification flags) were evaluated at the reported concentration in the radiological evaluation.
- Rejected ("R"-qualified) data were not used in the radiological evaluation.
- If duplicate and/or split sample results were available for a sample, the highest reported concentration was used.

The principal distinction for data use in the radiological evaluation was the sample depth. Analytical data from samples collected at depths of 4.6 m (15 ft) or less (shallow-zone soil) were evaluated for potentially unacceptable radiation dose and cancer risk to humans from exposure under an industrial-land-use scenario. Analytical data from samples collected at all depths (deep-zone soil) were evaluated for potential groundwater impacts using the RESRAD vadose- and saturated-zone transport models.

Radionuclides detected in one or more samples at depths of 0 m to 4.6 m (15 ft), and additional radionuclides detected only at depths below 4.6 m (15 ft), are listed in Table 5-1.

5.4.1.2 Background Screening

Hanford Site 90th percentile background values were used to identify potentially waste site-related contaminants in the background screening. The background values were identified in Table 5-1 of DOE/RL-96-12.

Summary statistics are provided in Table 5-1 of DOE/RL-96-12 for several fallout radionuclides including Co-60, Cs-137, Eu-154, Eu-155, Pu-238, Pu-239, and Sr-90. Background data for fallout radionuclides pertain to only undisturbed surface soil, and even then are sufficient to calculate a 90th percentile value for only Cs-137, Sr-90 and Pu-239 (DOE/RL-96-12). Background comparisons will not be performed for fallout radionuclides because the waste sites evaluated in this report do not have undisturbed surface soils and because all site data have been collected from deep-zone soils that are not associated with deposition of fallout radionuclides.

The background screening is conducted separately for shallow-zone (0 to 4.6 m [15 ft]) soils and deep-zone (0 m to groundwater) soils. The background comparisons for radionuclides detected in the shallow-zone soils are presented in Table 5-10. Background comparisons for radionuclides detected in the deep-zone soils is presented in Table 4-5. The use of shading in the tables indicates a concentration of a radionuclide that exceeds the background screening value.

As shown in Figure 5-3, shallow-zone soil radionuclide concentrations are evaluated for health impacts related to surface exposure, whereas radionuclide concentrations from any depth may be evaluated for potential groundwater impacts. Contaminants with a maximum detected concentration exceeding background in one or both soil strata (shading) are evaluated in RESRAD in Section 5.4.3.

The following contaminants are present at maximum concentrations greater than background or do not have an applicable background value, and will be evaluated further for either surface exposure and/or potential groundwater impacts:

- **216-T-28 Crib.** Am-241, Sb-125, C-14, Cs-134, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Np-237, Ni-63, Pu-238, Pu-239/240, Tc-99, Th-228, Sr-90, tritium, total uranium, U-233/234, U-235, and U-238
- **216-S-20 Crib.** Am-241, C-14, Cs-137, Co-60, Eu-154, Eu-155, Np-237, Ni-63, Pu-238, Pu-239/240, Ra-228, Tc-99, Th-228, Th-232, Sr-90, tritium, total uranium, U-233/234, U-235, and U-238
- **216-Z-7 Crib.** Am-241, Cs-137, Co-60, Eu-154, Eu-155, Np-237, Pu-238, Pu-239/240, Tc-99, Sr-90, tritium, total uranium.

5.4.2 RESRAD Assumptions and Input Parameters

Waste site-specific or Hanford Site-specific data were used where available as input parameters for the RESRAD modeling. The types of parameters for which such data were used included vadose zone hydrogeologic characteristics, radionuclide K_d values, the dimensions of each site, and the depth of cover material on each site. A detailed explanation of the derivation and application of waste site-specific and Hanford Site-specific physical data for the RESRAD modeling is provided in Chapter 4.0.

K_d values used preferentially in the RESRAD simulations were "conservative" values from PNNL-11800, Table E.15, Source Category "F" K_d values, corresponding to low-organic/low-salts/near-neutral-pH releases.

An industrial exposure scenario is used to evaluate potential surface exposure to radionuclides in soil. The exposure scenario pathway assumptions and generic RESRAD input parameter values are generally consistent with previous work in the 200-UP-1 OU. The input parameter values also are largely in accordance with those described in Appendices A and B of WDOH/320-015. The specific parameter values and associated references for each RESRAD input parameter are provided in Table 5-11 for industrial land use. Specific input parameter values and associated references for groundwater protection modeling using RESRAD are provided in Tables 4-10 through 4-12 for the 216-T-28 Crib, in Tables 4-13 through 4-15 for the 216-S-20 Crib, and in Tables 4-16 through 4-18 for the 216-Z-7 Crib.

Maximum detected concentrations of radionuclides in the 0 m to 4.6 m (15 ft) shallow-zone soil layer were evaluated for potential radiation dose and cancer risk in the industrial-land-use scenario. The specific radionuclides and exposure concentrations used in RESRAD are those indicated in shading in the column labeled "Shallow-Zone Maximum Concentration" in Table 5-10. Potential radiation dose and cancer risk associated with these concentrations were assessed under two conditions. In the first condition, labeled the "cover" scenario, the maximum detected concentration was assumed to be uniformly present across the entire site area to a depth of 4.6 m (15 ft) or more, but the site-specific depth of cover identified in Tables 2-1 and 2-2 of the Work Plan (DOE/RL-2001-66) was accounted for in the RESRAD modeling. The cover material was assumed to be "clean," meaning that the cover was free of any radionuclides. In the second condition, labeled the "no cover" scenario, the maximum detected concentration was assumed to be uniformly present across the entire site area from 0 m to 4.6 m (15 ft) bgs, or deeper if borehole data indicated.

An exception to the general protocol for evaluating radionuclides in the shallow-zone soil layer was made for the 216-T-28 Crib and the 216-S-20 Crib. At the 216-T-28 Crib no samples were collected within the shallow-zone soils; therefore, no surface exposure modeling was conducted at this site. It is anticipated, however, that the major zones of contamination are at or below 4.6 m (15 ft) because of the depth of the crib. At the 216-S-20 Crib the depth of cover is approximately 11 m (36 ft). Because the depth of cover was so great, removing the cover to create a "no cover" scenario was judged to be implausible at this site. In addition, an evaluation of surface exposure to buried contamination with the existing cover in place was not conducted at this site because the depth of cover was considerably greater than shallow-zone soils (0 m to 4.6 m [15 ft]). However, an evaluation of surface exposure to radionuclides at the 216-S-20 Crib was still possible because radionuclide COPCs were identified in the samples of the cover material at the site. To ascertain whether unacceptable impacts may be associated with the COPCs, potential exposure to radionuclides in the existing cover was evaluated under the "no-cover" scenario.

Maximum detected concentrations of radionuclides from 0 m to the top of the water table (deep-zone soil layer) were evaluated for potential groundwater impacts. The specific radionuclides and source-zone concentrations used in RESRAD for this evaluation are those indicated in shading in the column labeled "Deep-Zone Maximum Concentration" in Table 4-5. The actual vertical distribution of contamination indicated in the RI data was used to assign a protective estimate of the thickness of the contaminated zone for the groundwater-impact modeling.

5.4.3 RESRAD Results

Radionuclides with maximum detected concentrations exceeding background screening values, or for which background values were unavailable or not applicable, were evaluated for potential human health effects and groundwater impacts using the RESRAD computer code (ANL 2002). The results of RESRAD modeling for surface exposure to contaminants in the shallow-zone soil layer and groundwater protection modeling for the deep-zone soil layer are discussed in this section.

RESRAD modeling results are presented for the individual waste sites in Sections 5.4.3.1 through 5.4.3.3. Results are presented for both present-day surface conditions (existing cover material, if present) and potential worst-case surface conditions (no cover). Although the model computes solutions continuously, specific RESRAD output for this analysis was obtained at the following model years: 0, 1, 10, 30, 100, 150, 250, 500, 1,000, and 10,000. The discussion of results in Sections 5.4.3.1 through 5.4.3.3 reflects information obtained at these points in the modeling period of 0 to 1,000 years.

5.4.3.1 RESRAD Results for the 216-T-28 Crib

Industrial Scenario. No RESRAD modeling was performed at this waste site because no samples were collected in the shallow-zone soils (0 to 4.6 m [0 to 15 ft]). Because of the depth of the crib, the zones of major contamination are anticipated to be at or below 4.6 m (15 ft).

Groundwater Protection. The RESRAD modeling was run to 10,000 years. Of the radionuclides present in the subsurface, only Tc-99 and tritium migrate to the groundwater within 1,000 years. Neptunium and plutonium (all isotopes) reach the groundwater with maximum doses ranging from 4.0×10^{-5} to 1.7×10^{-2} mrem/yr at 10,000 years. Uranium (all isotopes) reaches groundwater with a maximum dose of 105 mrem/yr at 6,000 years. The excess cancer risk related to neptunium and plutonium is below 1.0×10^{-6} during the modeling period. The maximum excess cancer risk related to uranium is 5.0×10^{-4}. Carbon-14 reaches the groundwater with a maximum dose of 0.04 mrem/yr at 1,600 years. The maximum excess cancer risk related to C-14 is 6.5×10^{-7}.. No other radionuclides reach groundwater within 10,000 years. Figures 5-4 through 5-7 present the summed dose and summed risk for all radionuclides reaching groundwater beneath the 216-T-28 Crib.

The results of dose and risk calculations for the groundwater pathway are summarized in Table 5-12. The only two contaminants of concern are Tc-99 and tritium. Both contaminants reach the hypothetical groundwater well in very short time (4.5 years) and their dose and/or excess cancer risk are above the groundwater protection limits.

5.4.3.2 RESRAD Results for the 216-S-20 Crib

Industrial Scenario. The dose assessment and risk assessment results for the 216-S-20 Crib are shown in Tables 5-13 and 5-14, respectively. In addition to the radiation dose and cancer risk over time, the tables indicate the primary radionuclide and exposure pathway associated with dose and risk at each time. The percent contribution of individual radionuclides to dose and cancer risk is expressed in terms of the original radionuclides present at a site, rather than as the percent contribution across all parents and progeny present at some specific time. For example, dose and risk over time from some nuclides may be associated with progeny as well as the parent nuclides themselves. If no single radionuclide contributes 40 percent or more to the total dose via the primary pathway, multiple radionuclides associated with the primary pathway are tabulated.

Health effects are modeled from the present day to 1,000 years in the future. Cancer risk estimates employ cancer risk morbidity slope factors from EPA/402/R-99/001, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*, Federal Guidance Report No. 13, provided in the RESRAD computer code. The depth of cover over the contaminated zone at the 216-S-20 Crib is approximately 11 m (36 ft). Therefore, the contaminated zone lies below the 0 m to 4.6-m (15-ft) soil layer evaluated for possible surface exposure. Low concentrations of one radionuclide (Eu-155) were measured where background data are unavailable. Although this radionuclide is present at a very low concentration in the cover material, potential health effects related to surface exposure were evaluated to provide assurance that no significant impacts are likely under current site conditions. Because the depth of cover was so great, removing the "cover" was judged to be implausible and a "no-cover" evaluation was conducted only because the fill material itself was contaminated with no protective clean fill over the contaminated soil.

Radionuclide doses for each exposure pathway and radionuclide are summed to calculate the total dose to an individual. Radiation doses over the 1,000-year modeling period are below the 15 mrem/yr target dose limit. Cancer risks for each exposure pathway and radionuclide are summed to calculate the total cancer risk to an individual. Cancer risk estimates are evaluated relative to the target risk range of 10^{-6} to 10^{-4} described in 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan." Cancer risk estimates at the 216-S-20 Crib (1.005×10^{-8} at year 0 to 0 within 500 years) are below the target risk range of 10^{-6} to 10^{-4} throughout the modeling period. The time of maximum total dose (1.98×10^{-3} mrem/year) and risk is 1.005×10^{-8} at year 0. Figure 5-8 shows the summed dose and summed risk from all radionuclides for the no cover scenario at the 216-S-20 Crib.

Groundwater Protection. The RESRAD model was run to 10,000 years to determine whether any radionuclides in deep-zone soil reached groundwater. Of the radionuclides present in the subsurface, only tritium migrates to the groundwater within 1,000 years. Carbon-14 reaches groundwater with the maximum dose 0.06 mrem/yr at 6,000 years (maximum excess cancer risk is 6×10^{-8}). Uranium reaches groundwater with a total maximum dose of 2830 mrem/yr at 6,000 years. The maximum excess cancer risk related to uranium is 2×10^{-3}. Plutonium (its daughters) reaches groundwater with the total maximum dose of 0.012 mrem/yr at 6300 years. The maximum excess cancer risk related to plutonium is 7.6×10^{-8}.

Figures 5-9 through 5-11 present the summed dose and summed risk for radiological contaminants reaching groundwater. The results of dose and risk calculations for the groundwater pathway are summarized in Table 5-15. The only contaminant of concern is tritium. Tritium reaches the hypothetical groundwater well in a very short time, and its excess cancer risk is above the groundwater protection limit. However, after 44 years, the excess cancer risk associated with tritium falls below the groundwater protection limit.

5.4.3.3 RESRAD Results for the 216-Z-7 Crib

Industrial Scenario. The dose assessment and risk assessment results for the 216-Z-7 Crib are shown in Tables 5-16 and 5-17, respectively. In addition to the radiation dose and cancer risk over time, the tables indicate the primary radionuclide and exposure pathway associated with dose and risk at each time. The percent contribution of individual radionuclides to dose and cancer risk is expressed in terms of the original radionuclides present at a site, rather than as the percent contribution across all parents and progeny present at some specific time. For example, dose and risk over time from some radionuclides may be associated with progeny as well as the parent radionuclides themselves. If no single radionuclide contributes 40 percent or more to the total dose via the primary pathway, multiple radionuclides associated with the primary pathway are tabulated.

Health effects are modeled from the present day to 1,000 years in the future. Cancer risk estimates employ cancer risk morbidity slope factors from EPA/402/R-99/001, provided in the RESRAD computer code. The depth of cover over the contaminated zone at the 216-Z-7 Crib is approximately 2.4 m (7.9 ft), suggesting that the contaminated zone exists within the 0 to 4.6 m

(15-ft) soil layer evaluated for possible surface exposure. Three radionuclide COPCs (Cs-137, Eu-155, Np-237) were identified in a sample interval beginning at 3.8 m (12.5 ft) bgs. Although these radionuclides likely are predominantly from deeper than 4.6 m (15 ft), these radionuclides were evaluated as if they were present in a contaminated zone within 4.6 m (15 ft) of the ground surface. Both "cover" and "no-cover" alternatives were evaluated for the 216-Z-7 Crib, where the cover depth was considered to be 2.4 m (7.9 ft) thick.

Radionuclide doses for each exposure pathway and radionuclide are summed to calculate the total dose to an individual. Radiation doses over the 1,000-year modeling period are below the 15 mrem/yr target dose limit both when the "cover" is in place and under the "no-cover" condition. Cancer risks for each exposure pathway and radionuclide are summed to calculate the total cancer risk to an individual. Cancer risk estimates are evaluated relative to the target risk range of 10^{-6} to 10^{-4} described in 40 CFR 300. Cancer risk estimates at the 216-Z-7 Crib are below the target risk range for the industrial exposure scenario with the existing "cover." Even without the existing "cover," cancer risk estimates lie well outside the target risk range of 10^{-6} to 10^{-4} throughout the modeling period, ranging between 9.806×10^{-7} and 2.57×10^{-7}. The time of maximum total dose and risk for the industrial scenario with existing "cover" is at 1,000 years. Under the "no-cover" condition, the maximum dose and risk occur at year 0. Figure 5-12 shows the summed dose and summed risk from all radionuclides for the "no-cover" condition. Figure 5-13 shows the summed dose and risk for the "cover" condition at the 216-Z-7 Crib.

Groundwater Protection. The RESRAD modeling was run to 10,000 years. Of the radionuclides present in the subsurface, only Tc-99, Am-241 and tritium migrate to the groundwater within 1,000 years. Technetium-99 reaches groundwater in about 500 years. The peak dose is 8.5 mrem/yr, which is above the 4 mrem/yr regulatory limit. The associated peak excess cancer risk also is above regulatory limit (1.8×10^{-4}). Americium-241 and tritium reach groundwater within the 1,000-year period. The total dose during this time period is below 0.3 mrem/yr. The peak excess cancer risk associated with tritium is 3.6×10^{-6} in year three, which is above regulatory limit. The maximum excess risk associated with Am-241 within 1,000-year period (1.6×10^{-6}) is only slightly above the regulatory limit of 1.0×10^{-6}. Considering that the concentration of Am-241 at the depths greater than 50 m (164 ft) is only 10 pCi/g, which is significantly lower than the concentration of 60,600 pCi/g used in the modeling, the dose associated with Am-241 should be considered insignificant. Since the excess cancer risk is just slightly above the regulatory limit, Am-241 can be excluded from the list of the potential contaminants of concern.

Figures 5-14 through 5-16 present the summed dose and summed risk for radiological contaminants reaching groundwater. Groundwater protection modeling results for the 216-Z-7 Crib are summarized in Table 5-18.

The only remaining contaminants of concern are Tc-99 and tritium. Both of them reach groundwater within the 1,000-year time period. While the peak doses associated with these radionuclides are below the regulatory limit, their excess cancer risk values are above the groundwater protection limits.

5.4.4 Uncertainty Analysis

The analysis of potential surface exposure and groundwater impacts using the RESRAD computer code contains protective biases meant to ensure that the results represent a reasonable worst-case evaluation. Sources of uncertainty that are considered particularly significant are described in the following paragraphs. This uncertainty analysis will focus on identifying and qualifying these biases.

The protective nature of the RESRAD transport model (one-dimensional flow with no lateral dispersion) is described in Section 4.1. Conditions that facilitate migration of a particular radionuclide from soil to groundwater at a site include a low K_d value, high soil concentration, and short distance to groundwater. The recharge rate also is an important factor in modeling transport through the vadose zone, but the RESRAD parameters affecting recharge were held constant across the three sites, so this factor does not differentiate one site from another in these simulations. Among the radionuclides that reached groundwater, all have K_d values of 0 except for C-14, which has a K_d of 0.5. The sensitivity of the RESRAD vadose and groundwater transport model to K_d value in these model runs is evident in the groundwater protection modeling for the 216-Z-7 Crib. Carbon-14 and the uranium isotopes, with K_d values of 0.5 and 0.6, respectively, did not reach groundwater until 6,000 years. By contrast, Tc-99 and tritium with K_d values of 0 reached groundwater after just 500 years. Because of the great sensitivity of K_d values in the RESRAD modeling, conservative estimates of K_d values were used in the groundwater protection screening. RESRAD distribution coefficient selection and sources for the values used is discussed in Section 4.3.2.

A major uncertainty associated with both the surface exposure and groundwater protection evaluations is the use of maximum detected contaminant concentrations to represent a soil source term across an entire site. The use of maximum detected contaminant concentrations almost certainly introduces a very conservative bias into the radionuclide dose and risk evaluations, although the magnitude of the bias cannot be well estimated with existing sample support.

The industrial exposure scenario is based on reasonable worst-case exposure conditions as listed in Table 5-10. Such input parameters as soil ingestion rate, exposure frequency, and exposure duration are biased toward the upper end of likely exposure values.

In addition to the protective bias related to specific parameter values, a question of theoretical versus actual land use arises when considering the RESRAD results. Presently, the primary potential receptors in the area of the waste sites in the 200-LW-1 and 200-LW-2 OUs are field personnel involved with sampling and monitoring and construction workers conducting maintenance activities. No chronic, daily exposure scenario is being realized at these sites at this time. Hence the industrial doses and risks are inherently theoretical. Where maximum exposure occurs at time 0, the industrial scenario results also are biased from temporal discontinuity between the model time and a time when the exposure scenario might actually be realized.

Considerable uncertainty is associated with the radionuclide dose conversion factors and slope factors applied within RESRAD for these calculations. Most generally, these factors employ dose-response models that extrapolate from effects observed at relatively high radiation dose rates to the relatively low dose rates more common in environmental assessments. This type of dose-response model assumes that effects observed at high doses, such as cancer incidence, also may be observed at lower doses, albeit at correspondingly lower frequency. As dose rates decrease, it is possible, though uncertain, that the model fails and that at some dose rates little or no correlation exists between dose and response.

5.5 ECOLOGICAL RISK ASSESSMENT

This section presents the methodology and results of the SLERA for the 200-LW-1 and 200-LW-2 OU Areas. The SLERA assesses the potential impacts of past releases to soil on wildlife using the area, assuming the absence of remediation. The objectives of this SLERA are to evaluate the potential for ecological exposures from these releases and to identify the likelihood of adverse impacts on wildlife populations that might use the investigation area. The outcome of this SLERA will be used to determine the environmental measurements necessary to support the RI/FS process and remedial decision making.

5.5.1 Investigation Area

As described in the site conceptual model (Section 4.2), all three representative waste sites contain habitat that wildlife could utilize. The following three 200-LW-1 and LW-2 OU waste sites are being evaluated in this SLERA:

- 216-T-28 Crib
- 216-S-20 Crib
- 216-Z-7 Crib.

These three sites were selected in the DOE/RL-96-81 and DOE/RL-98-28 and are considered to be representative of conditions for the 200-LW-1 and LW-2 OU waste sites. Section 2.4 discusses the representativeness of these three sites for other 200-LW-1 and 200-LW-2 OU waste sites.

5.5.2 Ecological Risk Assessment Guidance

The EPA, Ecology, and DOE have published guidance documents for performing SLERAs. The procedures used for this SLERA are consistent with those described in the following documents:

- **EPA/630/R-95/002F**, *Guidelines for Ecological Risk Assessment*

- **EPA/540/R-97/006,** *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (Interim Final*

- **EPA/910/R-97/005,** *EPA Region 10 Supplemental Ecological Risk Assessment Guidance for Superfund*

- **EPA/630/R-92/001**, *Framework for Ecological Risk Assessment*

- **DOE/STD-1153-2002,** *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*
- **DOE/RL-91-45,** *Hanford Site Risk Assessment Methodology*
- **DOE/RL-2001-54,** *Central Plateau Ecological Evaluation.*

5.5.3 Overview of the Ecological Risk Assessment Approach

The general approaches for conducting an SLERA in accordance with EPA, Ecology, and DOE guidance are presented in DOE/RL-2001-54. The following sections summarize the site-specific framework for the 200-LW-1 and LW-2 OU Area.

5.5.3.1 Nonradionuclides

The 200-LW-1 and LW-2 OU SLERA, which uses conservative screening values provided by Ecology (WAC 173-340-900), corresponds to Steps 1 (preliminary problem formulation) and 2 (screening) of EPA/540/R-97/006. The SLERA (Step 2 - SLERA) is intentionally conservative and serves to eliminate from further evaluation analytes and waste sites that obviously do not pose a risk to the environment despite the SLERA's bias towards overestimating risk. The SLERA is used to determine whether further evaluation (i.e., baseline ecological risk assessment) or remedial actions may be necessary. The site-specific Central Plateau SLERA framework is presented in Figure 5-17.

5.5.3.2 Radionuclides

EPA and Ecology guidance do not address radionuclides; therefore, the potential effects of surface residual contamination on terrestrial receptors were evaluated using the terrestrial radionuclide screening levels presented in DOE-STD-1153-2002, developed by the DOE and the BDAC. The BDAC has been assisting the DOE in developing a technical standard that provides a graded approach for evaluating radiation doses to biota. The technical standard has been approved by the DOE for assessing the ecological effects of radiological exposure when conducting SLERAs.

The DOE's graded approach for evaluating radiation doses to biota is a three-step process designed to guide a user from an initial, conservative general screening to a more rigorous analysis using site-specific information (if needed) and is consistent with the eight-step EPA approach for conducting SLERAs. The DOE recommends the following three-step process:

1. Assembling radionuclide concentration data and knowledge of sources, receptors, and routes of exposure for the area to be evaluated
2. Applying a general screening methodology that provides limiting radionuclide concentration values (i.e., the BCG, proposed by the BDAC in DOE-STD-1153-2002) in soil

3. If needed, conducting risk evaluation through site-specific screening, site-specific analysis, or an actual site-specific biota dose assessment within an ecological risk framework, similar to that recommended in EPA/630/R-95/002F.

Any of the steps in the graded approach may be used at any time. To avoid confusion with the eight-step EPA process, the DOE steps for evaluating risks posed by radionuclides are referred to as Levels 1 through 3 throughout the remainder of this document. These levels roughly coincide with Step 2 of the EPA's process. This SLERA uses Level 1, part of Level 2 (e.g., maximum concentrations), and a simplified Level 3 to assess the risks to wildlife potentially exposed to radionuclides at the 200-LW-1 and LW-2 OU Area.

The BCG contained in the technical standard guidance includes conservative screening concentrations that are judged to be protective of the most sensitive terrestrial organisms tested (e.g., small mammals), assuming a dose threshold of 0.1 rad/day. The BCGs were developed from dose-response relationships for chronic reproductive effects (Jones et al. 2003, "Principles and Issues in Radiological Ecological Risk Assessment"). Each radionuclide-specific BCG represents the limiting radionuclide concentration in environmental media (i.e., soil, sediment, or water) that would not exceed DOE's established or recommended dose standards for biota protection. Therefore, surface soil concentrations of less than the BCGs are not considered to pose a threat to terrestrial receptors.

5.5.4 Organization of the Ecological Risk Assessment

The remainder of this assessment has been organized into the following subjects to identify the potential for ecological risk at the 200-LW-1 and LW-2 OU representative waste sites:

- **Screening-Level Ecological Risk Assessment.** Presents the methodologies and results of the SLERA (Sections 5.5.6 and 5.5.7)
- **Characterization of Uncertainty.** Identifies uncertainties in the assumptions used to estimate risk to ecological endpoint species (Section 5.5.8)
- **Evaluation of Ecological Significance.** Discusses the significance of the results of the SLERA; collectively considers the results of the SLERA in light of the assumptions and inherent limitations of the analyses (Section 5.5.9)
- **Conclusions and Recommendations.** Summarizes the conclusions and recommendations based on the results of the SLERA (Section 5.5.10)
- **Data Gaps.** Presents a discussion of the usability of the data and identifies where additional data could refine the model further.

5.5.5 Screening-Level Ecological Risk Assessment

This SLERA is consistent with the eight-step SLERA process developed for the Superfund program in EPA/540/R-97/006. The process starts with a SLERA, which is considered to follow

Steps 1 and 2 of the EPA SLERA guidance. The primary purposes of Steps 1 and 2 are to quickly and efficiently identify analytes and sites with minimal potential for ecological risk and eliminate them from further evaluation. The first step, preliminary problem formulation, is considered a conservative, qualitative determination of whether ecological receptors, habitat, and exposure pathways are present at a site. The information provided in Sections 5.2.2 and 5.2.5 of this chapter satisfy Step 1 and indicate that a potential for complete ecological exposure pathways exists at the three 200-LW-1 and LW-2 OU waste sites being evaluated in the SLERA. The second step, ecological risk-based screening, is a conservative assessment of whether contaminants detected at the 200-LW-1 and LW-2 OU representative waste sites are present at concentrations that are sufficiently high to indicate a potential for risk at the waste sites and to support a decision to proceed to a baseline SLERA (Steps 3 through 7 of the 8-step SLERA process) or discuss remedial alternatives. Therefore, results of a SLERA are used to determine which of the following recommendations can be made:

- No further ecological investigations at the waste site
- Continuation of the risk assessment process at the next level (baseline SLERA)
- Take a removal or remedial action to address potential risks.

