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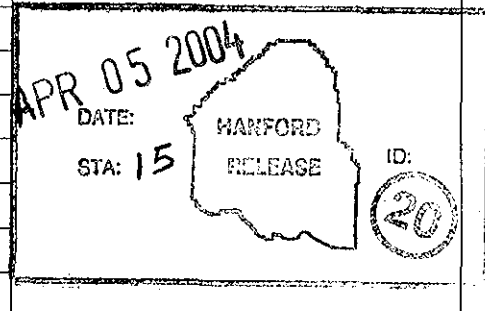
Document Number	RPP-16608	<input checked="" type="checkbox"/> Full Revision	<input type="checkbox"/> Page Change	New Rev. No.	1
Electronic File Name (Optional):	N/A				
Document Title	Site-Specific Single-Shell Tank Phase 1 RCRA Facility Investigation/Corrective Measures Study Work Plan Addendum for Waste Management Areas C, A-AX, and U				
Change Description	Incorporate comments from Washington Department of Ecology				
Change Justification	Comments from Washington Department of Ecology must be incorporated into document				

Approvals:

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Reviewer (Optional, Print/Sign) N/A		Date: N/A

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Site-Specific Single-Shell Tank Phase 1 RCRA Facility Investigation/Corrective Measures Study Work Plan Addendum for Waste Management Areas C, A-AX, and U

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U.S. Department of Energy Contract DE-AC27-99RL14047

EDT/ECN: *jda 4/5* ~~721689-RO~~ UC: 2000
Cost Center: 7P200 Charge Code: 116707AJ60
B&R Code: N/A Total Pages: *204 205 jda 4/5*

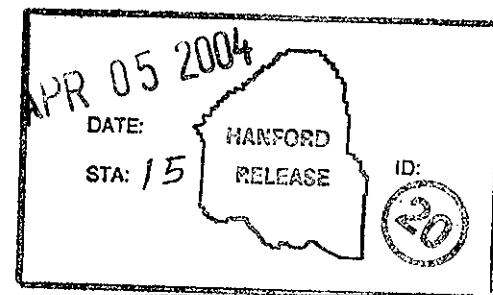
Key Words: Site-Specific, Single-Shell Tank, Phase 1, RCRA, WMA,
Waste Management Area, C, A-AX, U

Abstract: This Site-Specific Single-Shell Tank (SST) Phase 1 RCRA Facility Investigation (RFI)/Corrective Measures Study (CMS) Work Plan Addendum for Waste Management Areas (WMA) C, A-AX, and U has been prepared to outline the investigation efforts for collection of field characterization data in and near WMAs C, A-AX, and U in fiscal years (FYs) 2004 and 2005 to support waste retrieval and tank farm closure decision-making.

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**Site-Specific Single-Shell Tank Phase 1 RCRA
Facility Investigation/Corrective Measures Study
Work Plan Addendum for Waste Management
Areas C, A-AX, and U**