5.5.6 Screening-Level Ecological Risk Assessment Methodology

The SLERA process used is as described in DOE/RL-2001-54. For nonradionuclides, the SLERA is consistent with EPA/540/R-97/006 and EPA/630/R-95/002F and the process outlined in WAC 173-340-7493, "Site-Specific Terrestrial Ecological Evaluation Procedures." The methodology for the radionuclide ecological evaluation follows the process developed by the BDAC in DOE-STD-1153-2002. During the SLERA, site media concentrations are compared to conservative risk-based media concentrations that are anticipated to be without ecological consequences. These risk-based media concentrations were obtained from both Ecology (for nonradionuclides) and DOE (for radionuclides) sources.

5.5.6.1 Nonradionuclides

Under WAC 173-340, a distinction is made between commercial and/or industrial and all other types of land use. For a commercial or industrial property, only potential exposure pathways to wildlife need to be considered (that is, soil biota and plants are not intended to be protected because of the site land use), while plants and soil biota must be considered along with wildlife at sites designated for other land uses. According to WAC 173-340-200, "Definitions," 'industrial properties' are those that are or have been characterized by or are to be committed to traditional industrial uses such as processing or manufacturing of materials; marine terminal and transportation areas and facilities; fabrication, assembly, treatment, or distribution of manufactured products; or storage of bulk materials, that are zoned for industrial use by a city or county. The 200-LW-1 and LW-2 OU Area is considered commercial or industrial property, a designation that will remain unchanged in the future because of land-use restrictions. Therefore, each site was screened only against the wildlife screening values provided in WAC 173-340-900, Table 749-3. These values represent conservative no-observed-adverse-effect-level (NOAEL)-based screening levels that are protective of wildlife populations and include protection for potential chemical exposure through the food chain. Surface soil concentrations at 0 m to 4.6 m (0 to 15 ft bgs) are compared with these wildlife-screening values.

5.5.6.2 Radionuclides

The WAC regulations and the screening values presented in WAC 173-340-900, Table 749-3, address only nonradionuclide chemicals. Because radionuclide chemicals are present at the Hanford Site, BCG screening values provided in DOE-STD-1153-2002 have been used to screen radionuclides. The default terrestrial wildlife BCGs are soil concentrations that have been calculated for a hypothetical small mammal and use high-end exposure assumptions that include but are not limited to the following: small body weight, high ingestion rate compared to body weight, continuous exposure to radiation from all directions, 100 percent area use, and high incidental soil ingestion rates. The model also assumes that a dose of 0.1 rad/day is protective of ecological populations. This dose is based on preventing effects to the most sensitive species tested. Each radionuclide-specific BCG represents the limiting radionuclide concentration in environmental media that would not exceed DOE's recommended dose standards for biota. These BCG values represent conservative NOAEL-based screening levels assumed to be protective of wildlife populations and include protection for potential radionuclide exposures through the food chain. In addition, because the effects of exposure to multiple radionuclides can be additive, all radionuclide fractions (maximum concentration/BCG) have been summed as follows:

$$\text{Total risk estimate} = \sum (\text{maximum radionuclide concentration/BCG}).$$

If the total risk estimate (sum of all fractions) is less than 1.0, the ecological risk is considered acceptable and the evaluation for radionuclides is complete. The guidance uses three levels to evaluate the potential risk to ecological receptors, with the first level being the most conservative. Level 1 uses maximum detected concentrations rather than the 95-percent UCL recommended by the WAC 173-340 regulations for the initial screening. Level 2 uses a screening of the arithmetic mean concentrations against BCGs. Therefore, in accordance with DOE-STD-1153-2002, maximum radionuclide concentrations have been compared to their respective BCGs, and all fractions have been summed to determine if the sum is less than 1.0. The following lists outline the primary assumptions used for estimating a BCG at each level of the SLERA for radionuclides, in accordance with the DOE guidance.

Level 1 Assumptions

1. Source in soil is infinite (i.e., nondepleting) and terrestrial wildlife are exposed to uniform radionuclide doses.

2. Exposed species have infinitely small mass, which results in an overestimation of the external dose rate for finite-sized organisms.

3. Wildlife species are immersed 100 percent of the time in the waste site soils.

4. Ten percent of the total diet for the wildlife species is from incidental ingestion of soil.

5. Initial exposure parameters (e.g., bioaccumulation factors, ingestion rate, etc.) are specifically chosen to produce very conservative BCGs, and some of these factors may range over several orders of magnitude, depending on biotic and abiotic features at the sites (DOE-STD-1153-2002).

6. The 100-percent area use factor is applied (that is, the wildlife species are expected to forage and reside exclusively at each waste site).

7. Effects limits are based on the protection of the most radiologically sensitive species tested.

8. Maximum detected surface soil concentration is used in the BCG comparisons.

Level 2 Assumptions

For this SLERA, Level 2 assumptions are the same as Level 1 assumptions, except that mean surface soil concentrations are used for the BCG comparisons instead of the maximum detected concentration (includes all assumptions except 8).

Level 3 Assumptions

All of the conservative assumptions are the same as the Level 1 assumptions, except the following changes are made to assumption 4, part of assumption 5, and assumption 8.

1. Because the model is based on exposure to small mammals (e.g., mice), the highest incidental soil ingestion rates for any rodent (2.8 percent) reported in EPA/600/R-93/187a and b, *Wildlife Exposure Factors Handbook*, are applied in place of the default value of 10 percent.

2. Less conservative bioaccumulation factors (i.e., high-end instead of upper bound) from empirical studies reported in the DOE technical standard are applied. Specifically, the 95th percentile animal-to-soil bioaccumulation value (20 for Cs-137) from a kinetic or allometric method was applied (DOE-STD-1153-2002 and "A Probabilistic Approach to Obtaining Limiting Estimates of Radionuclide Concentration in Biota" [Higley et al. 2003]).

3. As in Level 2, mean surface soil concentrations are used for the BCG comparisons.

Threatened and endangered species are of high concern at the Hanford Site. As mentioned in Section 5.2.2.2, two Federally protected species have been observed at the Hanford Site: the Aleutian Canada goose (*Branta canadensis leucopareia*) and the bald eagle (*Haliaeetus leucocephalus*). As migratory birds, these species also are protected under the *Migratory Bird Treaty Act* (1918). Both of these species depend on the habitats along the river corridor for food and are rarely seen in the Central Plateau. No plants, invertebrates, amphibians, reptiles, or mammals are listed by the Federal or Washington State threatened and endangered species programs. Considering this, exposure of any Federal or State listed wildlife species is not likely to occur in the 200-LW-1 and LW-2 OU Area.

5.5.7 Analysis and Results

Data collection activities during the RI are discussed in Chapter 2.0. Samples were collected from the boreholes and were analyzed for volatile and semivolatile organic compounds, PCBs, inorganics (metals), total petroleum hydrocarbon, general chemistry, and radionuclides. Samples also were collected for physical properties analysis. Data were validated in accordance with the project's quality assurance plan. All samples collected during the remedial investigation were soil samples collected at depths ranging from 0 m to 11 m (0 to 36 ft) bgs beneath clean fill that has been added over the years to stabilize these waste sites (fill ranges from 0 m to 0.61 m [0 to 2 ft] thick). All the samples included in this risk assessment by station identification, sample identification, depth interval, and dates of collection are summarized in Tables A-1 and A-2. Consistent with EPA recommendations for a SLERA, all chemicals that are detected at least once in any of the shallow-zone soil samples were evaluated in this SLERA. The analyses and results of the screening are presented separately for nonradionuclides and radionuclides in Sections 5.5.7.1 and 5.5.7.2.

5.5.7.1 Nonradionuclides

For each representative waste site, the maximum detected concentration for each nonradionuclide contaminant was screened against the wildlife screening values presented in WAC 173-340-900, Table 749-3, to determine if any chemical concentrations exceeded their respective screening values. The results of this screening for each representative waste site are presented in Tables 5-19 through 5-21. The results of the terrestrial wildlife screening for nonradionuclides at the waste sites were as follows:

- **216-T-28 Crib**. No shallow data available for analysis
- **216-S-20 Crib**. None
- **216-Z-7 Crib**. None.

Bismuth was detected above background in samples from the 216-T-28 and 216-S-20 Cribs. However, because of low toxicity and low mobility, bismuth was excluded from further analysis.

5.5.7.2 Radionuclides

For each representative waste site, the maximum (Level 1) detected concentration of each radionuclide were screened against the BCGs proposed by the BDAC (DOE-STD-1153-2002). The results of this screening are presented in Tables 5-22 through 5-24. The results of the terrestrial wildlife screening comparison for radionuclides detected above background levels against proposed BCGs at each waste site were as follows:

- **216-T-28 Crib**. No shallow data available for analysis
- **216-S-20 Crib**. None
- **216-Z-7 Crib**. Np-237.

For each 200-LW-1 and LW-2 OU waste site except the 216-T-28 Crib, the total risk estimate (sum of all radionuclide fractions) was less than 1.0 for terrestrial wildlife. The sum of all fractions of radioactive contaminants in 216-S-20 Crib was 0.023. In the 216-Z-7 Crib, the sum of all fractions is 0.027. Although Np-237 was detected in the 216-Z-7 Crib, the sum of all fractions is less than 1.0, and by definition, the ecological risk is acceptable and screening is complete. It is unlikely that the Np-237 will present any ecological or biological significance. The individual radionuclides identified in previous paragraphs were the major contributors to the sum of fraction exceedances.

5.5.8 Characterization of Uncertainty

Uncertainties are inherent in all aspects of a SLERA. The nature and magnitude of uncertainties depend on the amount and quality of the data available, the degree of knowledge concerning site conditions, and the assumptions made to perform the SLERA. Uncertainties in SLERA methods can result in either understating or overstating the ecological risks. Risk estimates are subject to uncertainty from a variety of sources, including the following:

- Sampling, analysis, and data evaluation
- Fate and transport estimation
- Exposure estimation
- Toxicological data

5.5.8.1 Sampling, Analysis, and Data Evaluation

Uncertainty associated with sampling and analysis includes the inherent variability (standard error) in the analysis, representativeness of the samples, sampling errors, and heterogeneity of the sample matrix. The quality assurance and/or quality control program used in the investigation reduces these errors, but it cannot eliminate all errors associated with sampling and analysis. The degree to which sample collection and analyses reflect real soil concentrations partly determines the reliability of the risk estimates. Sample data used for the SLERA were generated from samples collected at known or suspected source areas, rather than randomly. Because exposure to wildlife is not likely to be limited solely to higher concentration areas, risk estimates for these areas may be conservatively high.

5.5.8.2 Fate and Transport Estimation

This SLERA makes simplifying assumptions about the environmental fate and transport of contaminants of ecological concern, specifically, that no chemical loss or transformation occurs. This assessment also assumes that the chemical concentrations detected in surface soil remain constant during the assessed exposure duration. In cases where natural attenuation and degradation processes are high, the analytical data chosen to represent soil concentrations may overstate actual long-term exposure levels. For example, this SLERA does not account for the decay of radionuclides over time; therefore, future exposure and risk from radionuclides at these waste sites will decrease.

5.5.8.3 Soil Contaminants

A number of the identified contaminants of potential ecological concern retained for risk analysis include general inorganic compounds found in soils, such as nitrate, phosphate, and sulfate.

Although these compounds were seen at some of the representative sites at concentrations above background values, they are unlikely to represent a potential threat to ecological receptors because they are naturally occurring elements of soil. Nitrate/nitrite, phosphate, ammonia, and fluoride were not considered further in the ecological evaluation because of their general status as nutrients, particularly for plant species, and typically low toxicity.

5.5.8.4 Exposure Estimation

The estimation of exposure requires many assumptions to describe potential exposure situations. Uncertainties exist regarding the likelihood of exposure, frequency of contact with contaminated media, concentration of contaminants at exposure points, and time period of exposure. The assumptions used tend to simplify and approximate actual site conditions and may over- or underestimate the actual risks. In general, these assumptions are intended to be conservative and yield an overestimate of the true risk or hazard.

For nonradionuclides, the EPCs used in the exposure assessment were the maximum detected concentration in the topmost 15 ft of the soil column. The EPC was intended to provide a high-end estimate of actual exposure at the site because the potential receptors are assumed to be exposed to the maximum detected contaminant concentration for the entire duration of exposure. The EPCs were assumed to remain constant for the duration of exposure. That is, physical, chemical, or biological processes that could reduce chemical concentrations or changes in the bioavailability of soil contaminants over time have not been factored into the estimate of the EPCs. Use of this conservative assumption is likely to overestimate exposure to receptor species.

The EPCs used for radionuclides in the SLERA were the maximum contaminant concentration in the topmost 15 ft of the soil column at each waste site. Because of the mobility of the potential terrestrial wildlife receptors, sampling at known or suspected contamination areas, and the lower quality foraging habitats at the representative waste sites relative to other nearby areas, the maximum will likely be an overly conservative exposure concentration for measuring population-level effects. Typically the mean serves as a good indicator of the actual risks to terrestrial wildlife populations; however, individual organisms (particularly less mobile organisms) could be exposed to higher concentrations; therefore the maximum detected concentration was used as the screening level for this activity.

Many of the waste sites have been backfilled with a layer of clean soil. The depth of the clean fill varies; however, depths are generally between 0 m and 11 m (0 and 36 ft bgs). Data used in this SLERA were collected at soil locations beneath the clean fill layers to depths of 4.6 m (15 ft) bgs. Most wildlife exposures occur in the upper 0.61 m (2 ft) of soil; therefore these data serve as a conservative estimate of exposure and potentially overstate the actual risks.

For this SLERA, an area use factor was not applied. That is, wildlife receptors are assumed to reside and exclusively forage within each waste site. Because the habitat quality at the waste sites in the 200-LW-1 and 200-LW-2 OU Area is marginal to poor and most wildlife species are highly mobile, wildlife are unlikely to use the waste sites exclusively. Use of this conservative assumption likely overestimates exposure to most potential receptor species.

5.5.8.5 Availability of Toxicological Data

Toxicological data for wildlife often are limited for many contaminants. Most wildlife toxicity information is generated by laboratory studies with selected test species. These studies frequently evaluate domestic animals under controlled laboratory conditions, with few tests involving native wildlife. Basic toxicity information can be extrapolated to native species in the wild, but consideration must also be given to the species involved and specific site conditions. The standard screening levels used in this SLERA were calculated for receptor species that could occur at the 200-LW-1 and LW-2 OU Area. Depending on whether wildlife species at the site are less or more sensitive to the contaminants of concern than the default species in Ecology and DOE guidance, the actual risk may be over- or underestimated. The BCGs in DOE-STD-1153-2002 are based on a 0.1 rad/day limit for terrestrial wildlife. This limit is based on the protection of populations of the most radiosensitive species tested (primarily reptiles and small mammals), which likely overestimates the risk to most terrestrial wildlife potentially using the 200-LW-1 and LW-2 OU Area (although some species could be more sensitive to radionuclide exposure). Also, because some of the contaminants detected at the representative waste sites did not have available screening levels on which to quantify risks, these contaminants could not be evaluated. In general, most of the contaminants that have no available toxicity data are considered less toxic because most of the toxicological literature focuses on those contaminants considered more toxic to ecological receptors.

5.5.8.6 Suitability of Alternate Habitat

It should be noted that while there is exploitable habitat within the waste areas, the land has been classified as industrial and has been since establishment of the Hanford Site. These habitats are low to poor quality, but nevertheless could be utilized by wildlife at the site. There are other higher quality habitat areas adjacent to but outside the waste areas, and it is more likely that local wildlife will use these higher quality habitats preferentially to the habitat found in the 200-LW-1 and 200-LW-2 OUs.

5.5.9 Evaluation of Ecological Significance

Step 1 (preliminary problem formulation) of the SLERA process revealed that ecological receptors and sufficient habitat are present or potentially present at the 200-LW-1 and LW-2 OU Area. The results of Step 2 (ecological risk-based screening) are provided in Tables 5-19 through 5-24 and indicate that with exception of Np-237 in the 216-Z-7 Crib, no screening values were exceeded at the representative waste sites evaluated. This section provides a qualitative and quantitative evaluation of the ecological significance of any Step 2 exceedances. More realistic assumptions (versus the defaults used during Step 2) and consideration of background concentrations are used to provide a perspective on the ecological significance of the Step 2 exceedances. This discussion is provided separately for nonradionuclides and radionuclides in Sections 5.5.9.1 and 5.5.9.2.

5.5.9.1 Nonradionuclides

With the exception of the 216-T-28 Crib, no contaminants exceeded established background or BCGs for terrestrial wildlife. No shallow data was available for the 216-T-28 Crib. Additional sampling should be considered during the FS. Site-wide soil background levels have been established for metals at the Hanford Site and are compared with site-specific concentrations in Tables 5-19 through 5-21.

Although there are no data for the shallow zone in the 216-T-28 Crib on which to model risk, several assumption can be made about the shallow zone beneath the crib and the ecological risk presented. Maximum contaminant concentrations detected in the subsurface below the 216-T-28 Crib are found at depths greater than 4.6 m (15 ft). Nearly all biological activity occurs within the top 0.61 m (2 ft) of the soil column. Currently, the construction of the crib and the material added for stabilization do not appear to be useful habitat or forage areas for surface and subsurface biota. Subsequently, the ecological risk presented by nonradionuclides in the shallow zone below the 216-T-28 Crib is considered negligible and can be excluded from further consideration.

5.5.9.2 Radionuclides

Level 1 risks to terrestrial wildlife from contamination in surface soil were estimated using a highly conservative model, where exposure and toxicity estimations for the most radiosensitive species (primarily reptiles and small mammals) tested were used to conservatively estimate the risks to larger order wildlife. In addition, the model used did not account for home range (i.e., an area use factor of 1 was assumed), availability of higher quality habitat for foraging in nearby areas, and the clean cover soil at some waste sites. The model assumes that a small mammal resides and forages exclusively at each waste site evaluated and that these small mammal populations and their food items are continuously exposed to high-end levels of radionuclides that have been measured at each waste site, sometimes at soil depths of over 4.6 m (15 ft) bgs. The ecological significance of the risks to wildlife potentially exposed at each area evaluated is discussed in the following bullets for the three 200-LW-1 and LW-2 OU representative waste sites at which radionuclide levels exceeded screening levels during the Level 2 screening. Tables 5-22 through 5-24 illustrate the radionuclide comparison.

- **216-T-28 Crib.** Although there are no data for the shallow zone in the 216-T-28 Crib on which to model risk, several assumption can be made about the shallow zone beneath the crib and the ecological risk presented. Maximum contaminant concentrations detected in the subsurface below the 216-T-28 Crib are found at depths greater than 4.6 m (15 ft). Nearly all biological activity occurs within the top 0.61 m (2 ft) of the soil column. Additionally, the construction of the crib and the material added for stabilization do not appear to be useful habitat or forage areas for surface and subsurface biota. Subsequently, the ecological risk presented by radionuclides in the shallow zone below the 216-T-28 Crib is considered negligible and can be excluded from further consideration.

- **216-S-20 Crib.** Using the maximum detected concentrations, the sum of all fractions for all radionuclides was 0.022. Only Eu-155 was detected above "background" at

0.062 pCi/g. When compared to the BCG of 20,000 pCi/g, Eu-155 was excluded from further consideration of risk.

- **216-Z-7 Crib**. Using the maximum detected concentrations, the sum of all fractions for all radionuclides was 0.023. Only Cs-137 and Np-237 were detected above background at 0.0835 pCi/g and 0.059 pCi/g, respectively, at a depth of 3.7-5.3 m (12-17.5 ft) bgs. The concentration of Cs-137 was compared to the BCG of 20 pCi/g, thus eliminating Cs-137 from further risk evaluation. There is no BCG for Np-237. Neptunium was detected at a depth of more than 4.7 m (12.5 ft) bgs. Most biological activity occurs in the topmost 2 ft of the soil column; indicating an approximately ten foot thick soil blanket between the contaminant and potential exposure points. Although Np-237 was detected in the 216-Z-7 Crib, the sum of all fractions is less than 1.0, and by definition, the ecological screening is complete. It is unlikely that the Np-237 will present any ecological or biological significance.

5.5.10 Conclusions and Recommendations

This SLERA assesses the potential impacts on terrestrial wildlife from past releases to soil at the 200-LW-1 and LW-2 OU waste sites and was conducted in accordance with EPA, Ecology, and DOE guidance. The resulting characterization of potential risk is expected to provide enough information that informed decisions can be made about these waste sites. The primary decision for which the results of the screening ecological risk assessment provide input is whether to address any areas and site-related contaminants at the waste site because of the potential threat to the environment. Therefore, results of a SLERA are used to determine which of the following recommendations can be made:

- No further ecological investigations at the waste site
- Continuation of the risk assessment process at the next level
- Undertake a removal or remedial action.

Based on the nature and extent of contaminant concentrations observed during the waste site investigation, and considering ecosystem characteristics, the following conclusions are made.

- On the basis of considering the background concentrations for metals at the Hanford Site and the screening levels for nonradionuclides, soil concentrations for nonradionuclides are not considered high enough to pose unacceptable risk to terrestrial wildlife at any of the 200-LW-1 and LW-2 OU representative waste sites evaluated.

- Radionuclide levels in soil do not exceed available Level 1 and 2 screening concentrations for terrestrial wildlife at the any of the waste sites.

- Although Np-237 was detected in samples from the 216-Z-7 Crib at a maximum concentration of 0.059 pCi/g, it was collected at a depth of 3.7-5.3 m (12 to 17.5 ft) bgs. Considering the conservative exposure and effect assumptions described in Section 5.2.6.3 used in the Level 1 screening for radionuclides, the magnitude of the exceedance of the screening level, reduced direct exposure with the stabilization cover, and the fact that the sum of all fractions is less than 1.0 the ecological significance of this exceedance to terrestrial wildlife populations is likely low.

Based on the results of this risk analysis, no further ecological investigations are warranted for the 200-LW-1 and LW-2 OU waste sites. Decisions on whether to undertake remedial actions are discussed in Chapter 6.0.

5.5.11 Data Gaps

Overall, the screening results suggest a negligible potential for adverse impact to ecological receptors at the waste sites. Missing data from the shallow zone in the 216-T-28 Crib is somewhat problematic, and appropriate sampling and analysis should be considered in the FS. Alternatively, one could draw an analogy between the 216-T-28 Crib and the 216-T-26 and 216-Z-7 Cribs, based on knowledge of the process streams that generated the wastes in the three cribs and based on similarities of inventories, construction, etc. and conclude that contaminants found in the 216-T-26 and 216-Z-7 Cribs likely would be found in similar concentrations in the 216-T-28 Crib. It would then follow that it is equally unlikely that any contaminants in the 216-T-28 Crib would be of ecological or biological significance.

5.6 SUMMARY OF RISK ASSESSMENT

Multimedia sampling and analysis results from three representative sites within the 200 Areas LW-1 and LW-2 OUs were analyzed for potential risk to human heath and ecological receptors. Contaminants included inorganic compounds, organic compounds, and radionuclides. Detections by grouping for the shallow soil interval are summarized as follows:

- **216-T-28 Crib.** Because of low sample recovery, analyses were not conducted on this interval, no samples above 4.6 m (15 ft) bgs
- **216-S-20 Crib.** Ten radionuclides, eight inorganic compounds, and no organic compounds were detected
- **216-Z-7 Crib.** Thirteen radionuclides, nine inorganic compounds, and no organic compounds were detected.

Detections by grouping for the deep soil interval are summarized as follows:

- **216-T-28 Crib.** Twenty-six radionuclides, 23 inorganic compounds, and 14 organic compounds were detected
- **216-S-20 Crib.** Twenty-two radionuclides, 21 inorganic compounds, and three organic compounds were detected
- **216-Z-7 Crib.** Twenty radionuclides, 22 inorganic compounds, and eight organic compounds were detected.

The risk assessment was conducted in accordance with the EPA risk assessment guidelines for superfund sites, WAC 173-340 regulations and guidelines, and established site precedent. The results of the risk assessment are summarized below.

Human Health Risk - Direct Exposure to Nonradiological Soil Contaminants

Risk-based soil screening levels were calculated for those exposure scenarios and exposure pathways that were considered complete. This includes the Industrial Worker exposure scenario with an ingestion exposure pathway. The exposure point is considered to be the topmost 4.6 m (15 ft) of the soil column. The exposure point concentration is the maximum contaminant concentration detected in this interval. Comparison of the EPCs to background, soil screening levels (SSL), and mobility analysis resulted in the following COPCs carried forward to the FS:

- **216-T-28 Crib**. Because of incomplete sample recovery, no shallow zone data is available for this representative site. Additional sampling should be considered in the FS and the potential risk calculated and re-evaluated
- **216-S-20 Crib**. None
- **216-Z-7 Crib**. None.

Human Health Risk – Protection of Groundwater from Nonradiological Soil Contaminants

Risk-based soil screening levels were calculated for protection of groundwater using Method B of the MTCA. The exposure point is considered to be the entire soil column. The exposure point concentration is the maximum contaminant concentration detected in this interval:

- **216-T-28 Crib**. Arsenic, bismuth, uranium, fluoride, ammonium ion as nitrogen, nitrate as nitrogen, nitrate and nitrate/nitrite as nitrogen, 4-chloro-3-methphenol, 2-butoxyethanol, phenol, TPH-kerosene range organics, TPH-diesel range organics
- **216-S-20 Crib**. Arsenic, bismuth, lead, mercury, uranium, methylene chloride
- **216-Z-7 Crib**. Arsenic, bismuth, uranium, nonadecane, 1,2,3-trichlorobenzene, ethyl acetate.

Bismuth, lead, and mercury all have K_ds greater than 40 and are considered to be immobile and are subsequently excluded from this risk assessment. Sulfide regulation is based on secondary aesthetic standards such as odor and taste. Subsequently, sulfide is excluded from further consideration. The concentration of fluoride is 1.6 times greater than the SSL; that of nitrate as nitrogen is only 1.02 times the SSL; and that of nitrate and nitrate/nitrite as nitrogen is only 1.14 times greater than the SSL. Although these compounds were detected above background concentrations and soil screening levels, the exceedances are small and are the maximum detected concentrations. Additionally, the groundwater beneath the Hanford Site is not currently used nor planned for in the future as a drinking water supply. The conservative assumptions used in the calculation of the SSLs suggest these exceedances present a negligible risk to human health.

The arsenic potential to reach the groundwater in 1,000 years was evaluated using RESRAD, Version 6.21. Uranium-238 was selected to emulate the arsenic behavior in the vadose zone since its half life is very large and a negligible portion of its mass is lost because of decay within 1,000 years. The U-238 K_d was specified equal to 29 L/kg, which is the arsenic K_d. Based on the RESRAD calculations it can be concluded that a non-decaying contaminant with the K_d equal to 29 L/kg will not reach groundwater within 1,000 years assuming that the current depth of contaminated zone extends to about 50 m (165 ft). Based on this, arsenic can be excluded from the list of the potential contaminants of concern.

Uranium has low distribution coefficient and would be expected to be mobile and reach groundwater quickly. However, uranium transport in the vadose zone considered in the radioactive contaminant analysis using RESRAD showed that none of the uranium isotopes reaches groundwater in 1,000 years. Based on this, uranium is excluded from the list of the potential contaminants of concern.

Nonadecane was detected in very low concentration (1.5 mg/kg) in only one sample. The concentration was estimated (the sample has laboratory qualifier marked as "J"). It is suspected that the detection of these contaminants is because of sample contamination in the laboratory. Consequently, nonadecane was not included on the list of potential contaminants of concern for further consideration.

The cyanide potential to reach the groundwater in 1,000 years was evaluated using RESRAD 6.21. Uranium-238 was selected to emulate the cyanide behavior in the vadose zone since its half life is very large and a negligible portion of its mass is lost because of decay within 1,000 years. The U-238 K_d was specified equal to 0 L/kg, which is the cyanide K_d. The concentration of uranium was specified equal to the concentration of cyanide (3.95 mg/kg). This concentration was converted to pCi/g (6.32×10^{-11} pCi/g). The uranium (cyanide) reaches the groundwater within 1,000 years with the maximum concentration at 700 yrs. The maximum concentration is 3.3×10^{-13} pCi/L, which is equivalent of 0.21 ug/L. The MCL for cyanide is 200 ug/L. Consequently, even though cyanide is likely to reach the groundwater within the 1,000-year time period, its maximum concentration will be significantly below the MCL. Based on this, cyanide is excluded from the list of the potential contaminants.

Nitrate is the only contaminant that exceeds background concentrations, exceeds the WAC 173-340 groundwater protection screening standards, and reaches groundwater in less than 1,000 years.

Human Health Risk - Direct Exposure to Radiological Soil Contaminants

Risk-based soil screening levels were calculated for the Industrial Worker exposure scenario with an ingestion exposure pathway. The exposure point is considered to be the topmost 4.6 m (15 ft) of the soil column. The exposure point concentration is the maximum contaminant concentration detected in this interval:

- **216-T-28 Crib**. Because of incomplete sample recovery, no shallow zone data are available for this representative site. Additional sampling should be considered in the FS and the risk calculated and re-evaluated

- **216-S-20 Crib**. Eu-155 (0.062pCi/g)

- **216-Z-7 Crib.** Cs-137 (0.0835 pCi/g), Eu-155 (0.062 pCi/g), Np-237 (0.059 pCi/g), U-237 (1310 pCi/g).

Although detected above background levels, these contaminants are very low in activity and are covered by more than 10 ft of soil. It is unlikely these contaminants will present a significant risk to human health.

Human Health Risk – Protection of Groundwater from Radiological Soil Contaminants

Risk-based soil screening levels were calculated for protection of groundwater using WAC 173-340, Method B. The exposure point is considered to be the entire soil column. The exposure point concentration is the maximum contaminant concentration detected in this interval. Radionuclides detected above background are summarized below:

- **216-T-28 Crib.** Am-241, Sb-125, C-14, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Np-137, Ni-63, Pu-238, Tc-99, Th-228, Sr-90, Tritium, U-233/234, U-235, U-238
- **216-S-20 Crib.** Am-241, C-14, Cs-137, Co-60, Eu-154, Eu-155, Np-237, Ni-63, Pu-238, Ra-228, Tc-99, Th-228, Sr-90, Tritium, U-233/234, U-235, U-238,. Pu-239, U-236
- **216-Z-7 Crib.** Am-241, Cs-137, Co-60, Eu-154, Eu-155, Np-237, Ni-63, Pu-238, Tc-99, Th-228, Th-232, Ra-238, Sr-90, Tritium, U-236.

RESRAD modeling has shown that of the radionuclides present, only tritium and technetium reach groundwater in less than 1,000 years. In the 216-T-28 Crib, these compounds reach groundwater in 4.5 years with excess cancer rates of 4.8×10^{-6} and 9.0×10^{-4}, respectively. In the 216-S-20 Crib, only tritium reaches groundwater in less than 1,000 years and represents an excess cancer risk of 7.0×10^{-6}. In the 216-Z-7 Crib, americium and tritium reach groundwater in less than 1,000 years. The total dose during this time period is below 0.3 mrem/yr. The peak excess cancer risk associated with tritium is 3.6×10^{-6} in year three, which is above regulatory limit. The maximum excess risk associated with Am-241 within 1,000-year period is only slightly above the regulatory limit (1.6×10^{-6}). Taking into account the fact that the concentration of Am-241 at the depths greater than 50 m (164 ft) is only 10 pCi/g, which is significantly lower than the concentration of 60,600 pCi/g used in the modeling, the dose associated with Am-241 is insignificant, and the excess cancer risk just slightly above the regulatory limit, Am-241 can be excluded from the list of the potential contaminants of concern. Tritium and technetium are the remaining contaminants of concern.

Screening Level Ecological Risk Assessment – Nonradionuclides and Radionuclides

Soil screening levels were calculated for protection of wildlife using general assumptions with an ingestion exposure pathway. The exposure point is considered to be the topmost 15 ft of the soil column. The exposure point concentration is the maximum contaminant concentration detected in this interval.

- **216-T-28 Crib.** Although there are no data for the shallow zone in the 216-T-28 Crib on which to model risk, several assumption can be made about the shallow zone beneath the crib and the ecological risk presented. Maximum contaminant concentrations detected in the subsurface below the 216-T-28 Crib are found at depths greater than 4.6 m (15 ft).

Nearly all biological activity occurs within the top 0.61 m (2 ft) of the soil column. Additionally, the construction of the crib and the material added for stabilization do not appear to be useful habitat or forage areas for surface and subsurface biota. Subsequently, the ecological risk presented by radionuclides in the shallow zone below the 216-T-28 Crib is considered negligible and can be excluded from further consideration.

- **216-S-20 Crib**. There are no nonradiological contaminants in the topmost 4.6 m (15 ft) of the soil column that exceed background or wildlife exposure factors. Using the maximum detected concentrations, the sum of all fractions for all radionuclides was 0.022. Only Eu-155 was detected above "background" at 0.062 pCi/g. When compared to the BCG of 20,000 pCi/g, Eu-155 was excluded from further consideration of risk.
- **216-Z-7 Crib**. There are no nonradiological contaminants in the topmost 4.6 m (15 ft) of the soil column that exceed background or wildlife exposure factors. Using the maximum detected concentrations, the sum of all fractions for all radionuclides was 0.023. Only Cs-137 and Np-237 were detected above background at 0.0835 pCi/g and 0.059 pCi/g, respectively, at a depth of 3.7-5.3 m (12-17.5 ft) bgs. The concentration of Cs-137 was compared to the BCG of 20 pCi/g, thus eliminating Cs-137 from further risk evaluation. There is no BCG for Np-237. Neptunium was detected at a depth of more than 3.8 m (12.5 ft) bgs. Most biological activity occurs in the topmost 2 ft of the soil column, indicating an approximately ten-foot thick soil blanket between the contaminant and potential exposure points. Although Np-237 was detected in the 216-Z-7 Crib, the sum of all fractions is less than 1.0, and by definition, the ecological risk is acceptable and screening is complete. It is unlikely that the Np-237 will present any ecological or biological significance.

Based on the analysis conducted on the data provided for the representative wastes sites in the 200 Area LW-1 and 200-LW-2 Operable Units, with the exception of the 216-T-28 Crib, there does not appear to be significant human health or ecological risks associated with these sites nor is any anticipated in the future.

From an ecological perspective, the risk presented by contaminants in the shallow zone beneath the 216-T-28 Crib can be considered as follows: although there are no data for the shallow zone in the 216-T-28 Crib on which to model risk, several assumption can be made about the shallow zone beneath the crib and the ecological risk presented. Maximum contaminant concentrations detected in the subsurface below the 216-T-28 Crib are found at depths greater than 4.6 m (15 ft). Nearly all biological activity occurs within the top 0.61 m (2 ft) of the soil column. Additionally, the construction of the crib and the material added for stabilization do not appear to be useful habitat or forage areas for surface and subsurface biota. Subsequently, the ecological risk presented by radionuclides in the shallow zone below the 216-T-28 Crib is considered negligible and can be excluded from further consideration.

From a human health perspective, further investigation is required to evaluate the risk presented by the 216-T-28 Crib waste site.

Figure 5-1. Conceptual Site Model for Human Health and Biota.

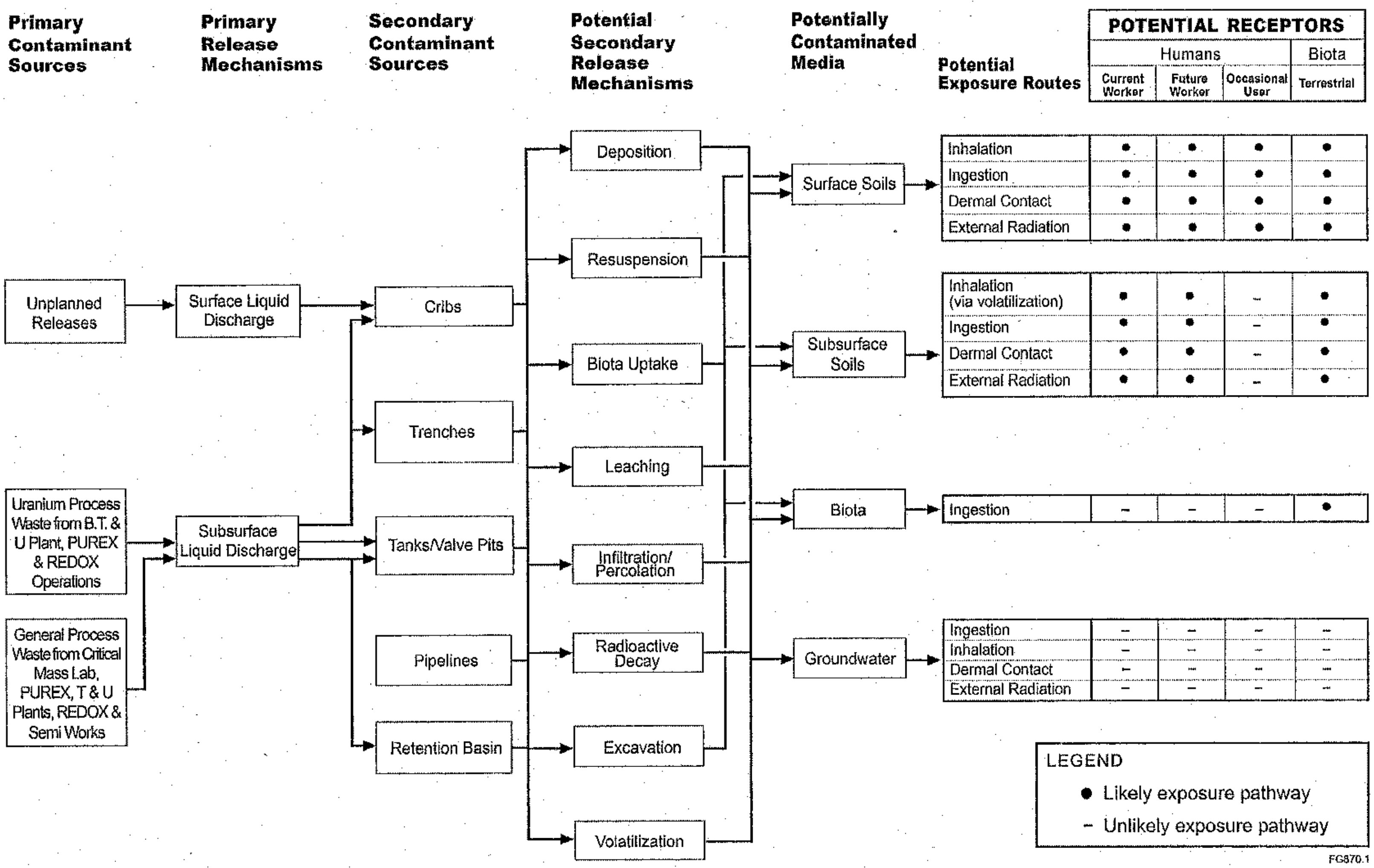
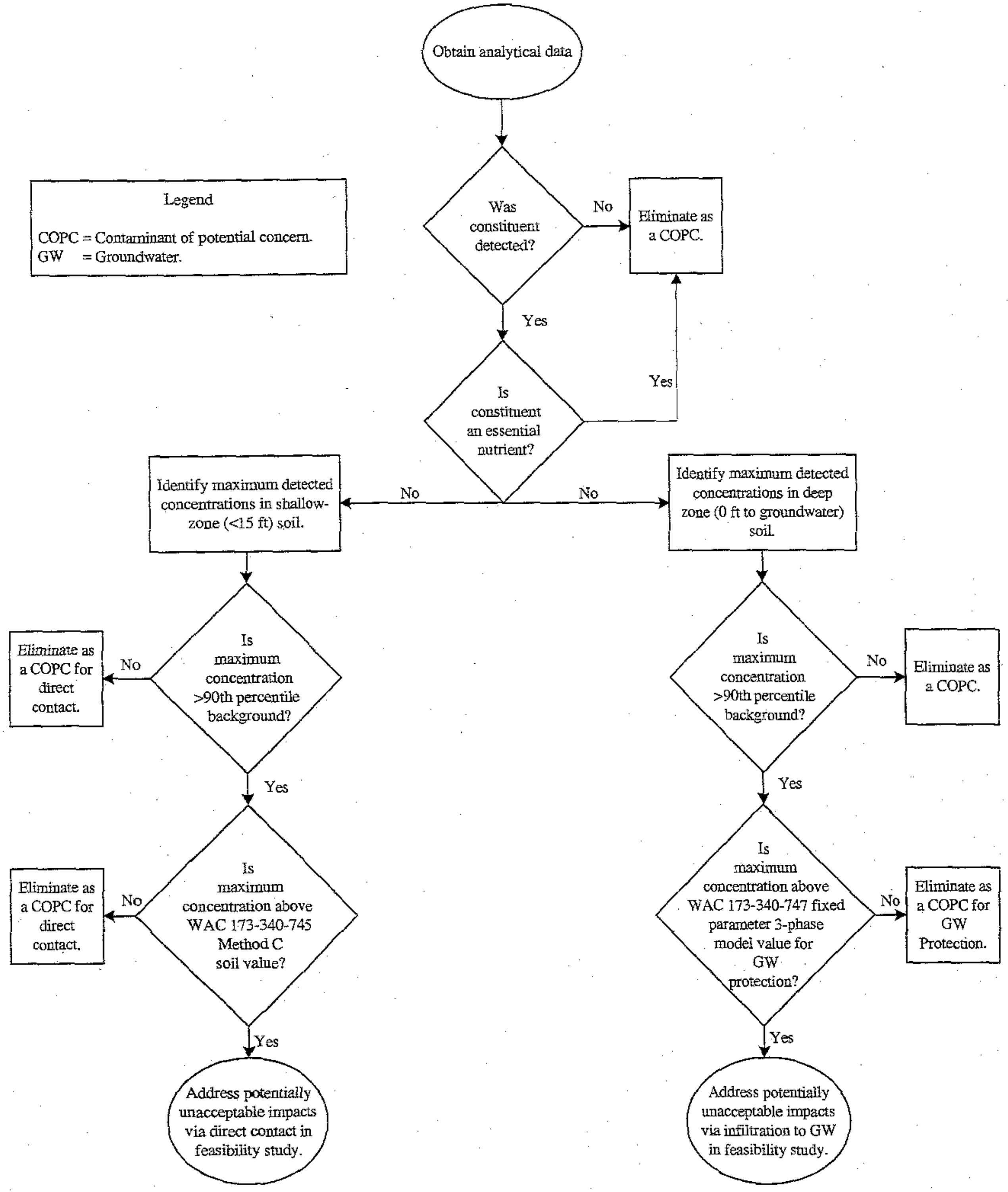


Figure 5-2. Human Health Flowchart for Nonradionuclides.



Note: All waste sites are within the boundaries of the 200 East or 200 West Areas, inside the Core Zone, and are analyzed under WAC 173-340-745 for direct contact.

Figure 5-3. Human Health Flowchart for Radionuclides.

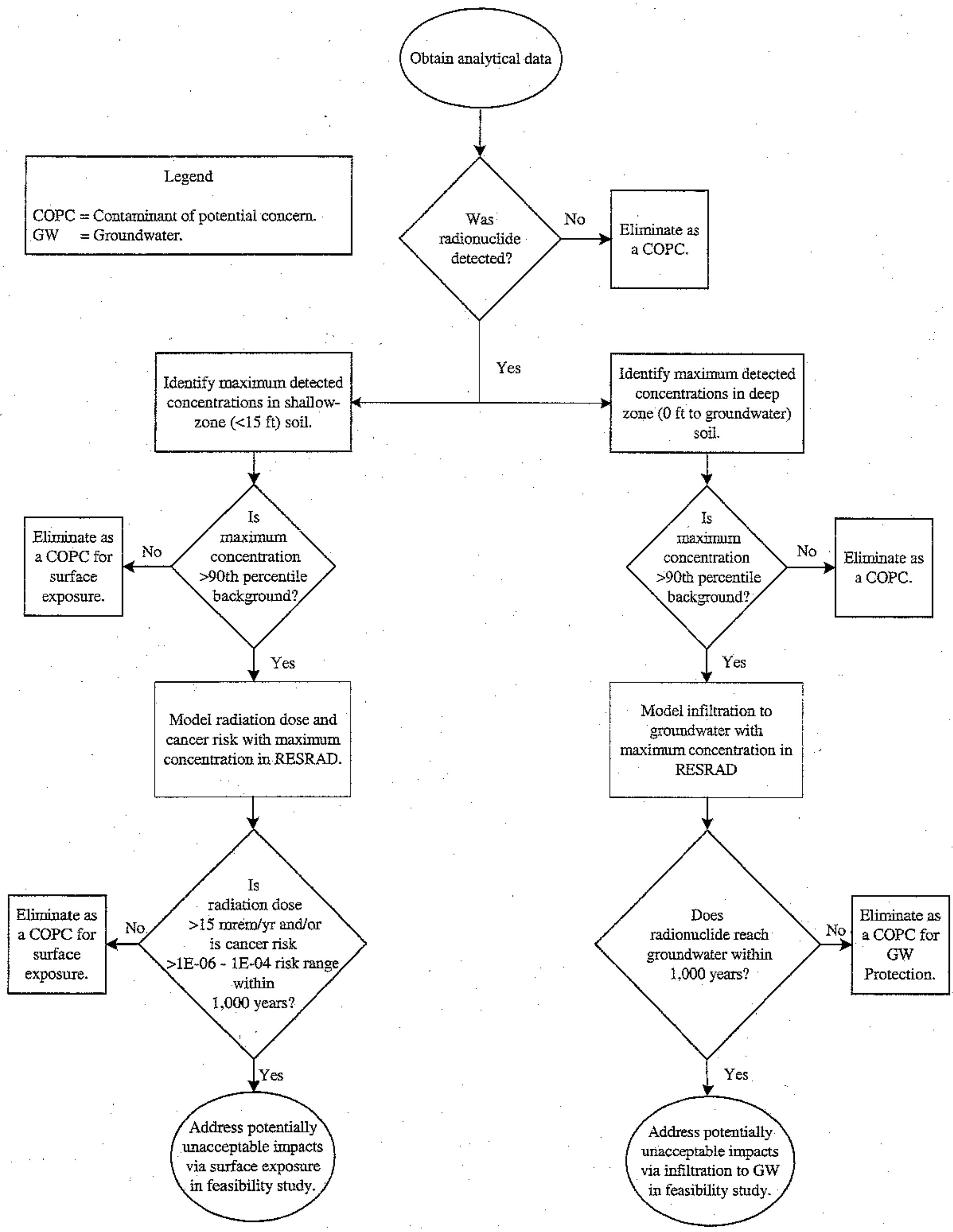
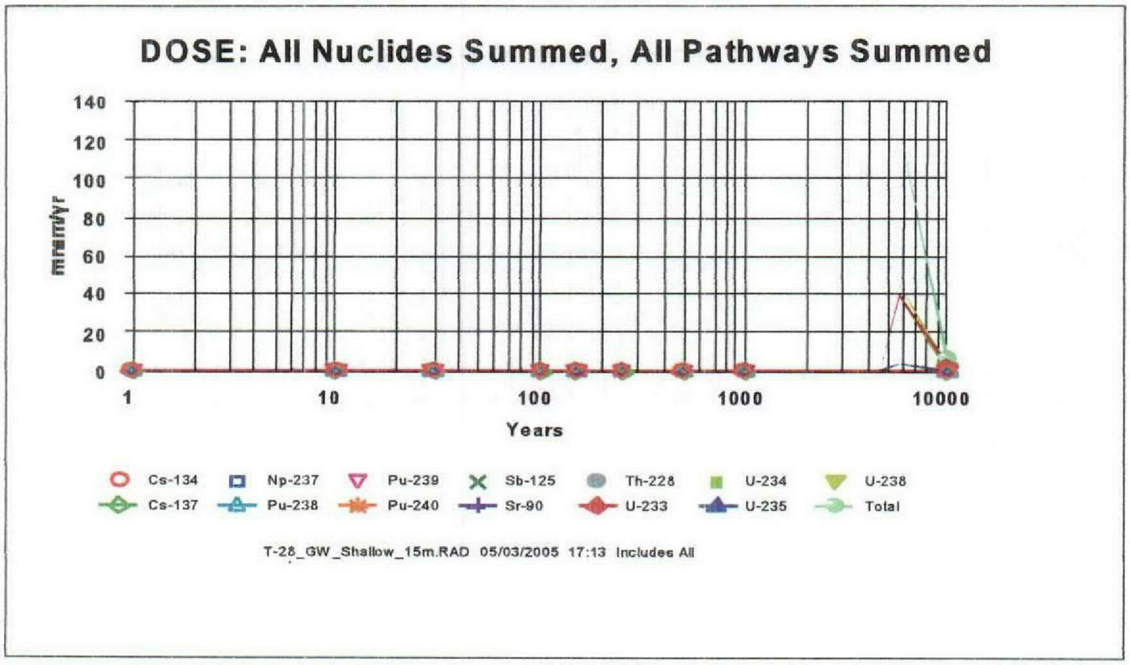


Figure 5-4. RESRAD Analysis for 216-T-28 Crib, Total Dose and Risk Groundwater Pathways Shallow Contaminant Transport Zone Depth of 15 m.



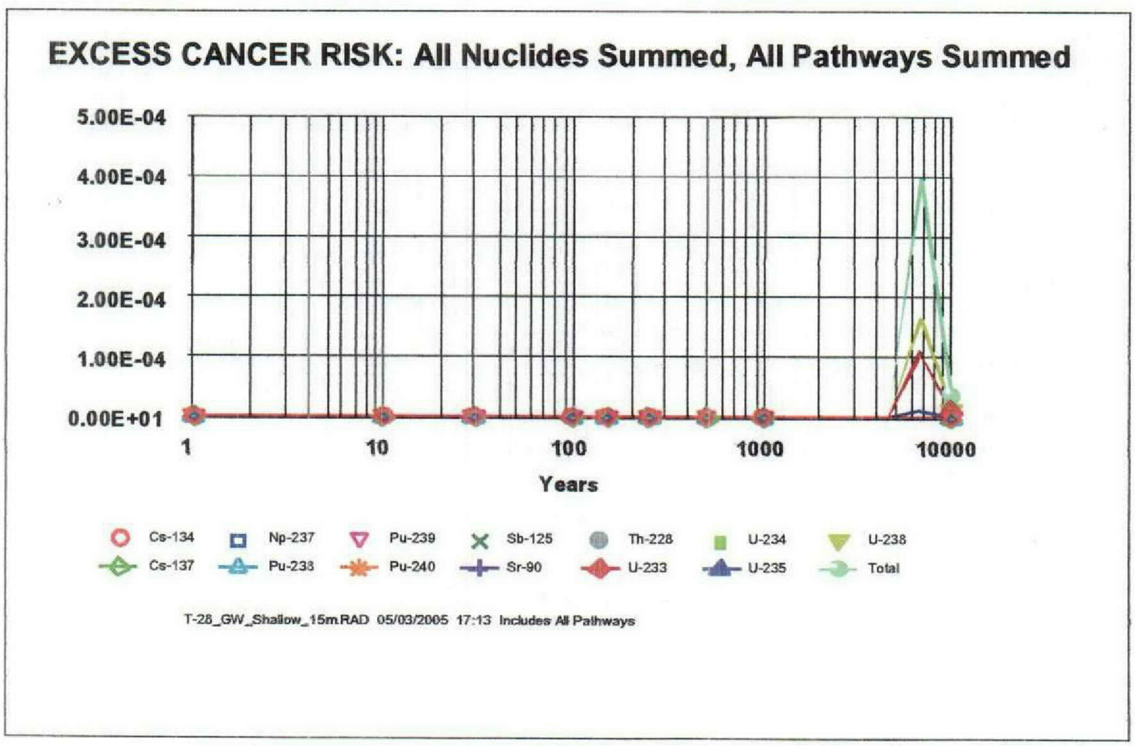
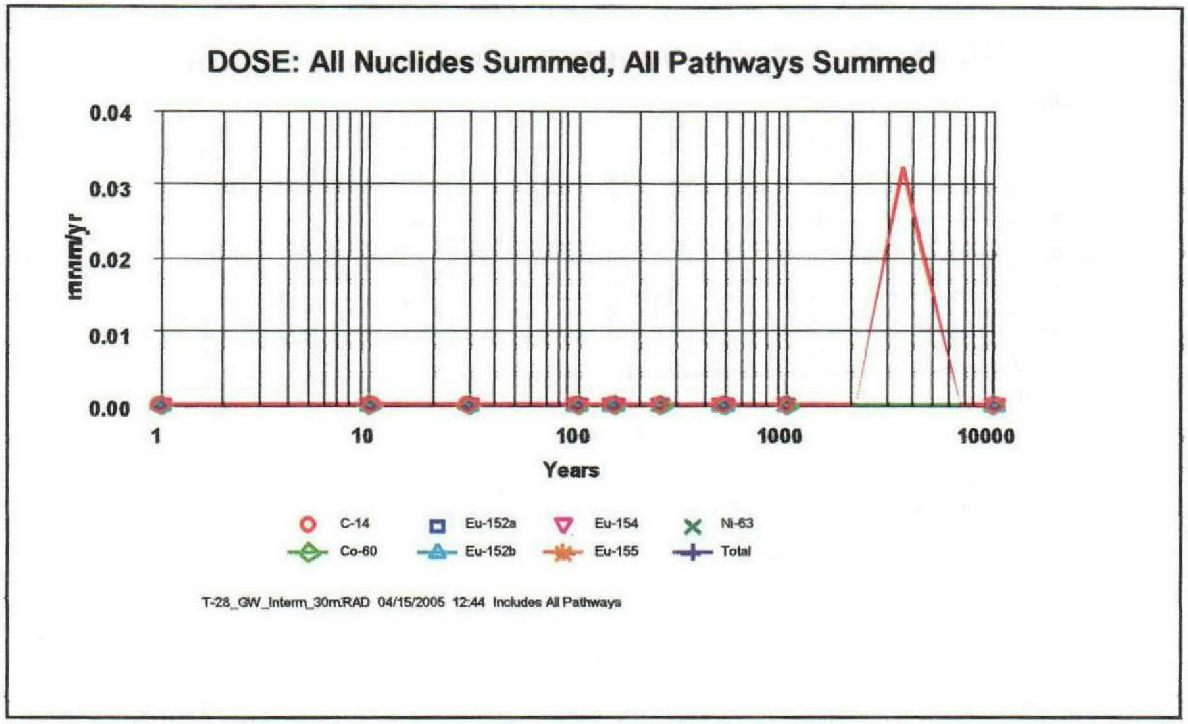


Figure 5-5. RESRAD Analysis for 216-T-28 Crib, Total Dose and Risk Groundwater Pathways, Intermediate Contaminant Transport Zone Depth of 30 m.