March 11, 2004

Prepared By
CH2M HILL Hanford Group, Inc.
Richland, Washington

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CONTENTS

1.0	INTRODUCTION	1-1
1.1	REGULATORY BACKGROUND	1-1
1.2	PURPOSE AND OBJECTIVE	1-6
1.3	SCOPE OF ACTIVITIES	1-7
1.4	SELECTION OF FIELD ACTIVITIES	1-8
1.5	ORGANIZATION OF THIS WASTE MANAGEMENT AREAS C, A-AX, AND U ADDENDUM.....	1-10
2.0	C, A, AND AX TANK FARM HISTORY AND SETTING	2-1
2.1	C, A, AND AX TANK FARM HISTORY	2-1
2.1.1	C, A, and AX Tank Farm Layouts	2-1
2.1.2	C, A, and AX Tank Farm History of Operations	2-3
2.1.3	Vadose Zone Leak Detection Systems in C, A, and AX Tank Farms.....	2-5
2.1.4	Associated Facilities	2-6
2.2	PHYSICAL SETTING	2-6
2.2.1	Topography	2-6
2.2.2	Geology.....	2-12
2.2.3	Hydrogeology	2-22
2.2.4	Surface Water Hydrology	2-33
3.0	INITIAL CONDITIONS AND CORRECTIVE ACTION REQUIREMENTS AND OBJECTIVES IN WASTE MANAGEMENT AREAS C AND A-AX	3-1
3.1	KNOWN AND SUSPECTED CONTAMINATION IN WASTE MANAGEMENT AREAS C AND A-AX	3-1
3.1.1	Sources.....	3-1
3.1.2	Releases to Sediment	3-4
3.1.3	Intentional Liquid Waste Disposals to Surrounding Cribs and Trenches	3-8
3.1.4	Groundwater	3-9
3.1.5	Surface Water and River Sediment.....	3-20
3.2	POTENTIAL CORRECTIVE ACTION REQUIREMENTS	3-20
3.3	POTENTIAL IMPACTS TO PUBLIC HEALTH AND THE ENVIRONMENT	3-20
4.0	U TANK FARM HISTORY AND SETTING.....	4-1
4.1	U TANK FARM HISTORY.....	4-1
4.1.1	U Tank Farm Layout.....	4-1
4.1.2	U Tank Farm History of Operations	4-3
4.1.3	Vadose Zone Leak Detection Systems in U Tank Farm.....	4-4
4.1.4	Associated Facilities	4-5

4.2	PHYSICAL SETTING	4-6
4.2.1	Topography	4-6
4.2.2	Geology	4-6
4.2.3	Hydrogeology	4-11
4.2.4	Surface Water Hydrology	4-15
5.0	INITIAL CONDITIONS AND CORRECTIVE ACTION REQUIREMENTS AND OBJECTIVES IN WASTE MANAGEMENT AREA U.....	5-1
5.1	KNOWN AND SUSPECTED CONTAMINATION IN WASTE MANAGEMENT AREA U.....	5-1
5.1.1	Sources	5-1
5.1.2	Releases to Sediment	5-4
5.1.3	Intentional Liquid Waste Disposals to Surrounding Cribs and Trenches	5-6
5.1.4	Groundwater	5-6
5.1.5	Surface Water and River Sediment	5-14
5.2	POTENTIAL CORRECTIVE ACTION REQUIREMENTS	5-14
5.3	POTENTIAL IMPACTS TO PUBLIC HEALTH AND THE ENVIRONMENT	5-14
6.0	WORK PLAN RATIONALE AND APPROACH	6-1
6.1	RATIONALE	6-1
6.2	DATA NEEDS	6-2
6.3	CHARACTERIZATION OPTIONS	6-3
6.3.1	Installation of Vertical Boreholes	6-4
6.3.2	Near-Surface Characterization	6-17
6.3.3	RCRA Monitoring Well Characterization	6-19
6.4	INVESTIGATIVE SAMPLING AND ANALYSIS AND DATA VALIDATION	6-19
7.0	RCRA FACILITY INVESTIGATION/CORRECTIVE MEASURES STUDY TASKS AND PROCESS	7-1
7.1	TASK 1 – PROJECT MANAGEMENT	7-1
7.2	TASK 2 – GEOLOGIC AND VADOSE ZONE INVESTIGATION	7-1
7.2.1	Subtask 2a – Field Activities	7-2
7.2.2	Subtask 2b – Laboratory Analysis	7-4
7.3	TASK 3 – DATA EVALUATION	7-5
8.0	SCHEDULE	8-1
9.0	PROJECT MANAGEMENT	8-4
9.1	PROJECT ORGANIZATION AND RESPONSIBILITIES	9-1
9.2	DOCUMENTATION AND RECORDS	9-2
10.0	REFERENCES	10-1
11.0	GLOSSARY	11-1

FIGURES

1.1.	Location Map of Waste Management Areas C and A-AX and Related Facilities	1-3
1.2.	Location Map of Waste Management Area U and Related Facilities	1-4
1.3.	Characterization Activities that Address Data Quality Objectives Process and Data Needs	1-8
2.1.	General Configuration of Tanks in Waste Management Areas C and A-AX.....	2-2
2.2.	Location Map of C Tank Farm and Surrounding Facilities.....	2-10
2.3.	Location Map of A and AX Tank Farms and Surrounding Facilities.....	2-11
2.4.	Stratigraphic Unit.....	2-13
2.5.	Structure Contour Map of the Top of Basalt	2-15
2.6.	Water Level Elevations in the 200 East Area in March 2002.....	2-24
2.7.	Hydrographs for Wells in the Waste Management Area C Monitoring Network – All data referenced to the NAVD88 datum. Spurious data have been removed.	2-25
2.8.	Hydrographs for Two Wells in the Waste Management Area A-AX Monitoring Network – All data referenced to the NAVD88 datum. Spurious data have been removed.	2-26
2.9.	Flow Direction Map of Wells in the Vicinity of Waste Management Areas C and A-AX Based on Colloidal Borescope Measurements.....	2-28
2.10.	Flow Direction Map of Wells Around Waste Management Area C Based on Colloidal Borescope Measurements	2-30
2.11.	Flow Direction Map of Wells Around Waste Management Area A-AX Based on Colloidal Borescope Measurements	2-31
3.1.	Distribution of Radionuclides in the Unconfined Aquifer in 200 East Area.....	3-10
3.2.	Distribution of Chromium and Nitrate in the Unconfined Aquifer in 200 East Area.....	3-11
3.3.	Trend Plots of Specific Conductance for Waste Management Area C.....	3-12
3.4.	Trend Plots of Specific Conductance, Cations and Anions for Well 299-E27-14.....	3-12
3.5.	Trend Plots of Technetium-99 for Waste Management Area C	3-13
3.6.	Trend Plots of Nitrate and Technetium-99 for Waste Management Area C	3-13
3.7.	Trend Plots of Specific Conductance for Waste Management Area A-AX	3-15
3.8.	Trend Plots of Sulfate for Waste Management Area A-AX.....	3-16
3.9.	Trend Plots of Nitrate for Waste Management Area A-AX	3-16
3.10.	Trend Plots of Technetium-99 for Waste Management Area A-AX.....	3-17
3.11.	Trend Plots for Filtered Chromium, Nickel, Manganese, and Iron for Well 299-E24-19.....	3-18
3.12.	Trend Plots for Filtered Chromium and Specific Conductance for Well 299-E24-19. These data are from filtered samples.	3-19
3.13.	Trend Plots for Filtered Chromium and pH for Well 299-E24-19	3-20
3.14.	Preliminary Generalized Waste Management Areas C and A-AX Vadose Zone Conceptual Model.....	3-23
4.1.	General Configuration of Tanks in Waste Management Area U.....	4-2
4.2.	Location Map of U Tank Farm and Surrounding Facilities.....	4-7
4.3.	Generalized Stratigraphic Column of the 200 West Area (BHI-00184).....	4-8

4.4.	Historical Depth Above Mean Sea Level at Well 299-W19-1 Just South of Waste Management Area U (PNNL-13282).....	4-12
4.5.	Recent Water Level Measurements from RCRA Monitoring Wells Around Waste Management Area U (PNNL-13282).....	4-13
5.1.	Nitrate Measurements at Monitoring Well 299-W19-12 (PNNL-13282)	5-7
5.2.	Technetium-99 and Gross Beta Measurements at Monitoring Well 299-W19-12 (PNNL-13282).....	5-8
5.3.	Nitrate Measurements at Monitoring Wells 299-W18-25, 299-W18-30, and 299-W18-31 (PNNL-13282).....	5-8
5.4.	Nitrate Measurements at Monitoring Wells 299-W19-12, 299-W19-31, 299-W19-32, 299-W19-41 and 299-W19-42 (PNNL-13282).....	5-9
5.5.	Technetium-99 Measurements at Monitoring Wells 299-W19-12, 299-W19-31, 299-W19-32, 299-W19-41 and 299-W19-42 (PNNL-13282).....	5-9
5.6.	Nitrate Measurements at Wells 299-W18-31, 299-W19-12, 299-W19-41, and 299-W19-42 (PNNL-13404).....	5-10
5.7.	Technetium-99 Measurements at Wells 299-W18-31, 299-W19-12, 299-W19-41 and 299-W19-42 (PNNL-13404).....	5-10
5.8.	Preliminary Generalized Waste Management Area U Vadose Zone Conceptual Model.....	5-16
6.1.	C Tank Farm Borehole Locations.....	6-8
6.2.	Plan View of the C Tank Farm Showing Drywells	6-9
6.3.	Sketch of Well Locations.....	6-10
6.4.	U Tank Farm Borehole Locations.....	6-12
8.1.	Preliminary Characterization Schedule.....	8-2