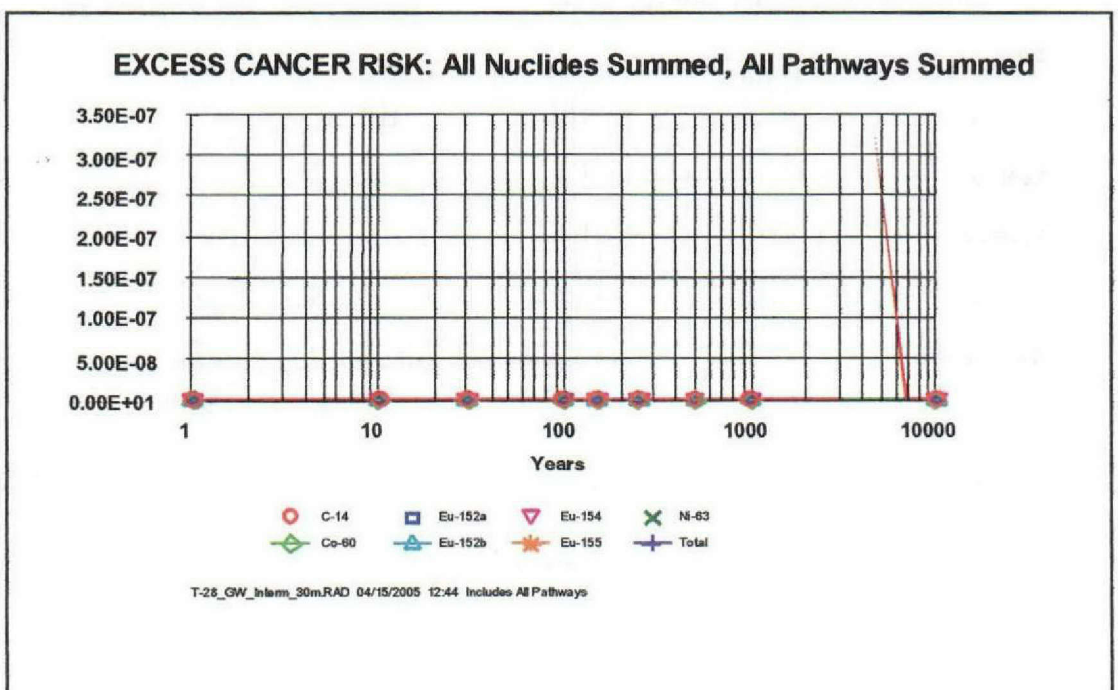
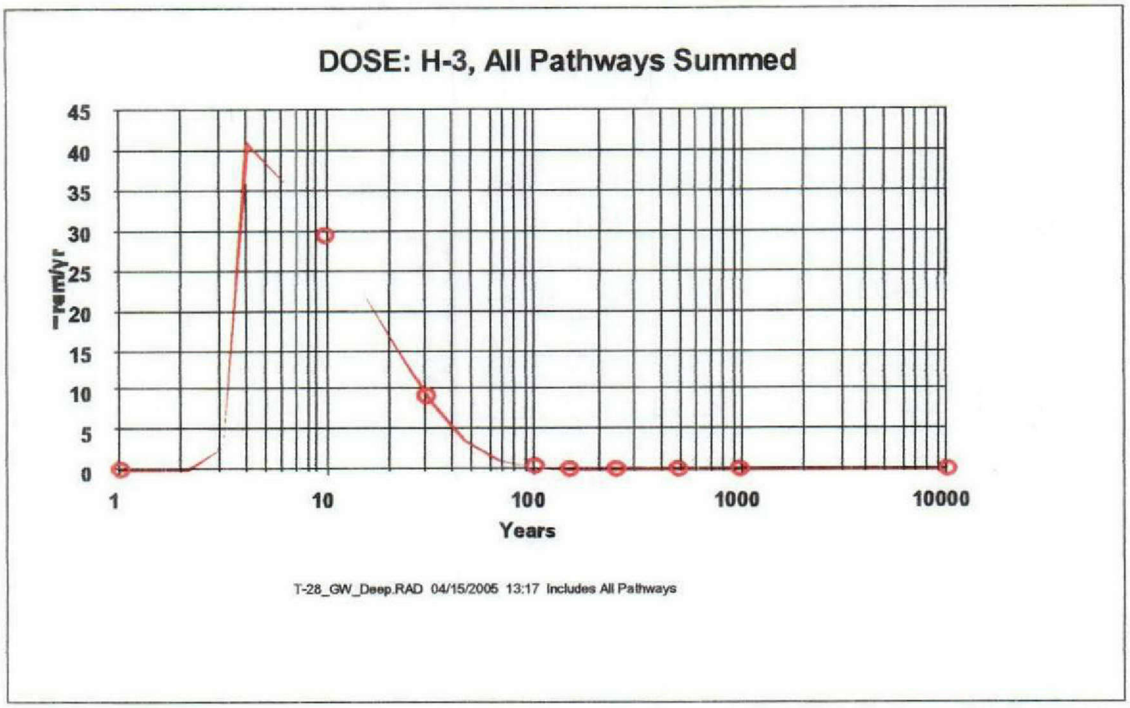


Figure 5-6. RESRAD Analysis for 216-T-28 Crib, Tritium Total Dose and Risk Estimates, Groundwater Pathway, Deep Contaminant Transport Zone Depth of 69 m.



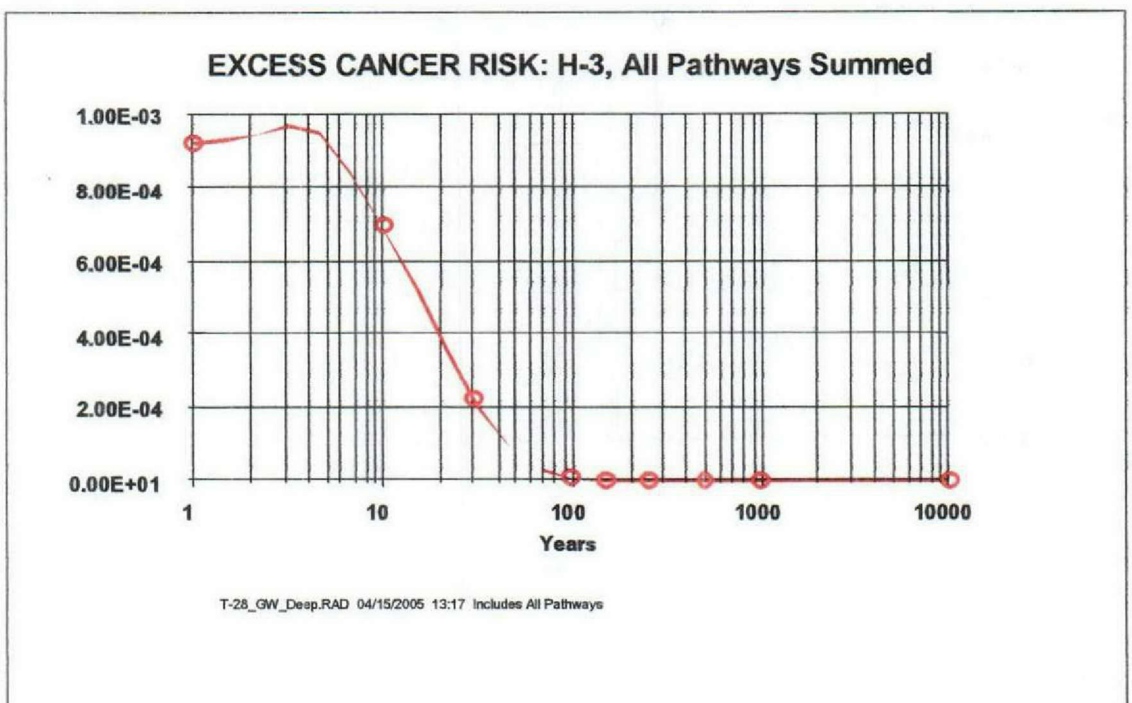
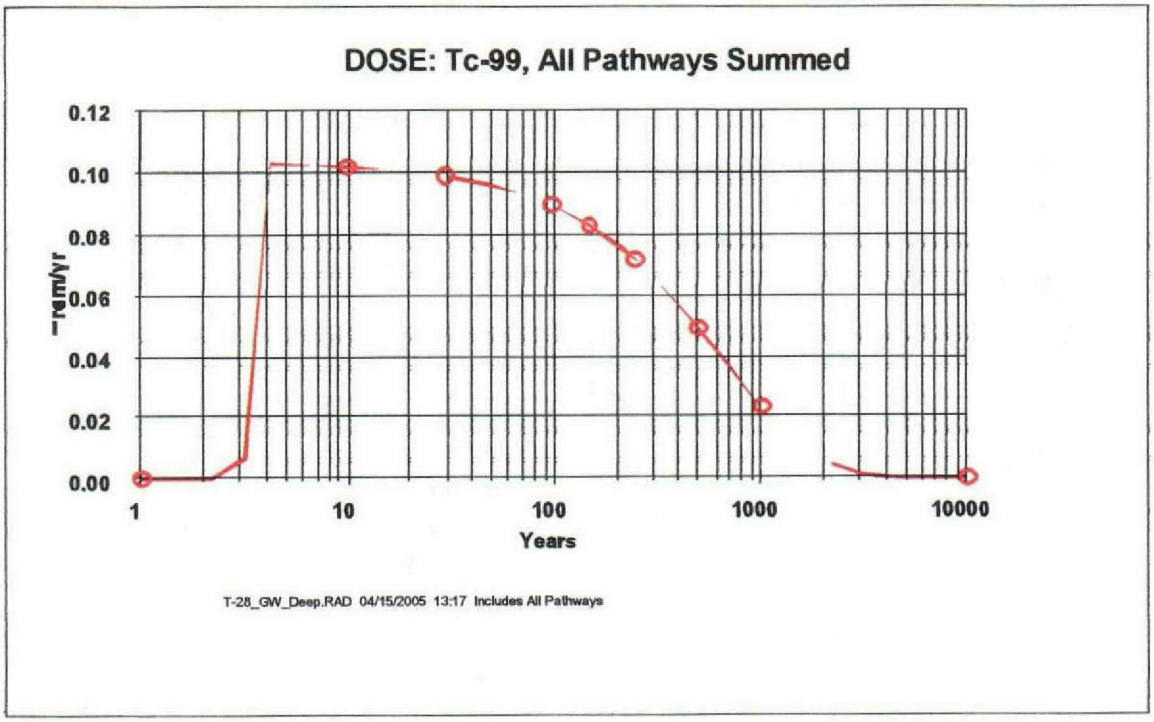


Figure 5-7. RESRAD Analysis for 216-T-28 Crib, Tc-99 Total Dose and Risk Groundwater Pathways, Deep Contaminant Transport Zone.



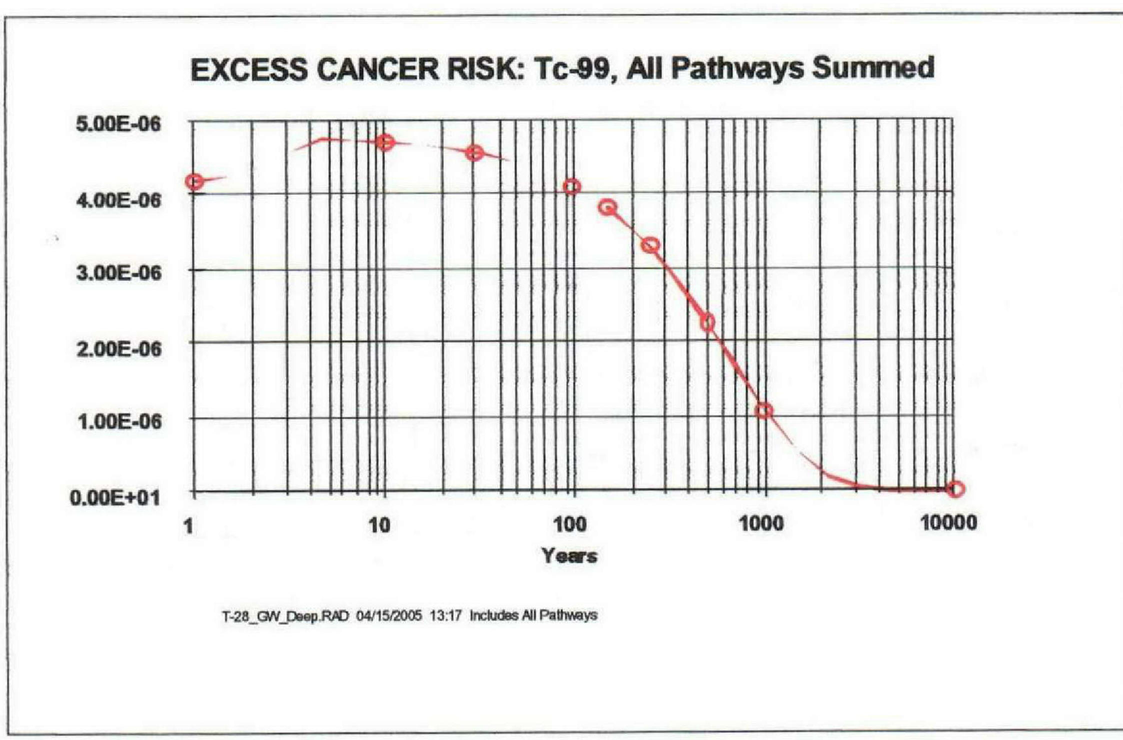
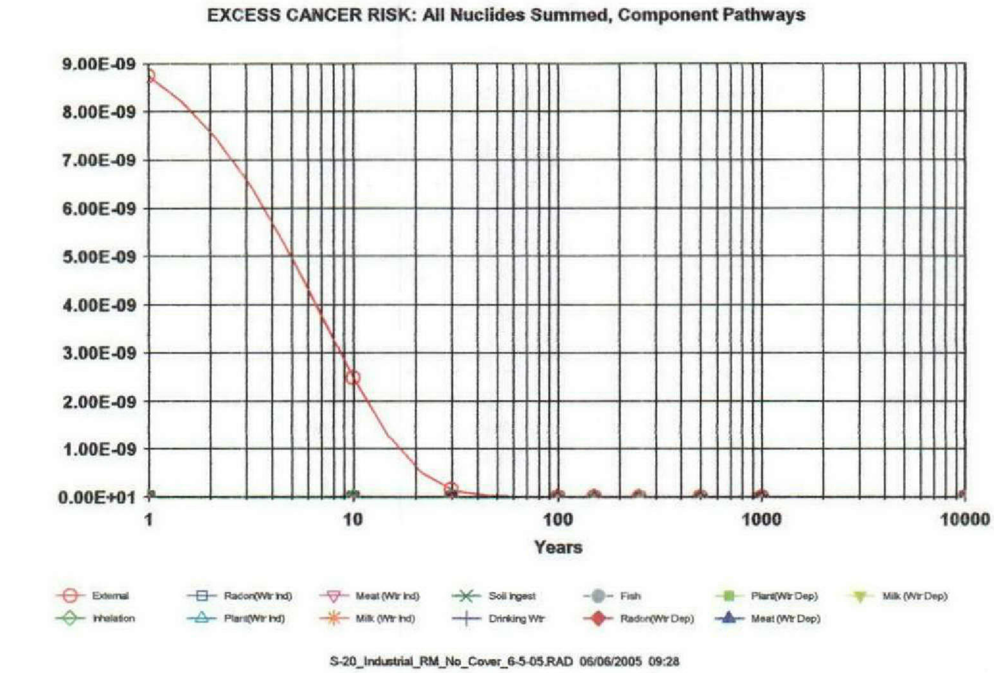


Figure 5-8. RESRAD Analysis for the 216-S-20 Crib, All Radionuclides, All Pathways Dose and Risk Estimates (No Cover, Industrial Scenario).



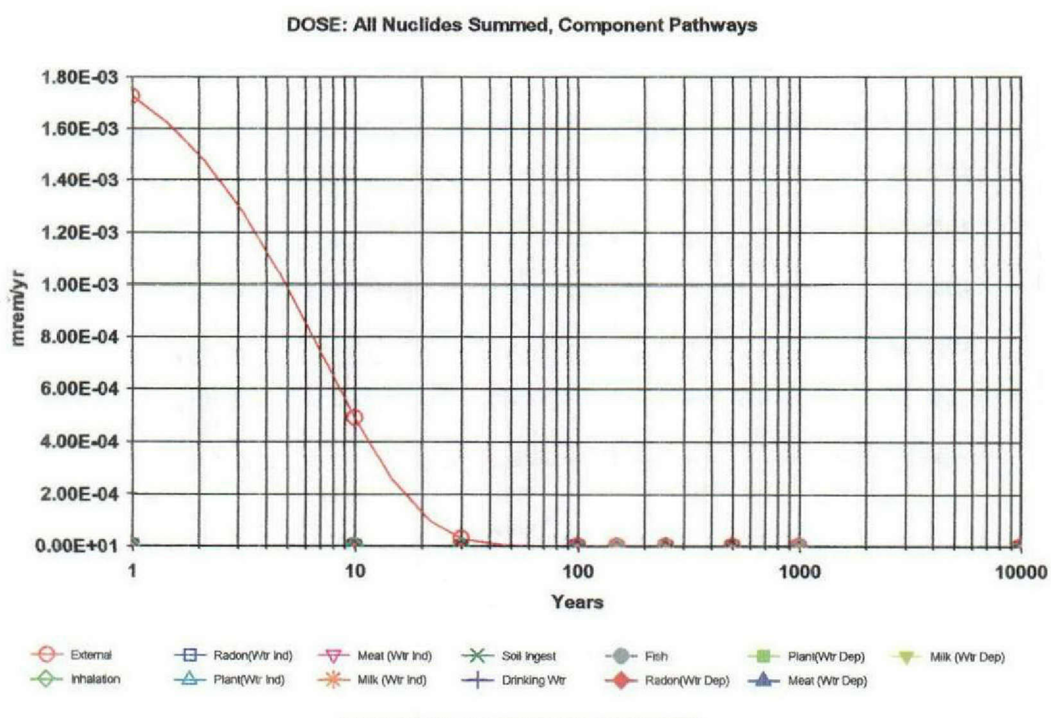
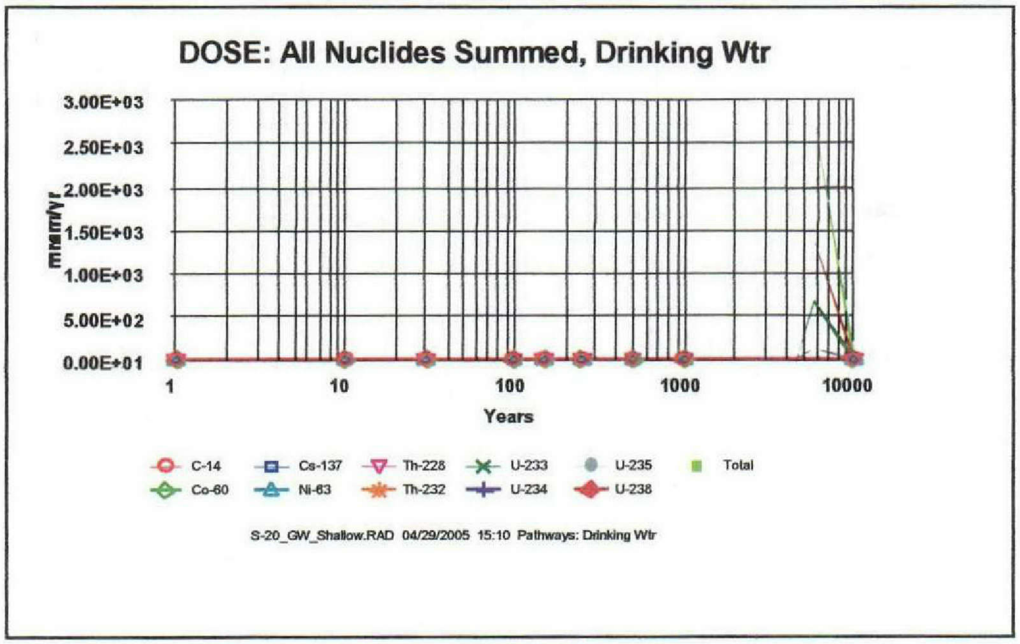


Figure 5-9. RESRAD Analysis for 216-S-20 Crib, Total Dose and Risk Groundwater Pathways, Shallow Contaminant Transport Zone Depth of 15 m.



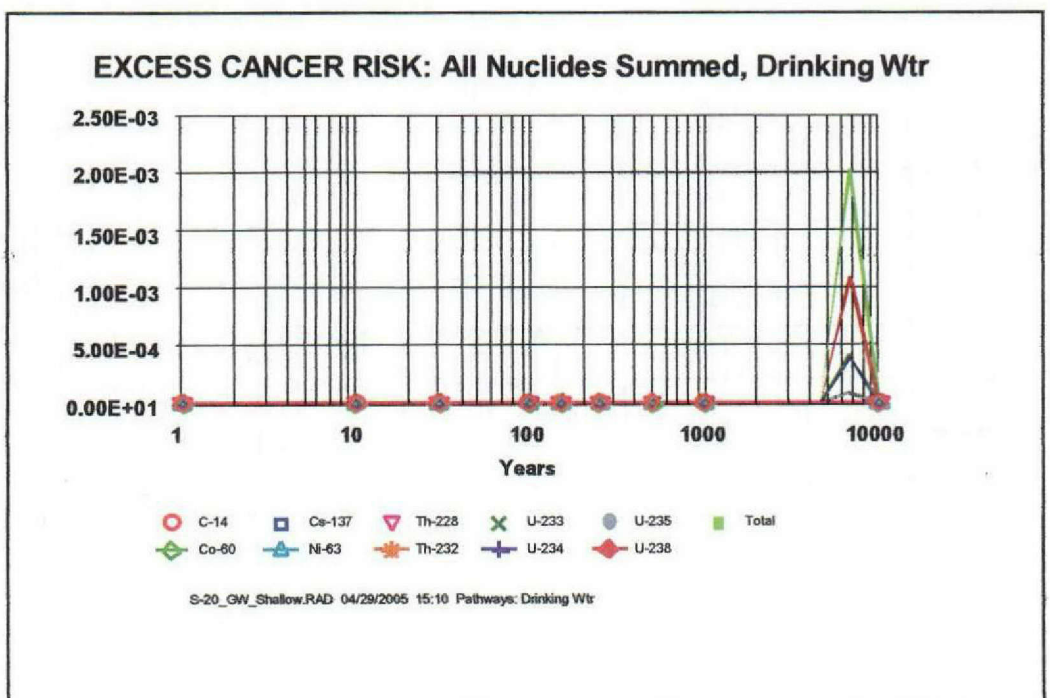
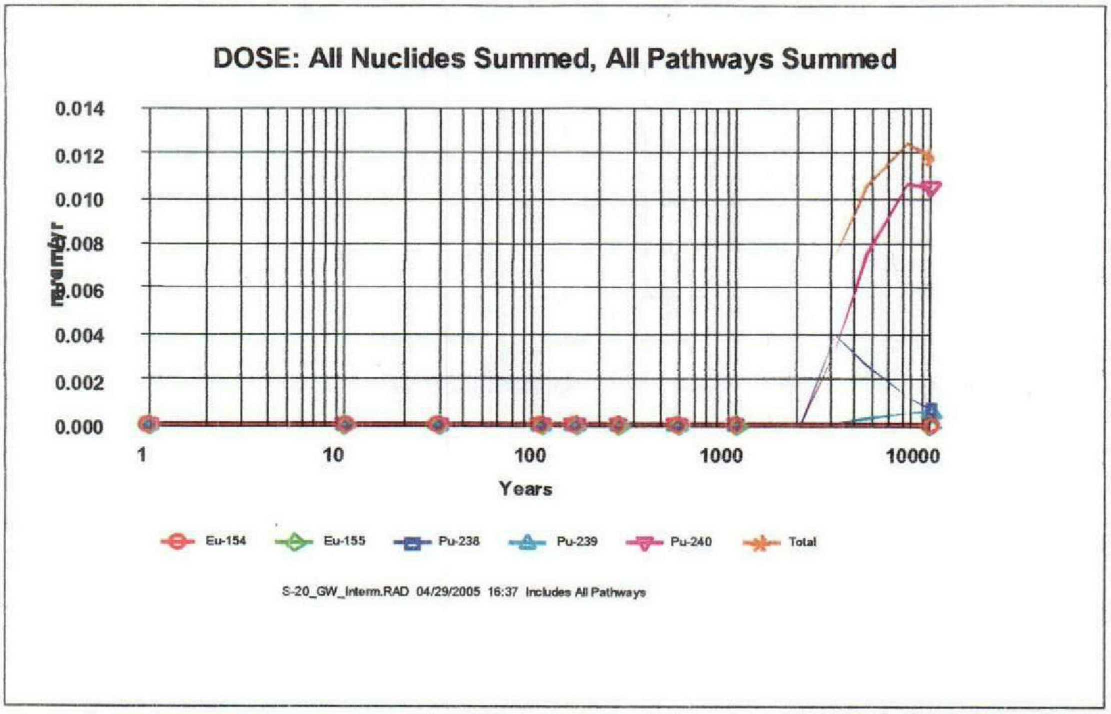


Figure 5-10. RESRAD Analysis for 216-S-20 Crib, Total Dose and Risk Groundwater Pathways, Intermediate Contaminant Transport Zone Depth of 50 m.



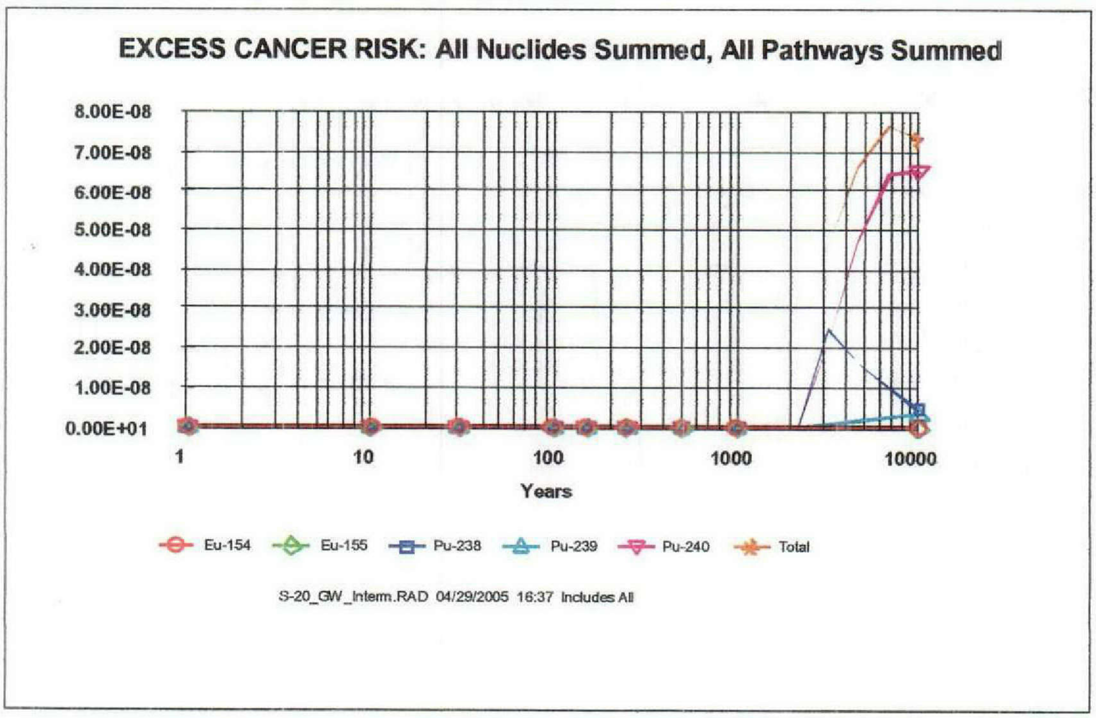
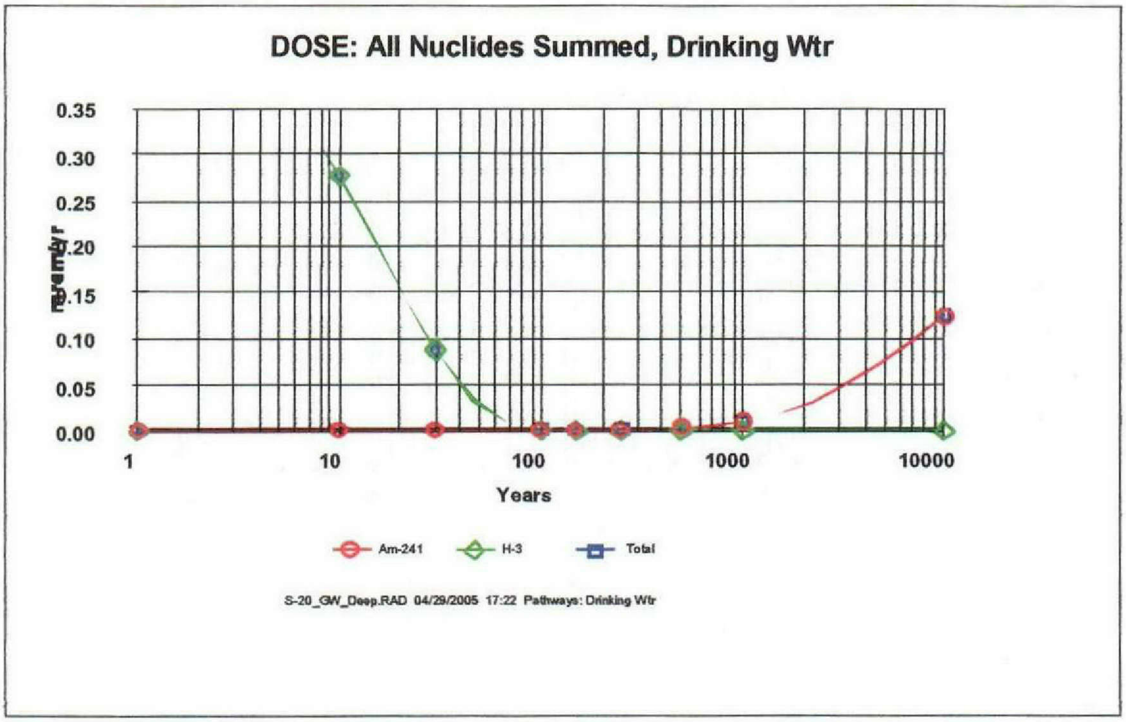


Figure 5-11. RESRAD Analysis for 216-S-20 Crib, Total Dose and Risk Groundwater Pathways, Deep Contaminant Transport Zone Depth of 73 m.



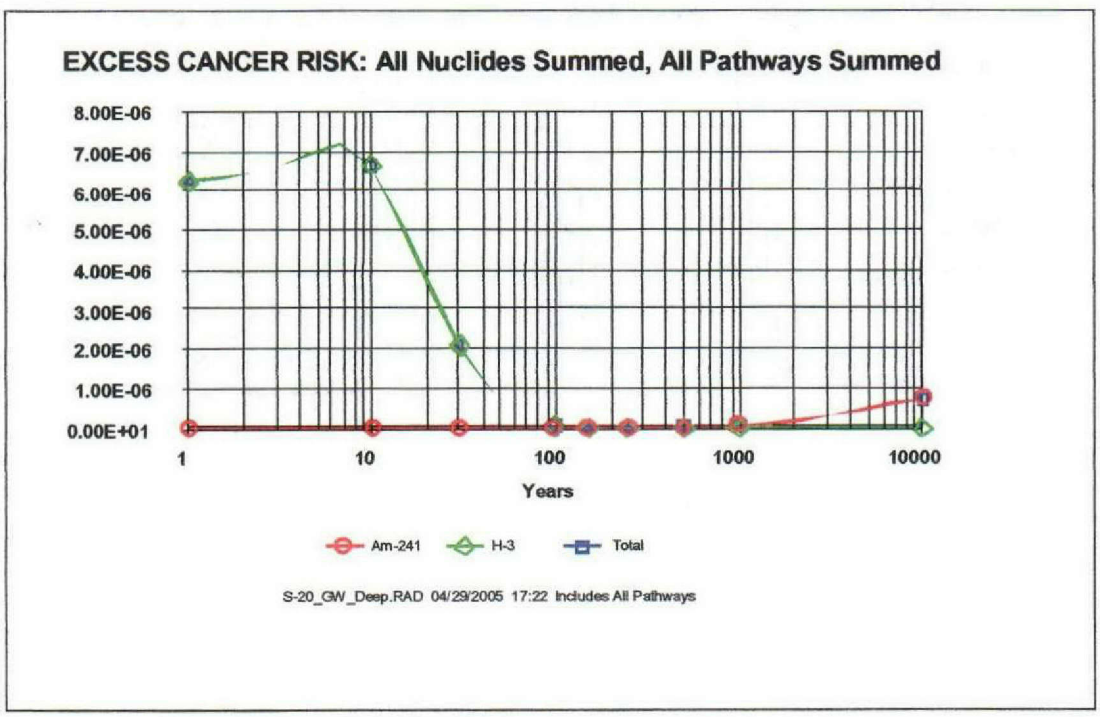
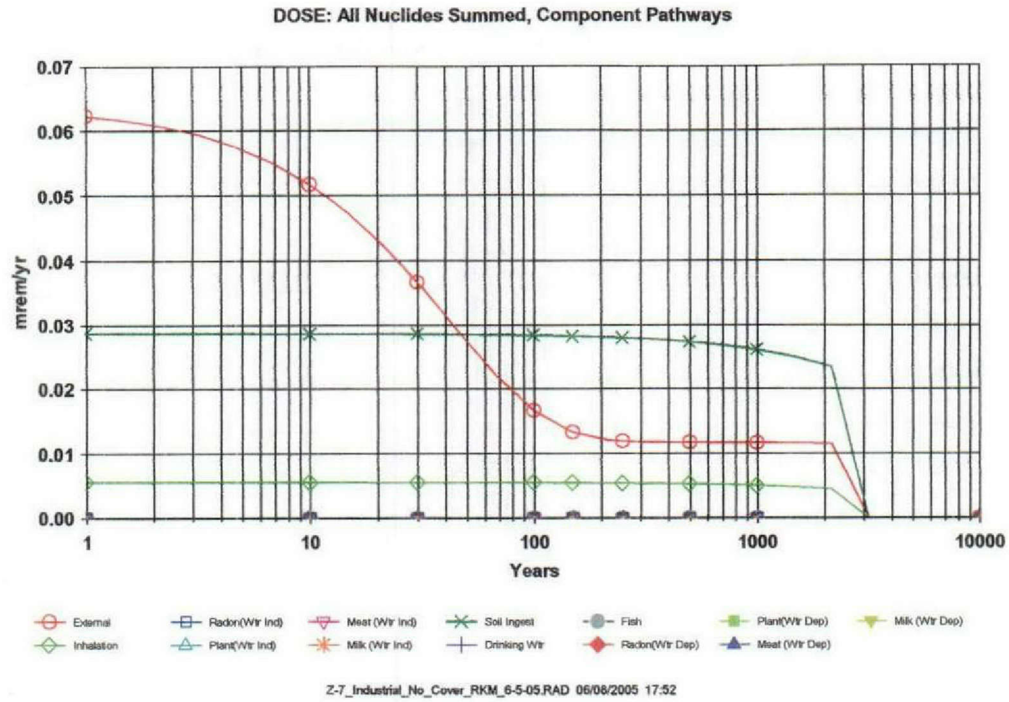


Figure 5-12. RESRAD Analysis for the 216-Z-7 Crib, All Radionuclides, All Pathways Dose and Risk Estimates (No Cover, Industrial Scenario).



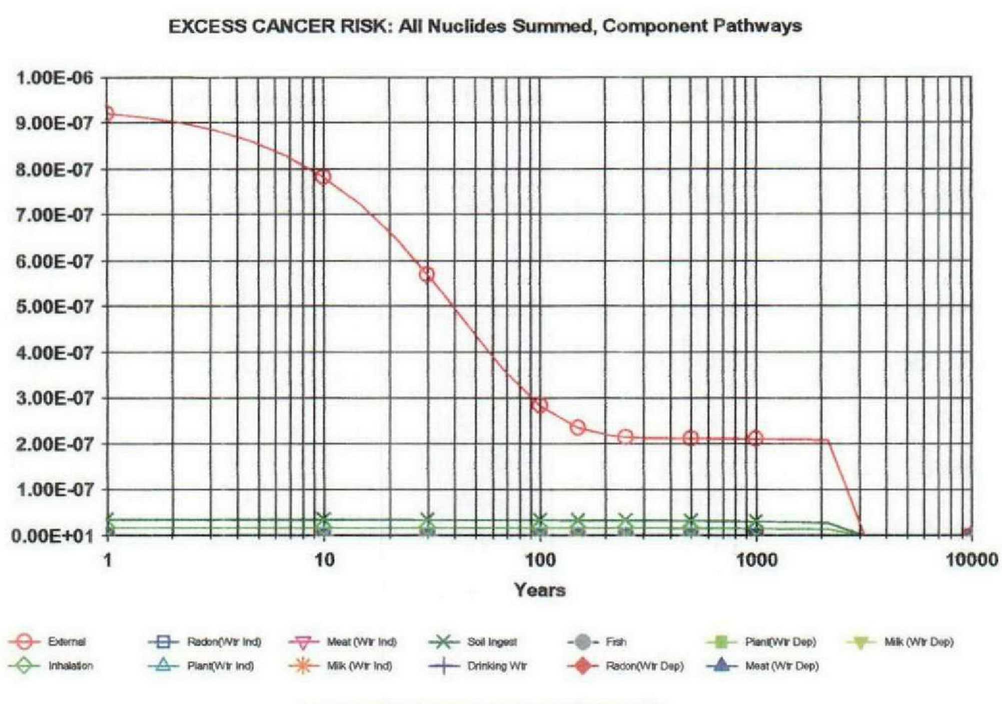
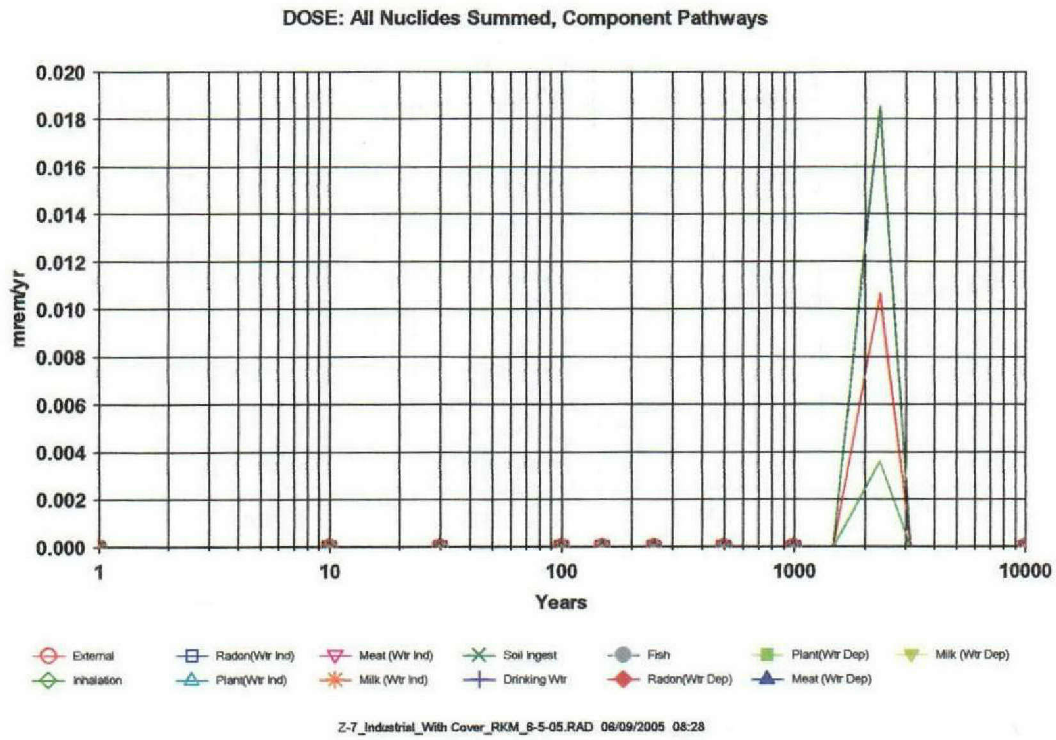


Figure 5-13. RESRAD Analysis for the 216-Z-7 Crib, All Radionuclides, All Pathways Dose and Risk Estimates (Cover, Industrial Scenario).



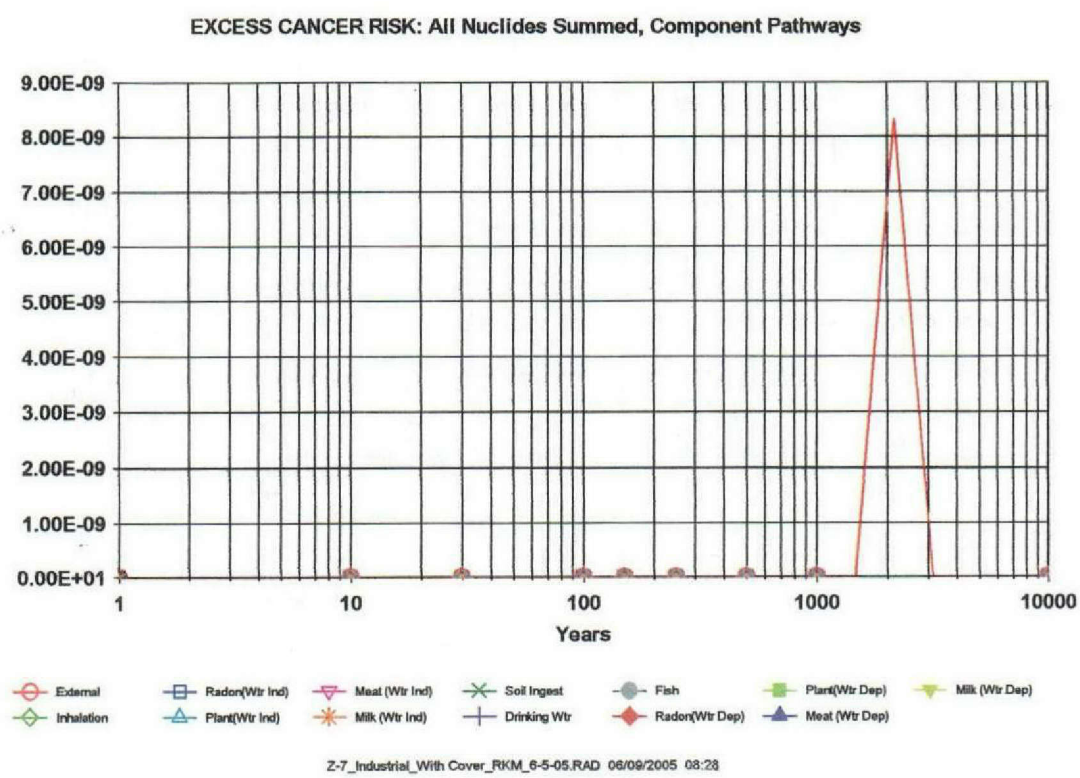
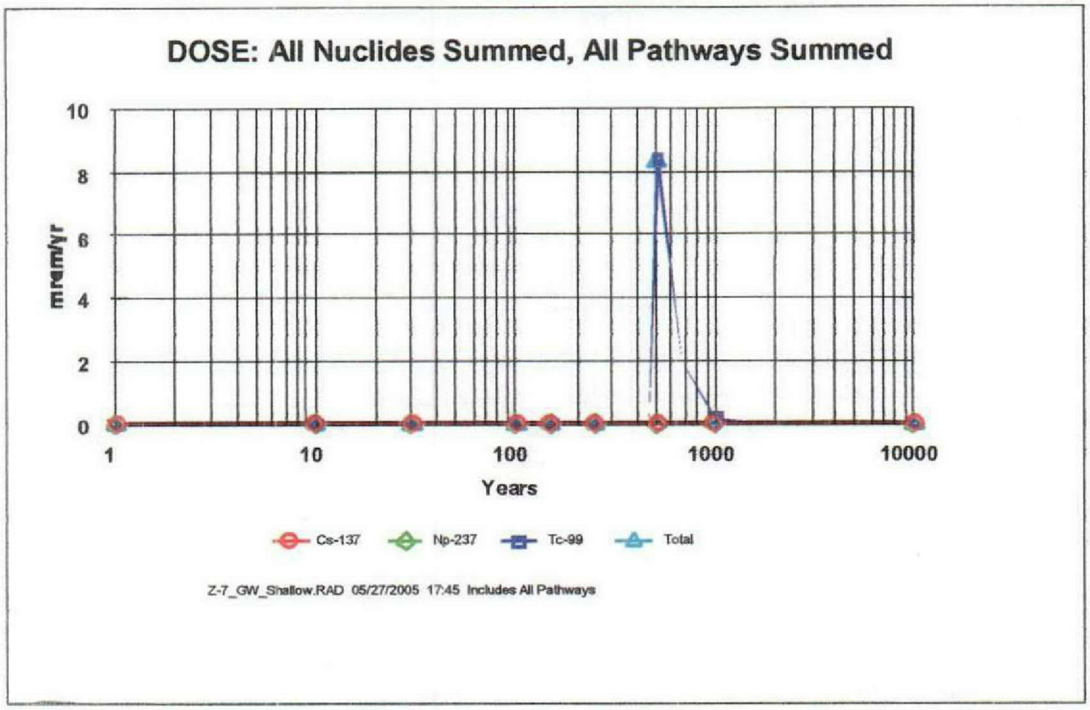


Figure 5-14. RESRAD Analysis for 216-Z-7 Crib, Total Dose and Risk Groundwater Pathways, Shallow Contaminant Transport Zone Depth of 18 m.



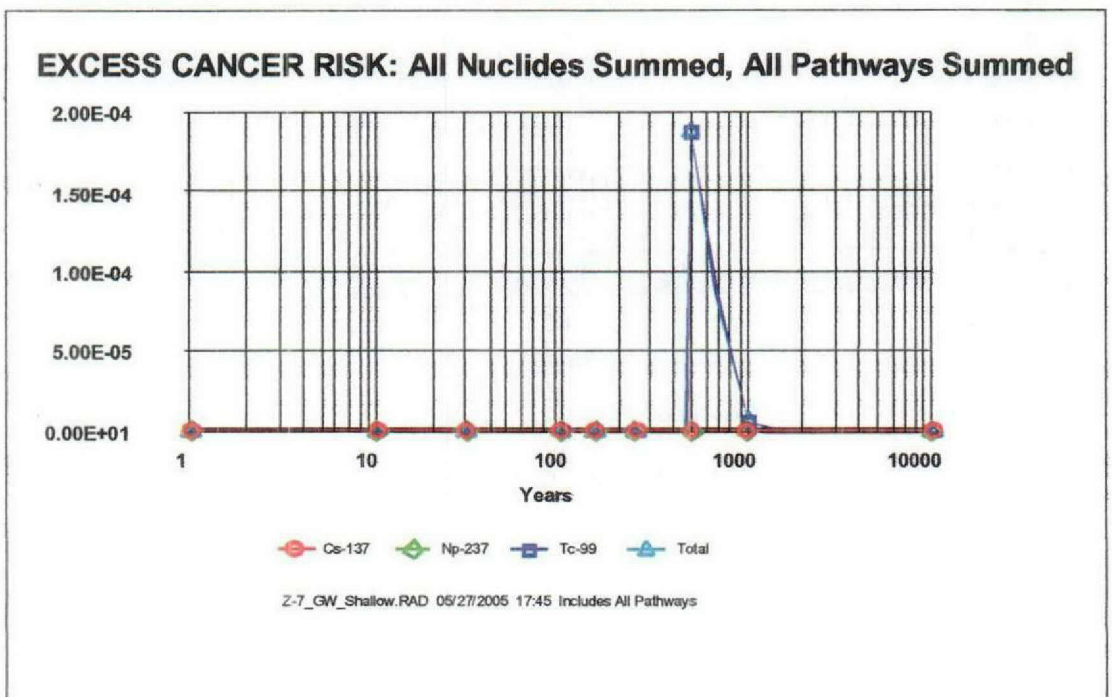
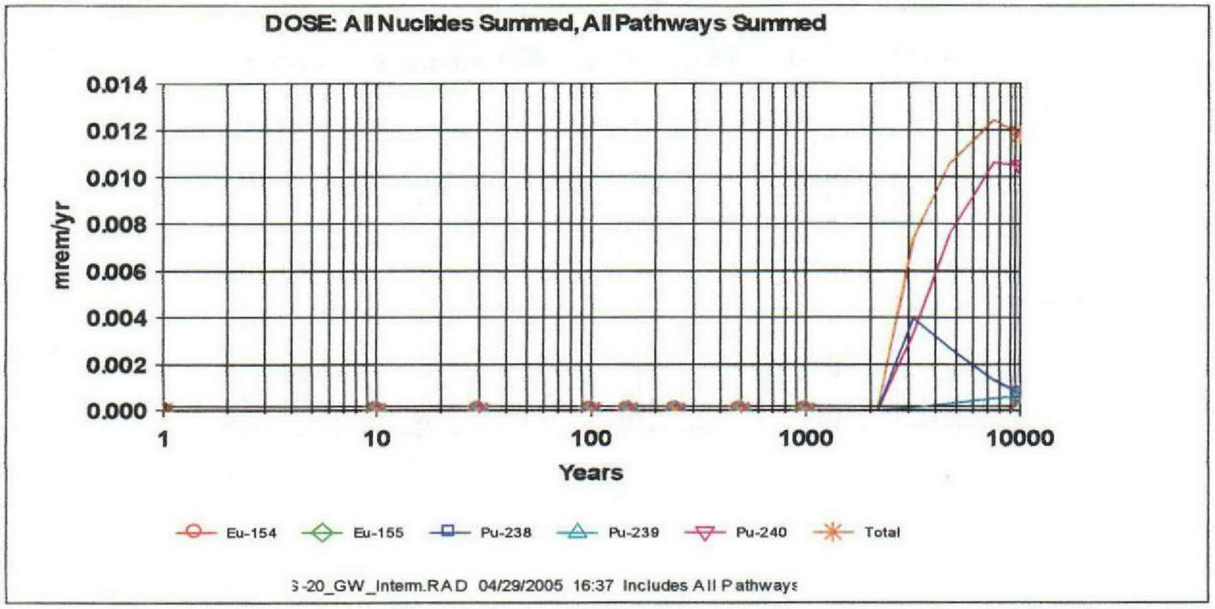


Figure 5-15. RESRAD Analysis for 216-Z-7 Crib, Total Dose and Risk Groundwater Pathways, Intermediate Contaminant Transport Zone Depth of 35 m.



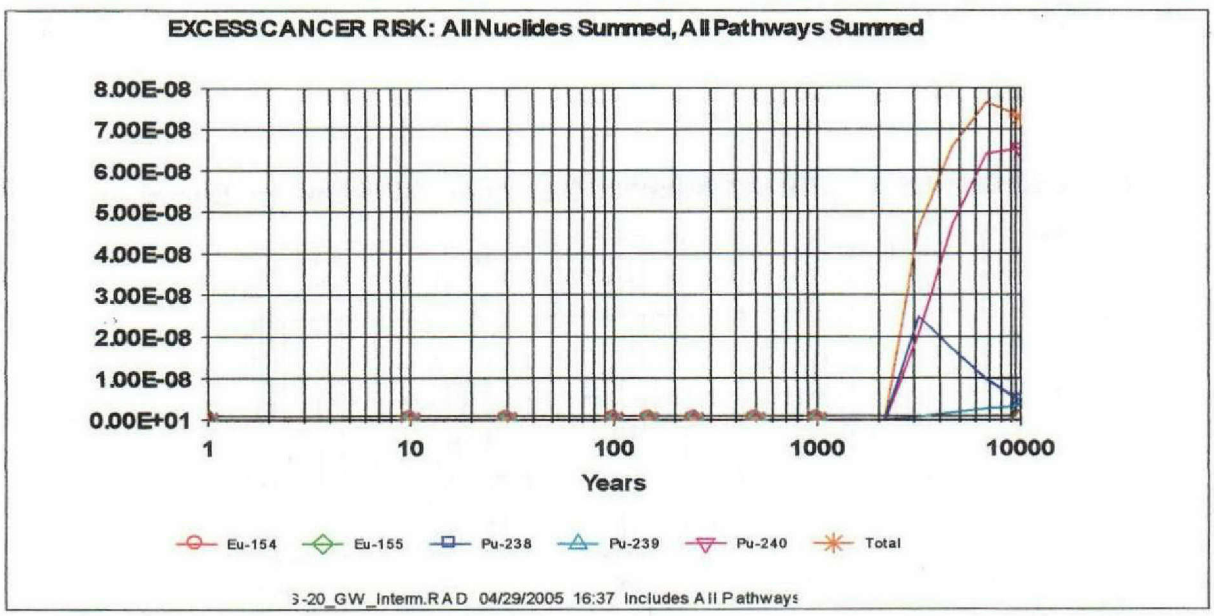
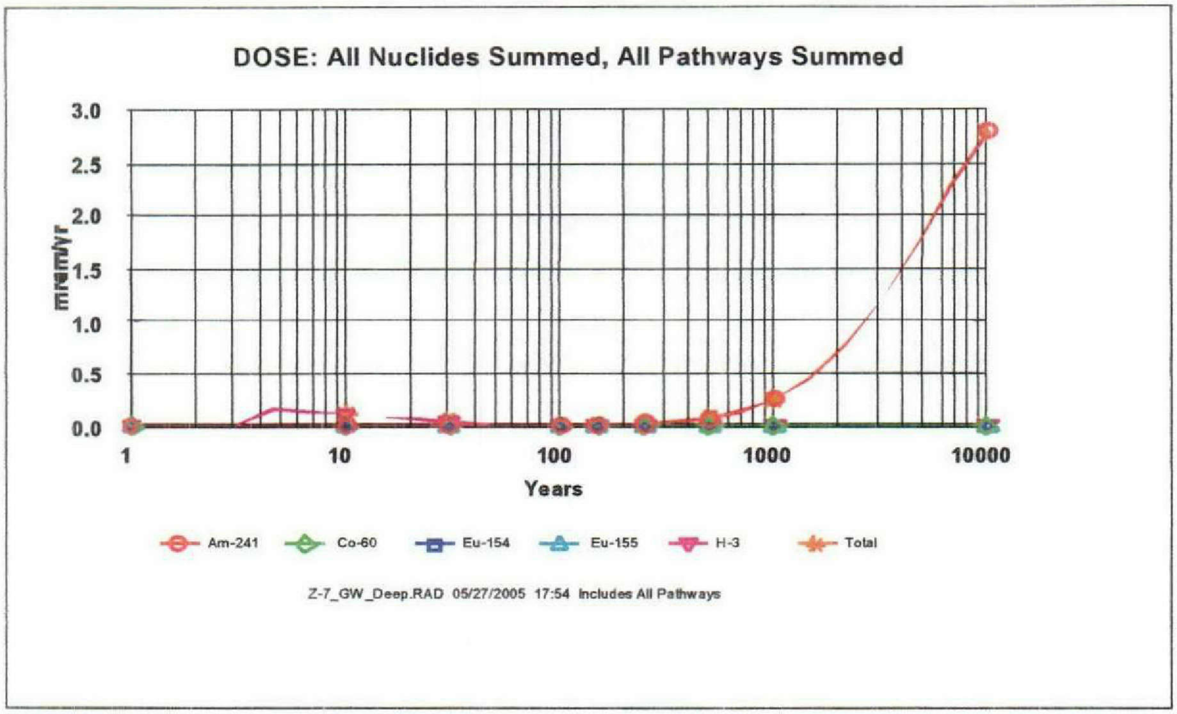


Figure 5-16. RESRAD Analysis for 216-Z-7 Crib, Total Dose and Risk Groundwater Pathways, Deep Contaminant Transport Zone Depth of 66 m.