TABLES

2.1.	Current Waste Volume in C, A, and AX Farm Tanks	2-7
2.2.	Treatment, Storage and/or Disposal Units and Associated Environmental Restoration Facilities at Waste Management Areas C and A-AX.....	2-8
3.1.	Estimated Past Leak Losses from A, AX, and C Single-Shell Tanks.....	3-3
4.1.	Current Waste Volume in U Farm Tanks	4-4
4.2.	Treatment, Storage, and/or Disposal Units and Associated Environmental Restoration Facilities at Waste Management Area U.....	4-5
5.1.	Estimated Past Leak Losses from U Single-Shell Tanks.....	5-3
6.1.	Proposed Waste Management Areas C, A-AX, and U Phase I Characterization Design.....	6-5

LIST OF TERMS

amsl	above mean sea level
bgs	below ground surface
CMS	corrective measures study
CoC	contaminant of concern
CRBG	Columbia River Basalt Group
DOE	U.S. Department of Energy
DQO	data quality objective
DWS	drinking water standard
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FY	fiscal year
HFFACO	<i>Hanford Federal Facility Agreement and Consent Order</i>
ICM	interim corrective measure
ITS	in-tank solidification
OWW	organic wash waste
ppb	parts per billion
PUREX	Plutonium-Uranium Extraction (Plant)
REDOX	reduction-oxidation
RCRA	<i>Resource Conservation and Recovery Act of 1976</i>
RFI	RCRA facility investigation
SST	single-shell tank
UPR	unplanned release
WMA	waste management area

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1.0 INTRODUCTION

This Site-Specific Single-Shell Tank (SST) Phase 1 *Resource Conservation and Recovery Act of 1976* (RCRA) Facility Investigation (RFI)/Corrective Measures Study (CMS) Work Plan Addendum for Waste Management Areas (WMAs) C, A-AX, and U has been prepared to outline the investigation efforts for collection of field characterization data in and near WMAs C, A-AX, and U in fiscal years (FYs) 2004 and 2005 to support waste retrieval and tank farm closure decision making. This WMAs C, A-AX, and U addendum will be used to identify and plan characterization efforts as part of an RFI. An RFI is covered under the categorical exclusion for the *National Environmental Policy Act of 1976* and categorical exemption under the “Washington State Environmental Policy Act (SEPA)” (“National Environmental Policy Act Implementing Procedures” [10 CFR 1021 Subpart D] and “SEPA Rules” [WAC 197-11]).

Documented in this WMAs C, A-AX, and U addendum are the agreements made through a planning process. These agreements include the tasks, project responsibilities, and schedule for the next characterization effort to fulfill Milestone M-45-55 of *Hanford Federal Facility Agreement and Consent Order* (HFFACO; Ecology et al. 1989). The field characterization efforts include the collection of vadose zone data from installation and sampling of four vertical boreholes (south of tank C-105, northeast of 241-C-152 diversion box, southeast of tank U-104, and northeast of tank U-112) ranging in depth to the top of Plio-Pleistocene unit to groundwater.