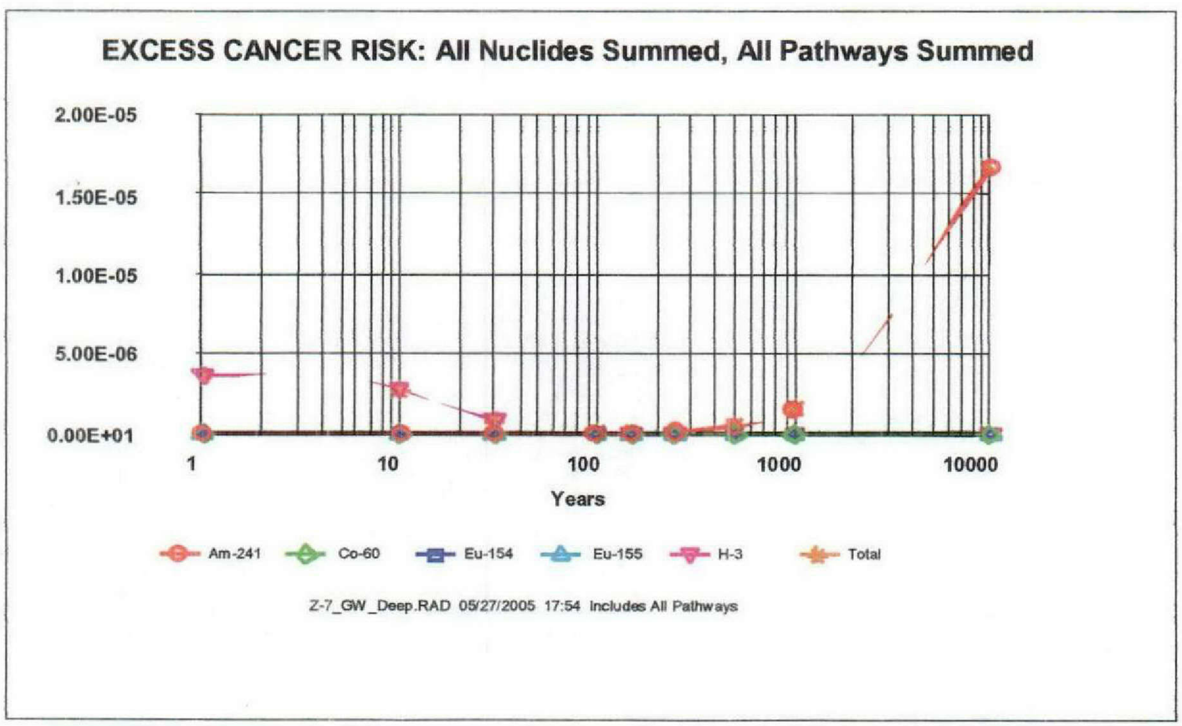
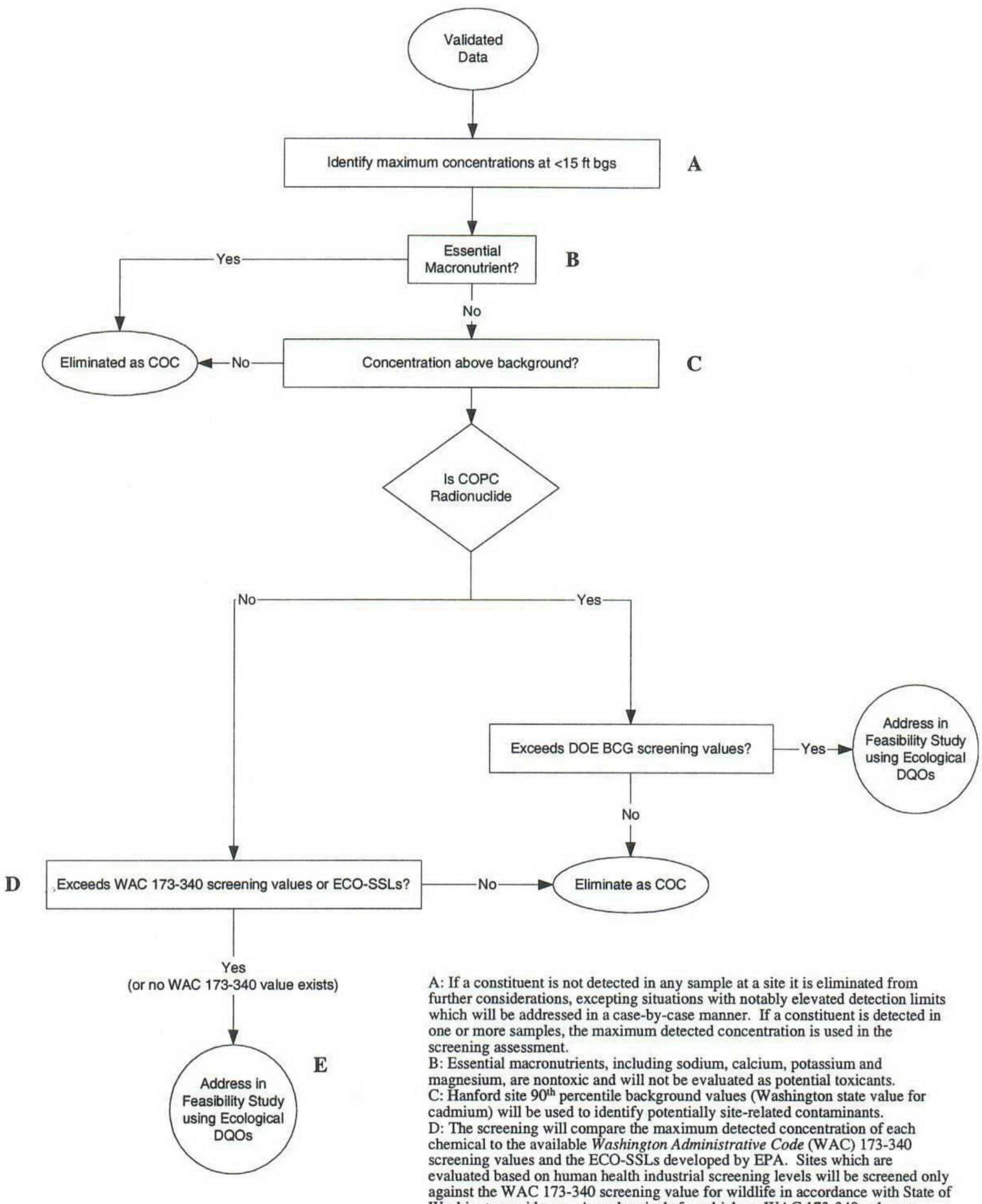


Figure 5-17. Ecological Risk Screening Approach.



A: If a constituent is not detected in any sample at a site it is eliminated from further considerations, excepting situations with notably elevated detection limits which will be addressed in a case-by-case manner. If a constituent is detected in one or more samples, the maximum detected concentration is used in the screening assessment.

B: Essential macronutrients, including sodium, calcium, potassium and magnesium, are nontoxic and will not be evaluated as potential toxicants.

C: Hanford site 90th percentile background values (Washington state value for cadmium) will be used to identify potentially site-related contaminants.

D: The screening will compare the maximum detected concentration of each chemical to the available *Washington Administrative Code* (WAC) 173-340 screening values and the ECO-SSLs developed by EPA. Sites which are evaluated based on human health industrial screening levels will be screened only against the WAC 173-340 screening value for wildlife in accordance with State of Washington guidance. Any chemicals for which no WAC 173-340 value or ECO-SSL screening levels exist will be carried through to the Feasibility Study.

E: Chemicals and radionuclides addressed in the Feasibility Study will be compared to screening levels developed for the site-specific suite of receptors developed under the site-wide ecological DQOs.

LEGEND:

BCG = Biota Concentration Guide
COC = Contaminant of Concern
DOE = Department of Energy
DQO = Data Quality Objectives
ECO-SSL = Ecological Soil Screening Level

Table 5-1. Summary of Maximum Detected Concentrations in both Shallow Zone and Deep Zone. (8 Pages)

Constituent	216-T-28 Crib		216-S-20 Crib		216-Z-7 Crib	
	Maximum Detected Concentration		Maximum Detected Concentration		Maximum Detected Concentration	
	Shallow Zone (0-15 ft)	Deep Zone (0-GW)	Shallow Zone (0-15 ft)	Deep Zone (0-GW)	Shallow Zone (0-15 ft)	Deep Zone (0-GW)
General Inorganic Chemistry (mg/kg)						
Ammonia as NH_3		14.5	NA	ND	NA	ND
Ammonium Ion		24.7	ND	2.87	0.304	0.649
Chloride		13.3	2.82	16.7	ND	5.34
Cyanide		ND	ND	ND	3.95	3.95
Fluoride		39.6	ND	6.51	ND	26
Nitrate		245	7.39	18.6	10.846	19.744
Nitrite		2.53	ND	ND	ND	ND
Nitrogen in Nitrate and Nitrite		45.8	2.8	3.4	2.0	2.5
Phosphate		59.1	ND	ND	ND	13
Sulfate		5.72	ND	16.7	ND	5.62
Sulfide		ND	ND	23.9	ND	ND
Metals (mg/kg)						
Antimony		5.03	ND	2.9	ND	2.8
Arsenic		9.29	6.7	9.16	13.4	13.4
Barium		110	112	136	72.1	80.5
Beryllium		0.912	ND	2.7	ND	0.380
Bismuth		202	ND	202	ND	123
Boron		ND	NA	13.5	ND	3.1
Cadmium		0.204	ND	0.280	ND	0.321
Chromium (total)		81.7	5.84	259	7.38	193
Copper		19.9	14.5	122	13.0	18.2
Hexavalent Chromium		1.5	ND	1.28	ND	2.05

Table 5-1. Summary of Maximum Detected Concentrations in both Shallow Zone and Deep Zone. (8 Pages)

Constituent	216-T-28 Crib		216-S-20 Crib		216-Z-7 Crib	
	Maximum Detected Concentration		Maximum Detected Concentration		Maximum Detected Concentration	
	Shallow Zone (0-15 ft)	Deep Zone (0-GW)	Shallow Zone (0-15 ft)	Deep Zone (0-GW)	Shallow Zone (0-15 ft)	Deep Zone (0-GW)
Lead		34.4	ND	489	ND	14.3
Mercury		6.84	ND	69.2	ND	5.6
Nickel		52.7	10.4	55.0	11.6	23.4
Selenium		0.869	ND	ND	ND	ND
Silver		4.98	ND	6	ND	4.7
Uranium		113	ND	652	ND	2.67
Radionuclides (pCi/g)						
Americium-241		802	ND	5800	ND	60600
Antimony-125		2.39	ND	ND	ND	ND
Carbon-14		4.52	ND	35.6	ND	ND
Cesium-134		456	ND	ND	ND	ND
Cesium-137		3100000	ND	95600	0.0835	2800
Cobalt-60		1180	ND	104	ND	58.3
Europium-152		0.733	ND	ND	ND	ND
Europium-154		43	ND	70.8	ND	10.5
Europium-155		19.9	0.062	0.144	0.0734	0.0829
Neptunium-237		0.011	ND	0.084	0.059	0.059
Nickel-63		843	ND	4548	ND	ND
Plutonium-238		84.5	ND	2.6	ND	5770
Plutonium-239/240		1110	ND	78	1.2	472000
Potassium-40		15	9.06	13.8	14.2	14.9
Radium-226d		0.523	0.358	0.594	0.41	0.807
Radium-228		0.974	0.624	0.687	0.58	0.729
Technetium-99		1.61	ND	9.18	ND	11

Table 5-1. Summary of Maximum Detected Concentrations in both Shallow Zone and Deep Zone. (8 Pages)

Constituent	216-T-28 Crib		216-S-20 Crib		216-Z-7 Crib	
	Maximum Detected Concentration		Maximum Detected Concentration		Maximum Detected Concentration	
	Shallow Zone (0-15 ft)	Deep Zone (0-GW)	Shallow Zone (0-15 ft)	Deep Zone (0-GW)	Shallow Zone (0-15 ft)	Deep Zone (0-GW)
Thorium-228d		2.69	0.64	15.9	1.16	1.18
Thorium-230d		0.932	0.319	1.03	1.03	1.03
Thorium-232		1.09	0.958	1.41	0.734	1.22
Strontium-90		642000	ND	96300	ND	437000
Tritium		19000	ND	63.1	ND	9.54
Uranium (metallic)		125000	ND	818000	1.31	27900
Uranium-233/234b		59.4	0.19	250	0.506	0.506
Uranium-235		3.44	0.02	26.4	ND	0.053
Uranium-238		35.1	0.22	270	0.696	0.696
Volatile Organic Compounds (µg/kg)						
1,1,1 – Trichloroethane		ND	ND	ND	ND	ND
1,1,2,2 – Tetrachloroethane		ND	ND	ND	ND	ND
1,1,2-Trichloroethane		ND	ND	ND	ND	ND
1,1-Dichloroethane		ND	ND	ND	ND	ND
1,1-Dichloroethene		ND	ND	ND	ND	ND
1,2,3-Trichlorobenzene		ND	ND	ND	ND	7.5
1,2,4-Trimethylbenzene		ND	ND	ND	NA	ND
1,2-Dichloroethane		ND	ND	ND	ND	ND
1,2-Dichloroethene (Total)		ND	ND	ND	ND	ND
1,2-Dichloropropane		ND	ND	ND	ND	ND
1-Butanol		ND	NA	ND	ND	ND
2-Butanone		ND	ND	ND	ND	ND
2-Hexanone		ND	ND	ND	ND	ND
4-Methyl-2-Pentanone		ND	ND	ND	ND	ND

Table 5-1. Summary of Maximum Detected Concentrations in both Shallow Zone and Deep Zone. (8 Pages)

Constituent	216-T-28 Crib		216-S-20 Crib		216-Z-7 Crib	
	Maximum Detected Concentration		Maximum Detected Concentration		Maximum Detected Concentration	
	Shallow Zone (0-15 ft)	Deep Zone (0-GW)	Shallow Zone (0-15 ft)	Deep Zone (0-GW)	Shallow Zone (0-15 ft)	Deep Zone (0-GW)
Acetone		8	ND	ND	ND	ND
Acetonitrile		ND	ND	ND	NA	ND
Benzene		ND	ND	ND	ND	ND
Bromodichloromethane		ND	ND	ND	ND	ND
Bromoform		ND	ND	ND	ND	ND
Bromomethane		ND	ND	ND	ND	ND
Carbon disulfide		ND	ND	ND	ND	1.1
Carbon tetrachloride		ND	ND	ND	ND	ND
Chlorobenzene		ND	ND	ND	ND	ND
Chloroethane		ND	ND	ND	ND	ND
Chloroform		ND	ND	ND	ND	ND
Chloromethane		ND	ND	ND	ND	ND
cis-1,3-Dichloropropene		ND	ND	ND	ND	ND
Dibromochloro-methane		ND	ND	ND	ND	ND
Ethyl acetate		ND	ND	ND	ND	5.5
Ethylbenzene		ND	ND	ND	ND	ND
Ethylene glycol		ND	ND	ND	ND	ND
Hexane		ND	ND	ND	ND	ND
Methylene chloride		25	ND	4.7	ND	8
n-Butylbenzene		ND	ND	ND	ND	ND
Styrene		ND	ND	ND	ND	ND
Tetrachloroethene		ND	ND	ND	ND	ND
Toluene		4.9	ND	ND	ND	ND
trans-1,3-Dichloropropene		ND	ND	ND	ND	ND

Table 5-1. Summary of Maximum Detected Concentrations in both Shallow Zone and Deep Zone. (8 Pages)

Constituent	216-T-28 Crib		216-S-20 Crib		216-Z-7 Crib	
	Maximum Detected Concentration		Maximum Detected Concentration		Maximum Detected Concentration	
	Shallow Zone (0-15 ft)	Deep Zone (0-GW)	Shallow Zone (0-15 ft)	Deep Zone (0-GW)	Shallow Zone (0-15 ft)	Deep Zone (0-GW)
Trichloroethene		ND	ND	ND	ND	2.0
Vinyl chloride		ND	ND	ND	ND	ND
Xylenes (total)		ND	ND	ND	ND	ND
Semivolatile Organic Compounds (µg/kg)						
1,2,4-Trichlorobenzene		ND	ND	ND		
1,2-Dichlorobenzene		ND				
1,3-Dichlorobenzene		ND				
1,4-Dichlorobenzene		ND	ND	ND		
2,4,5-Trichlorophenol		ND				
2,4,6-Trichlorophenol		ND				
2,4-Dichlorophenol		ND				
2,4-Dimethylphenol		ND				
2,4-Dinitrophenol		ND				
2,4-Dinitrotoluene		ND			ND	ND
2,6-Dinitrotoluene		ND	ND	ND		
2-Butoxyethanol		150				
2-Chloronaphthalene		ND				
2-Chlorophenol		ND	ND	ND		
2-Methyl-naphthalene		ND				
2-Methylphenol (cresol, o-)		ND			ND	ND
2-Nitroaniline		ND				
2-Nitrophenol		ND	ND	ND		
3,3'-Dichloro-benzidine		ND				
3-Nitroaniline		ND				

Table 5-1. Summary of Maximum Detected Concentrations in both Shallow Zone and Deep Zone. (8 Pages)

Constituent	216-T-28 Crib		216-S-20 Crib		216-Z-7 Crib	
	Maximum Detected Concentration		Maximum Detected Concentration		Maximum Detected Concentration	
	Shallow Zone (0-15 ft)	Deep Zone (0-GW)	Shallow Zone (0-15 ft)	Deep Zone (0-GW)	Shallow Zone (0-15 ft)	Deep Zone (0-GW)
4,6-Dinitro-2-methylphenol		ND				
4-Bromophenyl-phenyl ether		ND				
4-Chloro-3-methylphenol		23				
4-Chloroaniline		ND				
4-Chlorophenyl-phenyl ether		ND				
4-Methylphenol (cresol, p-)		ND				
4-Nitroaniline		ND				
4-Nitrophenol		ND			ND	ND
Acenaphthene		ND	ND	ND	ND	ND
Acenaphthylene		ND				
Anthracene		ND				
Benzo(a) anthracene		ND				
Benzo(a) pyrene		ND				
Benzo(b) fluoranthene		ND				
Benzo(ghi) perylene		ND				
Benzo(k) fluoranthene		ND				
Bis(2-chloro-1-methylethyl)ether		ND				
Bis(2-Chloroethoxy) methane		ND				
Bis(2-chloroethyl) ether		ND				
Bis(2-ethylhexyl) phthalate		700				
Butylbenzyl-phthalate		ND				
Carbazole		ND				
Chrysene		ND				
Dibenz[a,h] anthracene		ND				

Table 5-1. Summary of Maximum Detected Concentrations in both Shallow Zone and Deep Zone. (8 Pages)

Constituent	216-T-28 Crib		216-S-20 Crib		216-Z-7 Crib	
	Maximum Detected Concentration		Maximum Detected Concentration		Maximum Detected Concentration	
	Shallow Zone (0-15 ft)	Deep Zone (0-GW)	Shallow Zone (0-15 ft)	Deep Zone (0-GW)	Shallow Zone (0-15 ft)	Deep Zone (0-GW)
Dibenzofuran		ND				
Diethylphthalate		730			NA	460
Dimethyl phthalate		ND				
Di-n-butylphthalate		1700	ND	1200	NA	2100
Di-n-octylphthalate		ND				
Eicosane		970				
Fluoranthene		ND				
Fluorene		ND				
Hexachloro-benzene		ND				
Hexachloro-butadiene		ND				
Hexachloro-cyclopentadiene		ND				
Hexachloro-ethane		ND				
Hexadecanoic acid (9Cl)		180				
Isophorone		ND				
Naphthalene		ND				
n-Hexanoic Acid		570				
Nitrobenzene		ND				
N-Nitrosodi-n-dipropylamine		ND	ND	ND	ND	ND
N-Nitrosodi-phenylamine		ND				
Nonadecane					ND	1500
Penta-chlorophenol		ND	ND	ND	ND	ND
Phenanthrene		ND				
Phenol		24	ND	ND	ND	ND
Pyrene		21	ND	ND	ND	ND

Table 5-1. Summary of Maximum Detected Concentrations in both Shallow Zone and Deep Zone. (8 Pages)

Constituent	216-T-28 Crib		216-S-20 Crib		216-Z-7 Crib	
	Maximum Detected Concentration		Maximum Detected Concentration		Maximum Detected Concentration	
	Shallow Zone (0-15 ft)	Deep Zone (0-GW)	Shallow Zone (0-15 ft)	Deep Zone (0-GW)	Shallow Zone (0-15 ft)	Deep Zone (0-GW)
Tributyl phosphate		ND	ND	ND	ND	ND
Miscellaneous Organic Analyses (µg/kg)						
Aroclor-1016*		ND	ND	ND	ND	ND
Aroclor-1221		ND	ND	ND	ND	ND
Aroclor-1232		ND	ND	ND	ND	ND
Aroclor-1242		ND	ND	ND	ND	ND
Aroclor-1248		ND	ND	ND	ND	ND
Aroclor-1254		240	ND	170	ND	ND
Aroclor-1260		ND	ND	ND	ND	ND
Aroclor-1262		ND	ND	ND	ND	ND
Aroclor-1268		ND	ND	ND	ND	ND
Oil and grease		1080000	ND	ND	ND	727000
Total petroleum hydrocarbons - diesel range		13000	ND	ND	ND	ND
Total petroleum hydrocarbons - gasoline range		ND	ND	ND	ND	ND
Total petroleum hydrocarbons - kerosene range		13000	ND	ND	ND	ND

Shaded cells indicate that no shallow data available for 216-T-28.
Blank cells indicate that the analyte was not included in analysis.
*Aroclor is an expired trademark.
GW = groundwater.
NA = not analyzed, but included in the data summary.
ND = not detected.

Table 5-2. Summary of Inorganic Chemicals that Exceed Background.

Constituent Name	216-T-28 Crib		216-S-20 Crib		216-Z-7 Crib	
	Shallow Zone	Deep Zone	Shallow Zone	Deep Zone	Shallow Zone	Deep Zone
Ammonia as N		X				
Ammonium ion as N		X		X		X
Antimony[1]		X		X		X
Arsenic		X	X	X	X	X
Barium				X		
Beryllium				X		
Bismuth[1]		X		X		X
Boron[1]				X		X
Cadmium						
Total chromium		X		X		X
Chloride		X				
Copper				X		
Cyanide					X	
Fluoride		X		X		
Hexavalent Chromium[1]		X		X		X
Lead		X		X		X
Mercury		X		X		X
Nickel		X		X		X
Nitrate as N		X		X		X
Nitrite as N[1]		X				
Nitrate and nitrate/nitrite as N[1]		X	X	X	X	X
Phosphate		X				X
Selenium[1]		X				
Silver		X		X		X
Sulfate						
Sulfide				X		
Uranium		X		X		X

[1]Constituent was detected but no background value was available for this constituent.

Note: Blank cells indicate that constituents were not present in concentrations that exceeded the background screening values.

No shallow data are available for 216-T-28.

Table 5-3. Comparison of Maximum Detected Values in Shallow-Zone Soils (0 to 4.6 m [0 to 15 ft]) to Background Concentrations. (3 Pages)

Constituent Class	Constituent Name	Units	Maximum Detected Result	90th Percentile Background Concentration	Does Maximum Concentration Exceed Background?
216-T-28 Crib (no shallow data)					
METAL	Antimony	mg/kg		--	
METAL	Arsenic	mg/kg		6.47	
METAL	Barium	mg/kg		132	
METAL	Beryllium	mg/kg		1.51	
METAL	Bismuth	mg/kg		--	
METAL	Boron	mg/kg		--	
METAL	Cadmium	mg/kg		0.81	
METAL	Chromium (total)	mg/kg		18.5	
METAL	Hexavalent chromium	mg/kg		--	
METAL	Copper	mg/kg		22	
METAL	Lead	mg/kg		10.2	
METAL	Mercury	mg/kg		0.33	
METAL	Nickel	mg/kg		19.1	
METAL	Selenium	mg/kg		--	
METAL	Silver	mg/kg		0.73	
METAL	Uranium	mg/kg		3.21	
GENCHEM	Ammonium ion as N	mg/kg		9.23	
GENCHEM	Ammonia as N	mg/kg		9.23	
GENCHEM	Chloride	mg/kg		100	
GENCHEM	Cyanide	mg/kg		--	
GENCHEM	Fluoride	mg/kg		2.81	
GENCHEM	Nitrate as N	mg/kg		12	
GENCHEM	Nitrite as N	mg/kg		--	
GENCHEM	Nitrate and nitrate/nitrite as N	mg/kg		--	
GENCHEM	Phosphate	mg/kg		0.785	
GENCHEM	Sulfate	mg/kg		237	
GENCHEM	Sulfide	mg/kg		--	
216-S-20 Crib					
METAL	Antimony	mg/kg	ND	--	No
METAL	Arsenic	mg/kg	6.7	6.47	Yes
METAL	Barium	mg/kg	112	132	No
METAL	Beryllium	mg/kg	ND	1.51	No
METAL	Bismuth	mg/kg	ND	--	No

Table 5-3. Comparison of Maximum Detected Values in Shallow-Zone Soils (0 to 4.6 m [0 to 15 ft]) to Background Concentrations. (3 Pages)

Constituent Class	Constituent Name	Units	Maximum Detected Result	90th Percentile Background Concentration	Does Maximum Concentration Exceed Background?
METAL	Boron	mg/kg	ND	--	No
METAL	Cadmium	mg/kg	ND	0.81	No
METAL	Chromium (Total)	mg/kg	5.84	18.5	No
METAL	Hexavalent Chromium	mg/kg	ND	--	No
METAL	Copper	mg/kg	14.5	22	No
METAL	Lead	mg/kg	ND	10.2	No
METAL	Mercury	mg/kg	ND	0.33	No
METAL	Nickel	mg/kg	10.4	19.1	No
METAL	Selenium	mg/kg	ND	--	No
METAL	Silver	mg/kg	ND	0.73	No
METAL	Uranium	mg/kg	ND	3.21	No
GENCHEM	Ammonium ion as N	mg/kg	ND	9.23	No
GENCHEM	Ammonia as N	mg/kg	NS	9.23	No
GENCHEM	Chloride	mg/kg	2.82	100	No
GENCHEM	Cyanide	mg/kg	ND	--	No
GENCHEM	Fluoride	mg/kg	ND	2.81	No
GENCHEM	Nitrate as N	mg/kg	7.39	52	No
GENCHEM	Nitrite as N	mg/kg	ND	--	No
GENCHEM	Nitrate and nitrate/nitrite as N	mg/kg	2.8	--	Yes
GENCHEM	Phosphate	mg/kg	ND	0.785	No
GENCHEM	Sulfate	mg/kg	ND	237	No
GENCHEM	Sulfide	mg/kg	ND	--	No
216-Z-7 Crib					
METAL	Antimony	mg/kg	ND	--	No
METAL	Arsenic	mg/kg	13.4	6.47	Yes
METAL	Barium	mg/kg	72.1	132	No
METAL	Beryllium	mg/kg	ND	1.51	No
METAL	Bismuth	mg/kg	ND	--	No
METAL	Boron	mg/kg	ND	--	No
METAL	Cadmium	mg/kg	ND	0.81	No
METAL	Chromium (total)	mg/kg	7.38	18.5	No
METAL	Hexavalent chromium	mg/kg	ND	--	No
METAL	Copper	mg/kg	13.0	22	No
METAL	Lead	mg/kg	ND	10.2	No

Table 5-3. Comparison of Maximum Detected Values in Shallow-Zone Soils (0 to 4.6 m [0 to 15 ft]) to Background Concentrations. (3 Pages)

Constituent Class	Constituent Name	Units	Maximum Detected Result	90th Percentile Background Concentration	Does Maximum Concentration Exceed Background?
METAL	Mercury	mg/kg	ND	0.33	No
METAL	Nickel	mg/kg	11.6	19.1	No
METAL	Selenium	mg/kg	ND	--	No
METAL	Silver	mg/kg	ND	0.73	No
METAL	Uranium	mg/kg	ND	3.21	No
GENCHEM	Ammonium ion as N	mg/kg	0.304	9.23	No
GENCHEM	Ammonia as N	mg/kg	NS	9.23	No
GENCHEM	Chloride	mg/kg	ND	100	No
GENCHEM	Cyanide	mg/kg	3.95	--	Yes
GENCHEM	Fluoride	mg/kg	ND	2.81	No
GENCHEM	Nitrate as N	mg/kg	10.85	12	No
GENCHEM	Nitrite as N	mg/kg	ND	--	No
GENCHEM	Nitrate and nitrate/nitrite as N	mg/kg	2.0	--	Yes
GENCHEM	Phosphate	mg/kg	ND	0.785	No
GENCHEM	Sulfate	mg/kg	ND	237	No
GENCHEM	Sulfide	mg/kg	ND	--	No

Shaded cells indicate constituents that exceeded background, or which had a detect but no background.
Blank cells indicate that the constituent was not analyzed for in shallow-zone soils.
No shallow-zone soils data available for 216-T-28.

-- = no background value available.
GENCHEM = general chemistry.
METAL = metal suite.
NA = not available.
ND = not detected.
NS = not sampled.

Table 5-4. Summary of Exposure Assumptions for Industrial Soil Risk-Based Concentrations.

Parameter	Symbol	Units	Industrial Land Use [a, b]
Target risk	TR	unitless	1.0 E-05
Target hazard quotient	THQ	unitless	1
Oral reference dose	RfDo	mg/kg-day	chemical specific
Oral cancer potency factor	CPFo	kg-day/mg	chemical specific
Inhalation reference dose	CPFi	mg/kg-day	chemical specific
Inhalation cancer potency factor	RfDi	kg-day/mg	chemical specific
Unit conversion factor	UCF	mg/kg	1.0 E+06
Body weight –adult	BWa	kg	70
Carcinogenic averaging time	ATC	years	75
Noncarcinogenic averaging time	ATN	years	20
Exposure frequency	EF	unitless	0.4
Exposure duration	ED	years	20
Incidental soil ingestion rate	SIR	mg/day	50
Inhalation rate – carcinogens	INHc	m^3/day	20
Inhalation rate – noncarcinogens	INHnc	m^3/day	20
Gastrointestinal absorption factor	ABSgi	unitless	1
Inhalation absorption fraction	ABSinh	unitless	1

[a]WAC 173-340-745, "Soil Cleanup Standards for Industrial Properties," (equations 745-1 and 745-2).
[b]WAC 173-340-750(4), Cleanup Standards to Protect Air Quality," "Method C Air Cleanup Levels."
WAC = *Washington Administrative Code*.

Table 5-5. Summary of Exposure Assumptions for Risk-Based Concentrations for Groundwater Protection.

Parameter	Symbol	Units	WAC 173-340-720 Method B Parameter [a]
Target risk	TR	unitless	$1.00x10^{-6}$
Target hazard quotient	THQ	unitless	1
Oral reference dose	RfDo	mg/kg-day	chemical specific
Cancer potency factor	CPF	kg-day/mg	chemical specific
Unit conversion factor	UCF	µg/mg	1,000
Body weight – carcinogens	BW	kg	70
Body weight – noncarcinogens	BW	kg	16
Carcinogenic averaging time	ATC	years	75
Noncarcinogenic averaging time	ATN	years	6
Drinking water fraction	DWF	unitless	1
Exposure duration – carcinogens	ED	years	30
Exposure duration – noncarcinogens	ED	years	6
Drinking water ingestion rate – carcinogens	DWIR	L/day	2
Drinking water ingestion rate – noncarcinogens	DWIR	L/day	1
Inhalation correction factor - volatile compound	INH	unitless	2
Inhalation correction factor - nonvolatile compound	INH	unitless	1

[a]WAC 173-340-720, "Ground Water Cleanup Standards," (equations 720-1 and 720-2).
WAC = *Washington Administrative Code*.

Table 5-6. Summary of Toxicity Values Used to Calculate Risk-Based Concentrations. (2 Pages)

Chemical Name	Oral Cancer Potency Factor $(mg/kg\text{-}day)^{-1}$	Oral Reference Dose (mg/kg-day)	Inhalation Cancer Potency Factor $(mg/kg\text{-}day)^{-1}$	Inhalation Reference Dose (mg/kg-day)
Acetone	--	0.9	--	--
Antimony	--	0.0004	--	--
Aroclor-1254	2	2.0 E-5	2	--
Arsenic	1.5	0.0003	15.05	15
Barium	--	0.07	--	0.0001
Beryllium	--	0.002	8.4	5.71 E-6
Boron	--	0.09	--	--
Cadmium in water	--	0.0005	6.3	--
Chromium	--	1.5	--	--
Copper	--	0.037	--	--
Cyanide	--	0.02	--	--
Diethylphthalate	--	0.8	--	--
Di-n-butylphthalate	--	0.1	--	--
Fluoride	--	--	--	--
Hexavalent chromium	--	0.003	0.042	2.29 E-6
Lead	--	--	--	--
Mercury	--	0.0003	--	8.57 E-5
Methylene chloride	0.008	0.06	1.65 E-3	0.857
Nickel, soluble salt	--	0.02	--	--
Nitrate as N	--	0.1	--	--
Nitrite as N	--	0.1	--	--
Nitrate and nitrate/nitrite as N	--	0.1	--	--
Selenium	--	0.005	--	--
Silver	--	0.005	--	--
Toluene	--	0.2	--	0.114
Total petroleum hydrocarbons -diesel range	--	--	--	--
Total petroleum hydrocarbons -gasoline range w/o benzene	--	--	--	--
Total petroleum hydrocarbons -motor oil (high boiling)	--	--	--	--
Uranium, soluble salt	--	0.003	--	--

Table 5-6. Summary of Toxicity Values Used to Calculate Risk-Based Concentrations. (2 Pages)

Chemical Name	Oral Cancer Potency Factor $(mg/kg\text{-}day)^{-1}$	Oral Reference Dose (mg/kg-day)	Inhalation Cancer Potency Factor $(mg/kg\text{-}day)^{-1}$	Inhalation Reference Dose (mg/kg-day)

Aroclor is an expired trademark.

Data for this table were taken from the following sources:

Integrated Risk Information System (IRIS 2003), a database available through the EPA National Center for Environmental Assessment. http://www.epa.gov/iris/.

EPA, 2004, *EPA Region 3 Risk Based Concentration (RBC) Tables*, October 2004 Update, available on the Internet at www.epa.gov/reg3hwmd/risk/human/index.htm .

EPA, 2004, *Region 9 Preliminary Remediation Goals (PRG) 2004 Tables*, available on the Internet at http://www.epa.gov/region09/waste/sfund/prg/index.htm

EPA/540/R-97/036,*Health Effects Assessment Summary Tables FY 1997 Update*, July 1997.

-- = not applicable.

EPA = U.S. Environmental Protection Agency.

Table 5-7. Summary of COPCs Exceeding Screening Levels for the Human Health Risk Assessment. (2 Pages)

COPC	216-T-28 Crib		216-S-20 Crib		216-Z-7 Crib	
	Direct Exposure	Protection of GW	Direct Exposure	Protection of GW	Direct Exposure	Protection of GW
Ammonium Ion						
Arsenic		X		X		X
Bismuth		X*		X*		X*
Fluoride		X				
Lead						
Mercury		X		X*		X
Nitrate as N		X				
Nitrate and Nitrite [a]		X				
Sulfide [b]						
Uranium (metallic)		X		X		X
2-butoxyethanol						
4-chloro-3-methylphenol						
Eicosene [c]		X				
Hexadecanoic Acid [c]		X				
n-Hexanoic Acid [c]		X				
Phenol						
TPH – Kerosene Range		X				
Methylene Chloride						X
Nonadecane						
1,2,3-Trichlorobenzene						X

Table 5-7. Summary of COPCs Exceeding Screening Levels for the Human Health Risk Assessment. (2 Pages)

COPC	216-T-28 Crib		216-S-20 Crib		216-Z-7 Crib	
	Direct Exposure	Protection of GW	Direct Exposure	Protection of GW	Direct Exposure	Protection of GW

* Bismuth, lead, and mercury are excluded from further analysis, based on $K_d > 40$ L/mg.
[a] Compared to screening values for nitrate as N.
[b] Sulfide is excluded from further consideration, based on the fact that the regulatory criteria are based on secondary aesthetic standards.
[c] Excluded from further consideration, because no valid toxicity data are available.
COPC = contaminant of potential concern.
GW = groundwater.
TPH = total petroleum hydrocarbon.
Shaded cells indicate that no shallow data are available for 216-T-28.

Table 5-8. Comparison of Organic Chemicals Detected in Shallow-Zone Soils with WAC 173-340-745 Screening Levels.

Constituent Name	Maximum Detected Result in 0-15 ft bgs (µg/kg)	Direct-Exposure Screening level (µg/kg)	Does Maximum Concentration Exceed Screening level?
216-S-20 Crib			
Di-n-butylphthalate	ND	3.50 E+08	No
Methylene chloride	ND	1.75 E+07	No
Arochlor-1254	ND	65,600	No
216-Z-7 Crib			
Methylene Chloride	ND		No
Trichlorethene	ND		No
Diethylphthalate	ND		No
Di-n-butylphthalate	ND		No
Ethyl acetate	ND		
Nonadecane	ND		No
1,2,4-Trichlorobenzene	ND		

WAC 173-340-745, "Soil Cleanup Standards for Industrial Properties."
-- = No screening level is available.
ND = Included in analysis but not detected.

Table 5-9. Comparison of Shallow-Zone Maximum Soil Concentrations for Inorganic Chemicals Higher than Background to Direct Soil Exposure Screening Concentrations.

Constituent Class	Constituent Name	Units	Maximum Detected Result	Direct Exposure screening level	Does Maximum Concentration Exceed Screening level?
216-T-28 Crib (no shallow-zone data collected)					
216-S-20 Crib					
METAL	Arsenic	mg/kg	6.7	1.05 E+03	No
GENCHEM	Nitrate and nitrate/nitrite as N*	mg/kg	2.8	3.50 E+05	No
216-Z-7 Crib					
METAL	Arsenic	mg/kg	13.4	1.05 E+03	No
GENCHEM	Cyanide	mg/kg	3.95	2.1 E+05	No
GENCHEM	Nitrate and nitrate/nitrite as N*	mg/kg	2.00	3.50 E+05	No

Shaded cells indicate constituents that exceeded screening level, or which had no screening level.
Taken from WAC 173-340-745, "Soil Cleanup Standards for Industrial Properties."
*Nitrite screening level used for "Nitrate and nitrate/nitrite as N."
METAL = metals
GENCHEM = general chemistry.
No shallow data for 216-T-28.

Table 5-10. Background Comparisons for Radionuclides In Shallow-Zone Soils. (4 Pages)

Constituent Name	Background	Shallow Zone Maximum Concentration (pCi/g)	Depth of Shallow Zone Maximum (ft)
216-T-28 Crib			
Americium-241	NA	NS	
Antimony-125	NA	NS	
Carbon-14	NA	NS	
Cesium-134	NA	NS	
Cesium-137	N.A.	NS	
Cobalt-60	N.A.	NS	
Europium-152	NA	NS	
Europium-154	N.A.	NS	
Europium-155	N.A.	NS	
Neptunium-237	NA	NS	
Nickel-63	NA	NS	
Plutonium-238	N.A.	NS	
Plutonium-239/240	N.A.	NS	

Table 5-10. Background Comparisons for Radionuclides In Shallow-Zone Soils. (4 Pages)

Constituent Name	Background	Shallow Zone Maximum Concentration (pCi/g)	Depth of Shallow Zone Maximum (ft)
Potassium-40	16.6	NS	
Radium-226	0.815	NS	
Radium-228	1.32	NS	
Technetium-99	NA	NS	
Thorium-228[a]	1.32	NS	
Thorium-230	1.10	NS	
Thorium-232	1.32	NS	
Strontium-90[b]	N.A.	NS	
Tritium	NA	NS	
Uranium		NS	
Uranium-233/234	1.10	NS	
Uranium-235	0.109	NS	
Uranium-238	1.06	NS	
216-S-20 Crib			
Americium-241	NA	ND	
Antimony-125	NA	ND	
Carbon-14	NA	ND	
Cesium-134	NA	ND	
Cesium-137	N.A.	ND	
Cobalt-60	N.A.	ND	
Europium-152	NA	ND	
Europium-154	N.A.	ND	
Europium-155	N.A.	0.062	12.5-15
Neptunium-237	NA	ND	
Nickel-63	NA	ND	
Plutonium-238	N.A.	ND	
Plutonium-239/240	N.A.	ND	
Potassium-40	16.6	9.06	12.5-15
Radium-226	0.815	0.358	12.5-15
Radium-228	1.32	0.624	12.5-15
Technetium-99	NA	ND	
Thorium-228[a]	1.32	0.64	12.5-15
Thorium-230	1.10	0.319	12.5-15
Thorium-232	1.32	0.958	12.5-15
Strontium-90[b]	N.A.	ND	

Table 5-10. Background Comparisons for Radionuclides In Shallow-Zone Soils. (4 Pages)

Constituent Name	Background	Shallow Zone Maximum Concentration (pCi/g)	Depth of Shallow Zone Maximum (ft)
Tritium	NA	ND	
Uranium		ND	
Uranium-233/234	1.10	0.19	12.5-15
Uranium-235	0.109	0.02	12.5-15
Uranium-238	1.06	0.22	12.5-15
216-Z-7 Crib			
Americium-241	NA	ND	
Antimony-125	NA	ND	
Carbon-14	NA	ND	
Cesium-134	NA	ND	
Cesium-137	N.A.	0.0835	12.5-15
Cobalt-60	N.A.	ND	
Europium-152	NA	ND	
Europium-154	N.A.	ND	
Europium-155	N.A.	0.0734	12.5-15
Neptunium-237	NA	0.059	12.5-15
Nickel-63	NA	ND	
Plutonium-238	N.A.	ND	
Plutonium-239/240	N.A.	ND	
Potassium-40	16.6	14.2	12.5-15
Radium-226	0.815	0.41	12.5-15
Radium-228	1.32	0.58	12.5-15
Technetium-99	NA	ND	
Thorium-228 (a)	1.32	1.16	12.5-15
Thorium-230	1.10	1.03	12.5-15
Thorium-232	1.32	0.734	12.5-15
Strontium-90[b]	N.A.	ND	
Tritium	NA	ND	
Uranium		1310	12.5-15
Uranium-234	1.10	0.506	12.5-15
Uranium-235	0.109	ND	
Uranium-238	1.06	0.696	12.5-15

Table 5-10. Background Comparisons for Radionuclides In Shallow-Zone Soils. (4 Pages)

Constituent Name	Background	Shallow Zone Maximum Concentration (pCi/g)	Depth of Shallow Zone Maximum (ft)

[a]Background value based on secular equilibrium with thorium-232.
[b]Strontium-90 value based on analysis of total radioactive strontium.
Data presented for radionuclides with half-life greater than 1 year.
Shaded cells indicate radionuclides that exceeded background level, or which had a detect but no background level.
N.A. = not applicable; fallout radionuclide.
NA = not available.
ND = not detected.
NS= not sampled.

Table 5-11. RESidual RADioactivity Input Parameters – Industrial Scenario. (5 Pages)

Input Field Description	Parameter	Units	200-LW-1 Operable Unit	200-LW-2 Operable Unit		Rationale and Citation
			216-T-28 Crib	216-S-20 Crib	216-Z-7 Crib	
Exposure pathways	--	--	External gamma: active Inhalation: active Plant ingestion: suppressed Meat ingestion: suppressed Milk ingestion: suppressed	Aquatic foods: suppressed Drinking water: suppressed Soil ingestion: active Radon: suppressed		Based on DOE/RL-2001-66, Rev. 0, and WDOH/320-015.
Soil concentrations	Soil concentration	pCi/g	nuclide-specific	nuclide-specific	nuclide-specific	See Table 4-12 for source term data.
	Distribution coefficients	cm^3/g	nuclide-specific	nuclide-specific	nuclide-specific	Distribution coefficients were conservative values applicable to these sites, from Table E.15 of PNNL-11800. See Table 5-2 for nuclide-specific values.
	Radiation dose limit	mrem/yr	15	15	15	This dose limit pertains to calculation of soil guidelines WDOH/320-015.
Contaminated zone (CZ)	Area of CZ	m^2	83.6	334.5	765	Site-specific dimensions from DOE/RL-2001-66, Rev. 0, and shown in Table 1-2 of this RI report.
	Thickness of CZ (No Cover)	m	4.6 No COPCs in top 4.6 m (15 ft)	14	3.0	Assumes homogenous contamination at maximum concentrations from surface to at least 4.6 m (15 ft) bgs across site.
	Thickness of CZ (Cover)	m	2.4 No COPCs in top 4.6 m (15 ft)	3	0.61	Based on measured concentrations in RI data.
	Length parallel to aquifer flow	m	9	27.4	51	Site-specific. For screening purposes, this value is the longest axis of the site and is conservative.
Cover and contaminated zone (CZ) hydrological data	Cover depth (No Cover)	M	0 No COPCs in top 4.6 m (15 ft)	0	0	Assumes that site is contaminated at maximum concentration from surface to at least 4.6 m (15 ft) bgs.
	Cover depth (cover)	M	2.2 No COPCs in top 4.6 m (15 ft)	11	2.4	Based on measured thickness of fill in borehole logs and depth of waste site from DOE/RL-2001-66, Rev. 0, and shown in Table 1-2 of this RI.
	Cover material density	g/cm^3	1.48	1.48	1.59	Site-specific values based on RI results.

Table 5-11. RESidual RADioactivity Input Parameters – Industrial Scenario. (5 Pages)

Input Field Description	Parameter	Units	200-LW-1 Operable Unit	200-LW-2 Operable Unit		Rationale and Citation
			216-T-28 Crib	216-S-20 Crib	216-Z-7 Crib	
Cover and contaminated zone (CZ) hydrological data (cont.)	Cover erosion rate	m/yr	0.001	0.001	0.001	RESRAD default.
	Density of CZ	g/cm^3	1.96	1.96	1.756	Site-specific values based on RI results.
	CZ erosion rate	m/yr	0.001	0.001	0.001	RESRAD default.
	CZ total porosity	unitless	0.166	0.166	0.265	WHC-EP-0883; assumed to be equal to mean effective porosity for 200 Area soils.
	CZ field capacity	unitless	0.023	0.023	0.025	Based on residual water content; consistent with RI moisture content data.
	CZ Hydraulic conductivity	m/yr	39,420	39,420	708.1	WHC-EP-0883, mean values for 200 Area soils.
	CZ "b" parameter	unitless	4.05	4.05	4.05	Derived from RESRAD Table E.2.
	Humidity in air	g/cm^3	8	8	8	RESRAD default where H^{-3} is a COC.
	Evapo-transpiration coefficient	unitless	0.91	0.91	0.91	WDOH/320-015.
	Wind speed	m/s	3.4	3.4	3.4	PNNL-13033.
	Precipitation	m/yr	0.173	0.173	0.16	Based on 16 cm (6.3-in.) average annual rainfall (DOE/RL-92-19).
	Irrigation	m/yr	0	0	0	
	Irrigation mode		Overhead	Overhead	Overhead	
	Runoff coefficient	unitless	0.2	0.2	0.2	RESRAD default.
	Watershed area for nearby stream or pond	m^2	1.0 E+06	1.0 E+06	1.0 E+06	RESRAD default.
	Accuracy for water/soil computations	unitless	0.001	0.001	0.001	RESRAD default.

Table 5-11. RESidual RADioactivity Input Parameters – Industrial Scenario. (5 Pages)

Input Field Description	Parameter	Units	200-LW-1 Operable Unit	200-LW-2 Operable Unit		Rationale and Citation
			216-T-28 Crib	216-S-20 Crib	216-Z-7 Crib	
Saturated zone (SZ) hydrologic data	Density of SZ	g/cm^3	1.96	1.5	1.5	
	SZ total porosity	unitless	0.262	0.4	0.4	RESRAD default.
	SZ effective porosity	unitless	0.262	0.2	0.2	RESRAD default.
	SZ field capacity	unitless	0.044	0.2	0.2	RESRAD default.
	SZ hydraulic conductivity	m/yr	551.9	100	100	RESRAD default.
	SZ hydraulic gradient	unitless	1.54 E-03	0.02	0.02	RESRAD default.
	SZ "b" parameter	unitless	4.05	5.3	5.3	RESRAD default.
	Water table drop rate	m/yr	0.001	0.001	0.001	RESRAD default.
	Well pump intake depth below water table	m	4.6	4.6	4.6	Typical RCRA well screen length (DOE/RL-2002-42).
	Nondispersion or mass-balance transport model	--	ND	ND	ND	Per RESRAD guidance, nondispersion (ND) model used to model potential GW impacts for sites >1000 m^2. Mass-balance (MB) model, which uses assumption that all contamination leaching from the contaminated zone enters well water, used for sites <1000 m^2.
	Well pumping rate	m^3/yr	250	250	250	RESRAD default.
Uncontaminated unsaturated zone data	Number of unsaturated strata below CZ	--	4	1	1	RESRAD default.
	Thickness of unsaturated strata	m	4.5, 18.3, 9.1, 32.4	4.0	4.0	RESRAD default.

Table 5-11. RESidual RADioactivity Input Parameters – Industrial Scenario. (5 Pages)

Input Field Description	Parameter	Units	200-LW-1 Operable Unit	200-LW-2 Operable Unit		Rationale and Citation
			216-T-28 Crib	216-S-20 Crib	216-Z-7 Crib	
Uncontaminated unsaturated zone data (cont.)	Soil Density	g/cm^3	1.96, 1.59, 1.48, 3.24	1.5	1.5	RESRAD default.
	Total porosity	unitless	0.66, 0.346, 0.435, 0.262	0.4	0.4	RESRAD default.
	Effective porosity	unitless	0.166, 0.346, 0.435, 0.262	0.2	0.2	See Cover and CZ inputs.
	Field capacity	unitless	0.023, 0.027, 0.067, 0.044	0.2	0.2	Based on residual water content: WHC-EP-0883, mean value for 200 Area Soils.
	Hydraulic conductivity	m/yr	39420, 394.2, 75.69, 551.8	10	10	See Cover and CZ inputs.
	Soil-specific "b" parameter	unitless	4.05, 4.05, 4.38, 4.05	5.3	5.3	Derived from RESRAD Table E.2.
Occupancy	Inhalation rate	m^3/yr	7,300	7,300	7,300	WDOH/320-015
	Mass loading for inhalation	g/m^3	0.0001	0.0001	0.0001	WDOH/320-015
	Exposure duration	yr	25	25	25	WDOH/320-015
	Indoor dust filtration factor	unitless	0.4	0.4	0.4	RESRAD default.
	External gamma shielding factor	unitless	0.8	0.8	0.8	WDOH/320-015.
	Indoor time fraction	unitless	0.137	0.137	0.137	200 Area industrial scenario; on site 2,000 h/yr; indoors 60% (DOE/RL-2002-42).
	Outdoor time fraction	unitless	0.091	0.091	0.091	200 Area industrial scenario; on site 2000 h/yr; outdoors 40% (DOE/RL-2002-42).
	Shape factor	unitless	Circular Site specific; noncircular Site specific; noncircular Site specific; noncircular	Site specific; noncircular	Site specific; noncircular	Calculated for grossly noncircular sites using RESRAD program for external irradiation pathway. Shape factor area is used by RESRAD for area value in CZ field.

Table 5-11. RESidual RADioactivity Input Parameters – Industrial Scenario. (5 Pages)

Input Field Description	Parameter	Units	200-LW-1 Operable Unit	200-LW-2 Operable Unit		Rationale and Citation
			216-T-28 Crib	216-S-20 Crib	216-Z-7 Crib	
Ingestion pathway; dietary data	Soil ingestion rate	g/yr	36.5	36.5	36.5	WDOH/320-015.
	Drinking water intake	L/yr	730	730	730	WDOH/320-015. Only used to screen transport of COCs to groundwater.
	Drinking water contaminated fraction		1	1	1	RESRAD default; only used to screen transport of COCs to groundwater.
Ingestion pathway; nondietary data	Depth of soil mixing layer	m	0.15	0.15	0.15	RESRAD default.
	Drinking water fractional use		1	1	1	RESRAD default; only used to screen transport of COCs to groundwater.
Storage Times	Well water storage time	days	1	1	1	RESRAD default; only used to screen transport of COCs to groundwater.