1.1 REGULATORY BACKGROUND

The HFFACO, which is signed by the Washington State Department of Ecology (Ecology), the U.S. Environmental Protection Agency (EPA), and the U.S. Department of Energy (DOE), addresses cleanup at more than 2,000 waste disposal and unplanned release sites on the Hanford Site. Some of these sites are treatment, storage, and/or disposal units that included 149 SSTs regulated under the Washington State “Hazardous Waste Management Act” and its implementing requirements in “Dangerous Waste Regulations” (WAC 173-303).

The SSTs are treatment, storage, and/or disposal units operating under interim status pending closure that must be operated, permitted, and maintained in compliance with the following:

- RCRA
- Washington State dangerous waste program regulations (WAC 173-303)
- HFFACO Milestones M-45-00 and M-24-00
- HFFACO Milestones M-45-51.

The tank farms will be closed under the “Hazardous Waste Management Act” and Major Milestone series M-45-00 of the HFFACO. The 149 SSTs are grouped into 12 SST farms, which are in turn grouped into 7 WMAs for purposes of “Hazardous Waste Management Act” groundwater monitoring. To date, tank leaks and past-practice releases of tank waste including dangerous waste and dangerous waste constituents have resulted in groundwater contamination documented at five of the seven SST WMAs (i.e., WMA B-BX-BY, WMA S-SX, WMA U, WMA TX-TY, and WMA T). DOE has initiated a corrective action program to address the impacts of past and potential future tank waste releases to the environment. *Phase 1 RCRA*

Facility Investigation/Corrective Measures Study Work Plan for Single-Shell Tank Waste Management Areas (DOE/RL-99-36) has been issued and establishes the overall framework and requirements for the program. This addendum presents details specific to WMAs C, A-AX, and U.

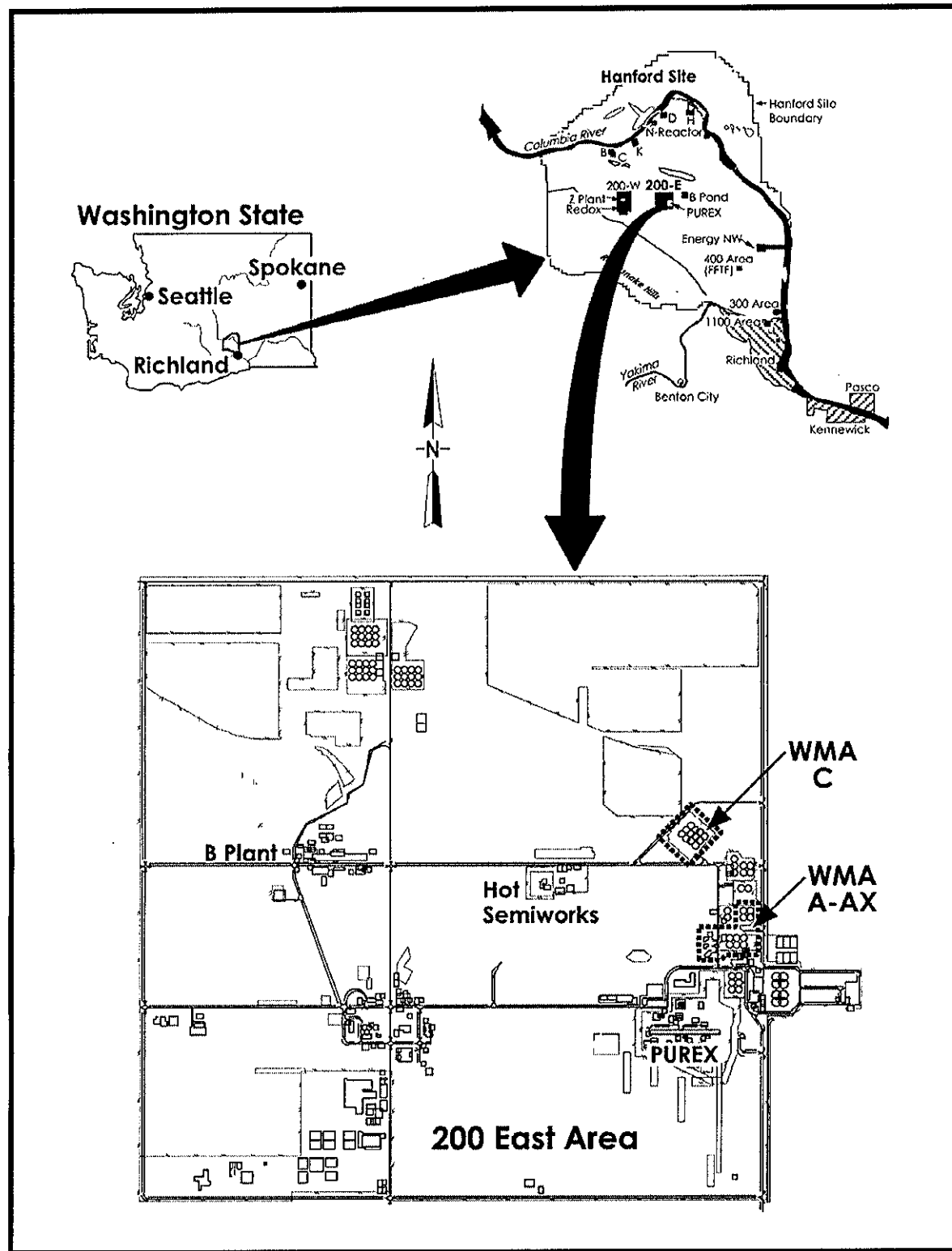
The investigation activities outlined in this addendum will be managed by the Tank Farm Vadose Zone Project as an integrated function of the Hanford Site Groundwater Protection Program. This WMAs C, A-AX, and U addendum is a document that will be submitted to Ecology for review and approval.