DOE/RL-92-19, *200 East Groundwater Aggregate Area Management Study.*
DOE/RL-2001-66, *Chemical Laboratory Waste Group Operable Units RI/FS Work Plan, Includes: 200-LW-1 and 200-LW-2 Operable Units.*
DOE/RL-2002-42, *Remedial Investigation Report for the 200-TW-1 and 200-TW-2 Operable Units (includes the 200-PW-5 Operable Unit).*
PNNL-11800, *Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site.*
PNNL-13033, *Recharge Data Package for the Immobilized Low-Activity Waste 2001 Performance Assessment..*
Resource Conservation and Recovery Act of 1976, 42 U.S.C. 6901, et seq.
WDOH/320-015, *Hanford Guidance for Radiological Cleanup.*
WHC-EP-0883, *Variability and Scaling of Hydraulic Properties for 200 Area Soils.*

COC = contaminant of concern.
COPC = contaminant of potential concern.
CZ = contaminated zone.
MB = mass balance.
ND = nondispersion.
RCRA = *Resource Conservation and Recovery Act of 1976.*
RESRAD = RESidual RADioactivity (ANL 2002, *RESRAD for Windows*, Version 6.21).
RI = remedial investigation.
SZ = saturated zone.

Table 5-12. Summary of Groundwater Pathway Doses and Risk Assessment – 216-T-28 Crib.

Radionuclide	Concentration in Contaminated Zone (pCi/g)	Depth of Contamination (m)	Maximum Dose (mrem/yr)	Maximum Excess Cancer Risk	Time of Maximum Dose (yr)
Sb-125	**2.39**	15 and 32.6	0	0	-
Cs-134	**456**	15 and 32.6	0	0	-
Cs-137	**3100000**	15 and 32.6	0	0	-
Np-237	**0.011**	15 and 32.6	7.0 E-05	9.0 E-10	10,000
Pu-238	**84.5**	15 and 32.6	3.0 E-03	2.0 E-07	10,000
Pu-239/240	**1110**	15 and 32.6	1.7 E-04	8.8 E-09	10,000
Sr-90	**642000**	15 and 32.6	0	0	-
Th-228	**2.69**	15 and 32.6	0	0	-
U-233/234	**59.4**	15 and 32.6	77	3.7 E-04	6,000
U-235	**3.44**	15 and 32.6	4.1	2.3 E-05	6,000
U-238	**35.1**	15 and 32.6	43	2.7 E-04	6,000
C-14	**4.52**	30	0.32	6.5 E-07	3,500
		50.3	0.34	6.5 E-07	1,600
Co-60	**1180**	30 and 50.3	0	0	-
Eu-152	**0.733**	30 and 50.3	0	0	-
Eu-154	43	30 and 50.3	0	0	-
Eu-155	**19.9**	30 and 50.3	0	0	-
Ni-63	**843**	30 and 50.3	0	0	-
Am-241	**802**	68.5	4.5 E-03	2.6 E-08	>10,000
Tc-99	**1.61**	68.5	0.1	**4.8 E-06**	**4.5**
H-3	**19000**	68.5	**41**	9.0 E-04	**4.5**

Shaded cells indicate radionuclides that present an excess cancer risk and reach groundwater within 1,000 years.

Table 5-13. Dose Assessment Results for the 216-S-20 Crib. (2 Pages)

Scenario	Total Dose (mrem/yr)	Time (year)	Primary Radionuclide	Primary Pathway	Percent Dose, Primary Rad and Pathway
Industrial, no cover	1.983 E-03	0	Eu-155	External	100%
	1.724 E-03	1	Eu-155	External	100%
	4.902 E-04	10	Eu-155	External	100%
	2.996 E-05	30	Eu-155	External	100%
	1.61 E-09	100	Eu-155	External	100%
	1.561 E-12	150	Eu-155	External	100%

Table 5-13. Dose Assessment Results for the 216-S-20 Crib. (2 Pages)

Scenario	Total Dose (mrem/yr)	Time (year)	Primary Radionuclide	Primary Pathway	Percent Dose, Primary Rad and Pathway
	1.331 E-18	250	Eu-155	External	100%
	0	500	Eu-155	External	0%
	0	1,000	Eu-155	External	0%

Table 5-14. Risk Assessment Results for the 216-S-20 Crib.

Scenario	Total Risk	Time (year)	Primary Radionuclide	Primary Pathway	Percent Risk, Primary Rad and Pathway
Industrial, no cover	1.005 E-08	0	Eu-155	External	100%
	8.737 E-09	1	Eu-155	External	100%
	2.484 E-09	10	Eu-155	External	100%
	1.518 E-10	30	Eu-155	External	100%
	8.568 E-15	100	Eu-155	External	100%
	7.912 E-18	150	Eu-155	External	100%
	6.746 E-24	250	Eu-155	External	100%
	0	500	Eu-155	External	0%
	0	1,000	Eu-155	External	0%

Table 5-15. Summary of Groundwater Pathway Doses and Risk Assessment - 216-S-20 Crib. (2 Pages)

Radionuclide	Concentration in Contaminated Zone (pCi/g)	Depth of Contamination (m)	Maximum Dose (mrem/yr)	Maximum Excess Cancer Risk	Time of Maximum Dose (yr)
C-14	**35.6**	15	0.06	6.0 E-08	6,000
Cs-137	**95600**	15	0	0	-
Co-60	**104**	15	0	0	-
Ni-63	**4580**	15	0	0	-
Th-228	**15.9**	15	0	0	-
Th-232	**1.41**	15	0	0	-
U-233/234	**250**	15	1300	8.2 E-04	6,000

Table 5-15. Summary of Groundwater Pathway Doses and Risk Assessment - 216-S-20 Crib. (2 Pages)

Radionuclide	Concentration in Contaminated Zone (pCi/g)	Depth of Contamination (m)	Maximum Dose (mrem/yr)	Maximum Excess Cancer Risk	Time of Maximum Dose (yr)
U-235	**26.4**	15	130	9.0 E-05	6,000
U-238	**270**	15	1400	1.1 E-03	6,000
Eu-154	**70.8**	50	0	0	-
Eu-155	**0.144**	50	0	0	-
Pu-238	**2.6**	50	4.0 E-03	6.9 E-10	3,000
Pu-239/240	**78.0**	50	0.01	8.6 E-07	>10,000
Am-241	**5800**	73	0.13	9.0 E-07	>10,000
H-3	63.1	73	0.31	7.2 E-06	8

Shaded cells indicate radionuclides that present an excess cancer risk and reach groundwater within 1,000 years.

Table 5-16. Dose Assessment Results for the 216-Z-7 Crib.

Scenario	Total Dose (mrem/yr)	Time (year)	Primary Radionuclide	Primary Pathway	Percent Dose, Primary Rad and Pathway
Industrial, existing cover	2.740 E-17	0	Cs-137	External	100%
	2.718 E-17	1	Cs-137	External	100%
	2.529 E-17	10	Cs-137	External	100%
	2.154 E-17	30	Cs-137	External	100%
	1.229 E-17	100	Cs-137	External	100%
	8.232 E-18	150	Cs-137	External	100%
	3.716 E-18	250	Cs-137	External	99%
	3.916 E-18	500	Np-237	External	87%
	5.918 E-14	1,000	Np-237	External	100%
Industrial, no cover	9.806 E-02	0	Cs-137	External	78%
	9.662 E-02	1	Cs-137	External	78%
	8.605 E-02	10	Cs-137	External	76%
	7.084 E-02	30	Cs-137	External	68%
	5.065 E-02	100	Pu-239	Ingestion	47%
	4.711 E-02	150	Pu-239	Ingestion	47%
	4.538 E-02	250	Pu-239	Ingestion	47%
	4.442 E-02	500	Pu-239	Ingestion	48%
	4.288 E-02	1,000	Pu-239	Ingestion	49%

Table 5-17. Risk Assessment Results for the 216-Z-7 Crib.

Scenario	Total Risk	Time (year)	Primary Radionuclide	Primary Pathway	Percent Risk, Primary Rad and Pathway
Industrial, existing cover	4.660 E-022	0	Cs-137	External	100%
	4.623 E-22	1	Cs-137	External	100%
	4.301 E-22	10	Cs-137	External	100%
	3.664 E-22	30	Cs-137	External	100%
	2.090 E-22	100	Cs-137	External	100%
	1.400 E-22	150	Cs-137	External	100%
	6.336 E-23	250	Cs-137	External	100%
	8.741 E-23	500	Np-237	External	90%
	1.367 E-18	1,000	Np-237	External	100%
Industrial, no cover	9.898 E-07	0	Cs-137	External	76%
	9.719 E-07	1	Cs-137	External	76%
	8.336 E-07	10	Cs-137	External	72%
	6.209 E-07	30	Cs-137	External	63%
	3.340 E-07	100	Np-237	External	75%
	2.851 E-07	150	Np-237	External	90%
	2.643 E-07	250	Np-237	External	99%
	2.604 E-07	500	Np-237	External	100%
	2.570 E-07	1,000	Np-237	External	100%

Table 5-18. Summary of Groundwater Pathway Doses and Risk Assessment - 216-Z-7 Crib.

Radionuclide	Concentration in Contaminated Zone (pCi/g)	Depth of Contamination (ft)	Maximum Dose (mrem/yr)	Maximum Excess Cancer Risk	Time of Maximum Dose (yr)
Am-241	60600	17.5-20	<0.3	1.6 E-06	1,000
Cs-137	2800	17.5-20	0	0	-
Co-60	58.3	17.5-20	0	0	-
Eu-154	10.5	17.5-20	0	0	-
Eu-155	0.0849	57.5-60	0	0	-
H-3	3.43	96.5-99	<0.3	3.6 E-06	1,000
Np-237	0.059	12.5-15	0	0	-
Pu-238	5770	17.5-20	0	0	-
Pu-239/240	472000	17.5-20	0	0	-
Sr-90	437000	17.5-20	0	0	-
Tc-99	11	22.5-25	8.5	1.8 E-06	500
Uranium	27900	17.5-20	0	0	-

Table 5-19. Ecological Screening Results for Nonradiological Contaminants at the 216-T-28 Crib. (2 Pages)

Chemical Name	Top 4.6 m (15 ft) Maximum Concentration	Background	Does Maximum Concentration Exceed Background?	Soil Indicator Value[a] (Wildlife)	COEC?	Justification
Inorganic metal (mg/kg)						
Antimony	N.A.	--		5[c]	Yes	Not analyzed
Arsenic	N.A.	20[d]		7	Yes	Not analyzed
Barium	N.A.	132		102	Yes	Not analyzed
Beryllium	N.A.	1.51		35[b]	Yes	Not analyzed
Bismuth	N.A.	--	--		Yes	Not analyzed

Table 5-19. Ecological Screening Results for Nonradiological Contaminants at the 216-T-28 Crib. (2 Pages)

Chemical Name	Top 4.6 m (15 ft) Maximum Concentration	Background	Does Maximum Concentration Exceed Background?	Soil Indicator Value[a] (Wildlife)	COEC?	Justification
Boron	N.A.	--		0.5[c]	Yes	Not analyzed
Cadmium	N.A.	0.81		14	Yes	Not analyzed
Chromium (total)	N.A.	18.5		67	Yes	Not analyzed
Chromium VI	N.A.	--		NA	Yes	Not analyzed
Copper	N.A.	22		217	Yes	Not analyzed
Lead	N.A.	10.2		118	Yes	Not analyzed
Mercury (inorganic)	N.A.	0.33		5.5	Yes	Not analyzed
Nickel	N.A.	19.1		980	Yes	Not analyzed
Selenium	N.A.	--		0.3	Yes	Not analyzed
Silver	N.A.	0.73		2[c]	Yes	Not analyzed
Uranium	N.A.	3.21		5[c]	Yes	Not analyzed
General Inorganic Compounds (mg/kg)						
Chloride	N.A.	100		NA	Yes	Not analyzed
Cyanide	N.A.	--		NA	Yes	Not analyzed
Fluoride	N.A.	2.81		NA	Yes	Not analyzed
Nitrate as N	N.A.	12		NA	Yes	Not analyzed
Phosphate	N.A.	0.785		NA	Yes	Not analyzed
Sulfate	N.A.	237		NA	Yes	Not analyzed
Sulfide	N.A.	--		--	Yes	Background not determined

[a]Unless otherwise footnoted, screening values represent WAC-173-340-900, "Tables," Table 749-3, soil values for terrestrial wildlife.

[b]No WAC-173-340-900, Table 749-3, terrestrial wildlife value available, screening value is soil screening level for wildlife from EPA 2003, *Guidance for Developing Ecological Soil Screening Levels*, OSWER Directive 9285.7-55.

[c]No WAC-173-340-900, Table 749-3, terrestrial wildlife value available, screening value is lowest of WAC-173-340-900, Table 749-3, soil values for plants and biota.

[d]Arsenic background value from WAC 173-340-900, Tables 740-1 and 745-1.

Shading indicates analyte was retained as a COEC.
No samples were collected in the shallow interval in 216-T-28 Crib.

COEC = contaminant of ecological concern.
NA = not applicable/not available.
N.A. = no analysis.
ND = not detected.
WAC = *Washington Administrative Code.*

Table 5-20. Ecological Screening Results for Nonradiological Contaminants at the 216-S-20 Crib. (2 Pages)

Chemical Name	Top 4.6 m (15 ft) Maximum Concentration	Back-ground	Does Maximum Concentration Exceed Background?	Soil Screening Value[a] (Wildlife)	COEC?	Justification
Inorganic metal (mg/kg)						
Antimony	ND	--	No	5[c]	No	Not detected
Arsenic	6.7	6.47[d]	Yes	7	No	Below SSL
Barium	112	132	No	102	No	Below background
Beryllium	ND	1.51	No	35[b]	No	Not detected
Bismuth	ND	--	NA	NA	No	Not detected
Boron	ND	--	NA	0.5[c]	No	Not detected
Cadmium	ND	0.81	No	14	No	Not detected
Chromium (total)	5.84	18.5	No	67	No	Below background
Chromium VI	ND	--	No	NA	No	Not detected
Copper	14.5	22	No	217	No	Below background
Lead	ND	10.2	No	118	No	Not detected
Mercury (inorganic)	ND	0.33	No	5.5	No	Not detected
Nickel	10.4	19.1	No	980	No	Below background
Selenium	ND	--	No	0.3	No	Not detected
Silver	ND	0.73	No	2[c]	No	Not detected
Uranium	ND	3.21	No		No	Not detected
General Inorganic Compounds (mg/kg)						
Ammonium Ion	ND					
Ammonia	ND	9.23	No	NA	No	Not detected
Chloride	2.82	100	No	NA	No	Below background
Cyanide	ND	--	NA	NA	No	Not detected
Fluoride	ND	2.81	No	NA	No	Not detected
N as Nitrate	7.39	12	No	NA	No	Below background
N as Nitrite	ND	--	NA	NA	No	Not detected
Nitrate and Nitrite / nitrate as Nitrogen	2.8	--	Yes	NA	No	Soil Constituent
Phosphate	ND	0.785	No	NA	No	Not detected

Table 5-20. Ecological Screening Results for Nonradiological Contaminants at the 216-S-20 Crib. (2 Pages)

Chemical Name	Top 4.6 m (15 ft) Maximum Concentration	Back-ground	Does Maximum Concentration Exceed Background?	Soil Screening Value[a] (Wildlife)	COEC?	Justification
Sulfate	ND	237	No	NA	No	Not detected
Sulfide	ND				No	Not detected

[a]Unless otherwise footnoted, screening values represent WAC-173-340-900, "Tables," Table 749-3, soil values for terrestrial wildlife.

[b]No WAC-173-340-900, Table 749-3, terrestrial wildlife value available, screening value is soil screening level for wildlife from EPA 2003, *Guidance for Developing Ecological Soil Screening Levels*, OSWER Directive 9285.7-55.

[c]No WAC-173-340-900, Table 749-3, terrestrial wildlife value available, screening value is lowest of WAC-173-340-900, Table 749-3, soil values for plants and biota.

[d]Arsenic background value from Table 6.9.a., DOE/RL-92-24, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*.

Shading indicates that analyte was retained as a COEC.

COEC = contaminant of ecological concern.
NA = not applicable/not available.
ND = not detected.
SSL = soil-screening level.
WAC = *Washington Administrative Code.*

Table 5-21. Ecological Screening Results for Chemicals at the 216-Z-7 Crib.

Chemical Name	Top 4.6 m (15 ft) Maximum Concentration	Back-ground	Does Maximum Concentration Exceed Background?	Soil Indicator Value[a] (Wildlife)	COEC?	Justification
Inorganic metal (mg/kg)						
Antimony	ND	--	NA	5[c]	No	Not detected
Arsenic	13.4	6.47[d]	No	7	No	Depth of result precludes exposure
Barium	72.1	132	No	102	No	Less than background
Beryllium	ND	1.51	No	35[b]	No	Not detected
Bismuth	ND	--	NA	NA	No	Not detected
Boron	ND	--	NA	0.5[c]	No	Not detected
Cadmium	ND	0.81	No	14	No	Not detected
Chromium (total)	7.38	18.5	No	67	No	Less than background
Chromium VI	ND	--	NA	NA	No	Not detected
Copper	13	22	No	217	No	Less than background
Lead	ND	10.2	No	118	No	Not detected
Mercury (inorganic)	ND	0.33	No	5.5	No	Not detected
Nickel	11.6	19.1	No	980	No	Less than background
Selenium	ND	--	NA	0.3	No	Not detected
Silver	ND	0.73	No	2[c]	No	Not detected
Uranium	ND	3.21	No	5[c]	No	Not detected
General Inorganic Compounds (mg/kg)						
Ammonia	ND	9.23	No	NA	No	Not detected
Chloride	ND	100	No	NA	No	Not detected
Cyanide	3.95	--	NA	NA	No	Not detected
Fluoride	ND	2.81	Yes	NA	No	Not detected
Nitrate as N	10.85	12	Yes	NA	No	Less than background
Nitrite as N	ND	--	NA	NA	No	Not detected
Phosphate	ND	0.785	Yes	NA	No	Not detected
Sulfate	ND	237	No	NA	No	Not detected
Sulfide	ND	--	NA	NA	No	Not analyzed

Table 5-21. Ecological Screening Results for Chemicals at the 216-Z-7 Crib.

Chemical Name	Top 4.6 m (15 ft) Maximum Concentration	Back-ground	Does Maximum Concentration Exceed Background?	Soil Indicator Value[a] (Wildlife)	COEC?	Justification

[a]Unless otherwise footnoted, screening values represent WAC-173-340-900, "Tables," Table 749-3, soil values for terrestrial wildlife.

[b]No WAC-173-340-900, Table 749-3, terrestrial wildlife value available, screening value is soil screening level for wildlife from EPA 2003, *Guidance for Developing Ecological Soil Screening Levels*, OSWER Directive 9285.7-55.

[c]No WAC-173-340-900, Table 749-3, terrestrial wildlife value available, screening value is lowest of WAC-173-340-900, Table 749-3, soil values for plants and biota.

[d]Arsenic background value from Table 6.9.a, DOE/RL-92-24.

Shading indicates analyte was retained as a COEC.

COEC = contaminant of ecological concern.

NA = not applicable/not available.

ND = not detected.

WAC = *Washington Administrative Code.*

Table 5-22. Ecological Screening Results for Radionuclides at 216-T-28 Crib. (2 Pages)

Radionuclides (pCi/g)	Exposure Point Concentration	90th Percentile Background Concentration	Exceeds Background?	DOE-STD-1153-2002 Biota Concentration Guideline (pCi/g)	COEC?	Justification
Americium-241	NLA	--	NA	4,000	Yes	No laboratory analysis
Antimony-125	NLA	--	NA	3,000	Yes	No laboratory analysis
Carbon-14	NLA	--	NA	--	Yes	No laboratory analysis
Cesium-134	NLA	--	NA	--	Yes	No laboratory analysis
Cesium-137	NLA	--[a]	Yes	20	Yes	No laboratory analysis
Cobalt-60	NLA	--[a]	No	700	Yes	No laboratory analysis
Europium-152	NLA	--	NA	--	Yes	No laboratory analysis
Europium-154	NLA	--[a]	No	1,000	Yes	No laboratory analysis
Europium-155	NLA	--[a]	Yes	20,000	Yes	No laboratory analysis
Neptunium-237	NLA	--	NA	--	Yes	No laboratory analysis
Nickel-63	NLA	--	NA	--	Yes	No laboratory analysis
Plutonium-238	NLA	--[a]	No	--	Yes	No laboratory analysis
Plutonium-239/240	NLA	--[a]	No	6,000	Yes	No laboratory analysis
Radium-226	NLA	0.815	Yes	50	Yes	No laboratory analysis
Radium-228	NLA	1.32	No	40	Yes	No laboratory analysis
Technetium-99	NLA	--	NA	4,000	Yes	No laboratory analysis
Thorium-228	NLA	1.32	No	--	Yes	No laboratory analysis
Thorium-230	NLA	1.10	Yes	--	Yes	No laboratory analysis
Thorium-232	NLA	1.32	No	2,000	Yes	No laboratory analysis
Thorium-234	NLA	--	NA	--	Yes	No laboratory analysis
Total Radioactive Strontium	NLA	--[a]	Yes	20	Yes	No laboratory analysis
Tritium	NLA	--	NA	200,000	Yes	No laboratory analysis
Uranium-234	NLA	1.10	No	5,000	Yes	No laboratory analysis
Uranium-235	NLA	0.109	No	3,000	Yes	No laboratory analysis

Table 5-22. Ecological Screening Results for Radionuclides at 216-T-28 Crib. (2 Pages)

Radionuclides (pCi/g)	Exposure Point Concentration	90th Percentile Background Concentration	Exceeds Background?	DOE-STD-1153-2002 Biota Concentration Guideline (pCi/g)	COEC?	Justification
Uranium-238	NLA	1.06	No	2,000	Yes	No laboratory analysis
				dose fractions sum		III for constituents with BCGs =

[a]Surface background for fallout radionuclides was not used for comparison because maximum may be in subsurface.
Shading indicates analyte was retained as a COEC.
DOE-STD-1153-2002, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota.*

COEC = Contaminant of Ecological Concern.
DOE = U.S. Department of Energy.
NA = not applicable/not available.
ND = not detected.
NLA = no laboratory analysis; because of poor sample recovery, no analysis of shallow soils was conducted.

Table 5-23. Ecological Screening Results for Radionuclides at the 216-S-20 Crib. (2 Pages)

Radionuclides	Exposure Point Concentration (pCi/g)	90th Percentile Background Concentration (pCi/g)	Exceeds Background?	DOE-STD-1153-2002 Biota Concentration Guideline (pCi/g)	COEC?	Justification
Americium-241	ND	--	NA	4,000	No	Not detected
Antimony-125	ND	--	NA	3,000	No	Not analyzed
Carbon-14	ND	--	NA	--	No	Not detected
Cesium-134	ND	--	NA	--	No	Not analyzed
Cesium-137	ND	--[a]	NA	20	No	Not detected
Cobalt-60	ND	--[a]	NA	700	No	Not detected
Europium-152	ND	--	NA	--	No	Not detected
Europium-154	ND	--[a]	NA	1,000	No	Not detected
Europium-155	ND	--[a]	NA	20,000	No	Not detected
Neptunium-237	ND	--	NA	--	Yes	Not detected
Nickel-63	ND	--	NA	--	No	Not detected
Plutonium-238	ND	--[a]	NA	--	No	Not detected

Table 5-23. Ecological Screening Results for Radionuclides at the 216-S-20 Crib. (2 Pages)

Radionuclides	Exposure Point Concentration (pCi/g)	90th Percentile Background Concentration (pCi/g)	Exceeds Background?	DOE-STD-1153-2002 Biota Concentration Guideline (pCi/g)	COEC?	Justification
Plutonium-239/240	ND	--[a]	NA	6,000	No	Not detected
Potassium-40	9.06	16.6	No	--	Yes	Less than background
Radium-226	0.319	0.815	No	50	No	Less than background
Radium-228	0.624	1.32	No	40	No	Less than background
Technetium-99	ND	--	NA	4,000	No	Not detected
Thorium-228	0.64	1.32	No	--	No	Less than background
Thorium-230	0.319	1.10	No	--	No	Less than background
Thorium-232	0.958	1.32	No	2,000	No	Less than background
Total radioactive strontium	ND	--[a]	NA	20	No	Not detected
Tritium	ND	--	NA	200,000	No	Not detected
Uranium-234	0.19	1.10	No	5,000	No	Less than background
Uranium-235	0.02	0.109	No	3,000	No	Less than background
Uranium-238	0.22	1.06	No	2,000	No	Less than background
					dose fractions sum	**HI for constituents with BCGs = 0.023**

[a]Surface background for fallout radionuclides was not used for comparison, because maximum may be in subsurface.
Shading indicates that radionuclide was retained as a COEC.
DOE-STD-1153-2002, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota.*

BCG = biota concentration guide.
COEC = contaminant of ecological concern.
NA = not applicable/not available.
ND = not detected.

Table 5-24. Ecological Screening Results for Radionuclides at the 216-Z-7 Crib. (2 Pages)

Radionuclides (pCi/g)	Exposure Point Concentration	90th Percentile Background Concentration	Exceeds Background?	DOE-STD-1153-2002 Biota Concentration Guideline (pCi/g)	COEC?	*Justification*
Americium-241	ND	--	NA	4,000	No	Not detected
Antimony-125	ND	--	NA	3,000	No	Not detected
Carbon-14	ND	--	NA	--	No	Not detected
Cesium-134	ND	--	NA	--	No	Not detected
Cesium-137	0.0835	--[a]	No	20	No	Not detected
Cobalt-60	ND	--[a]	No	700	No	Not detected
Europium-152	ND	--	NA	--	No	Not detected
Europium-154	ND	--[a]	No	1,000	No	Not detected
Europium-155	0.0734	--[a]	Yes	20,000	No	Less than BCG
Neptunium-237	0.059	--	NA	--	Yes	No BCG available
Nickel-63	ND	--	NA	--	No	Not detected
Plutonium-238	ND	--[a]	NA	--	No	Not detected
Plutonium-239/240	ND	--[a]	Yes	6,000	No	Not detected
Radium-226	0.41	0.815	No	50	No	Less than background
Radium-228	0.58	1.32	No	40	No	Less than background
Technetium-99	ND	--	NA	4,000	No	Not detected
Thorium-228	1.16	1.32	No	--	No	Less than background
Thorium-230	1.03	1.10	No	--	No	Less than background
Thorium-232	0.734	1.32	No	2,000	No	Less than background
Total Radioactive Strontium	ND	--[a]	Yes	20	No	Not detected
Tritium	ND	--	NA	200,000	No	Not detected
Uranium-234	0.506	1.10	Yes	5,000	No	Less than background

Table 5-24. Ecological Screening Results for Radionuclides at the 216-Z-7 Crib. (2 Pages)

Radionuclides (pCi/g)	Exposure Point Concentration	90th Percentile Background Concentration	Exceeds Background?	DOE-STD-1153-2002 Biota Concentration Guideline (pCi/g)	COEC?	Justification
Uranium-235	ND	0.109	Yes	3,000	No	Not detected
Uranium-238	ND	1.06	Yes	2,000	No	Not detected
				dose fractions sum		**HI for constituents with BCGs = 0.027**

[a]Surface background for fallout radionuclides was not used for comparison, because maximum may be in subsurface.
Shading indicates that radionuclide was retained as a COEC.
DOE-STD-1153-2002, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota.*
BCG = biota concentration guide.
DOE = U.S. Department of Energy.
COEC = contaminant of ecological concern.
NA = not applicable/not available.
ND = not detected.