The A, AX, C, and U tank farms comprise WMAs C, A-AX, and U. Only WMA U was placed in assessment groundwater monitoring in 2000 because of elevated specific conductance in downgradient monitoring wells (*Groundwater Quality Assessment for Waste Management Area U: First Determination* [PNNL-13282]). Figure 1.1 shows the location of the A, AX, and C tank farms in the 200 East Area of the Hanford Site. Figure 1.2 shows the location of the U tank farm in the 200 West Area of the Hanford Site. Only specific conductance has exceeded drinking water standards (*Drinking Water Regulations and Health Advisories* [EPA-822-B-96-002]) in WMA U. The drinking water exceedances in the RCRA-compliant monitoring wells are currently limited to well 299-W19-41 (PNNL-13282) (see Section 5.1.4).

In FY 1997, spectral gamma logging (i.e., collection of baseline gamma-specific radioisotope information in the upper vadose zone) was completed at the A tank farm. Spectral gamma logging was completed at the AX tank farm in FY 1996, and at the C tank farm in FY 1997. Spectral gamma logging was completed at the U tank farm in FY 1995. The spectral gamma logging program builds on a previous program in which gross gamma data were collected as a secondary means of leak detection from the SSTs. Both programs used the network of drywells installed around each tank in each SST farm. The March 1999 final report on spectral gamma logging at the A tank farm, *Vadose Zone Characterization Project at the Hanford Tank Farms: A Tank Farm Report* (GJO-HAN-23), indicates that gamma-emitting contaminants cesium-137, cobalt-60, and europium-154 were detected in the A tank farm with cesium-137 being present at a maximum depth of 38.1 m (125 ft) below ground surface (bgs) (total depth of borehole) (*Subsurface Conditions Description of the C and A-AX Waste Management Areas* [RPP-14430]). Several other high cesium-137 concentrations were detected in the boreholes; however, these concentrations were associated with near-surface contamination resulting from surface spills, pipe leaks, or the proximity of the boreholes to pipes containing contamination. The August 1997 final report on spectral gamma logging at the AX tank farm, *Vadose Zone Characterization Project at the Hanford Tank Farms: AX Tank Farm Report* (GJO-HAN-12), indicates that gamma-emitting contaminants cesium-137, antimony-125, and cobalt-60 were detected in several of the boreholes all above tank bottoms (RPP-14430).

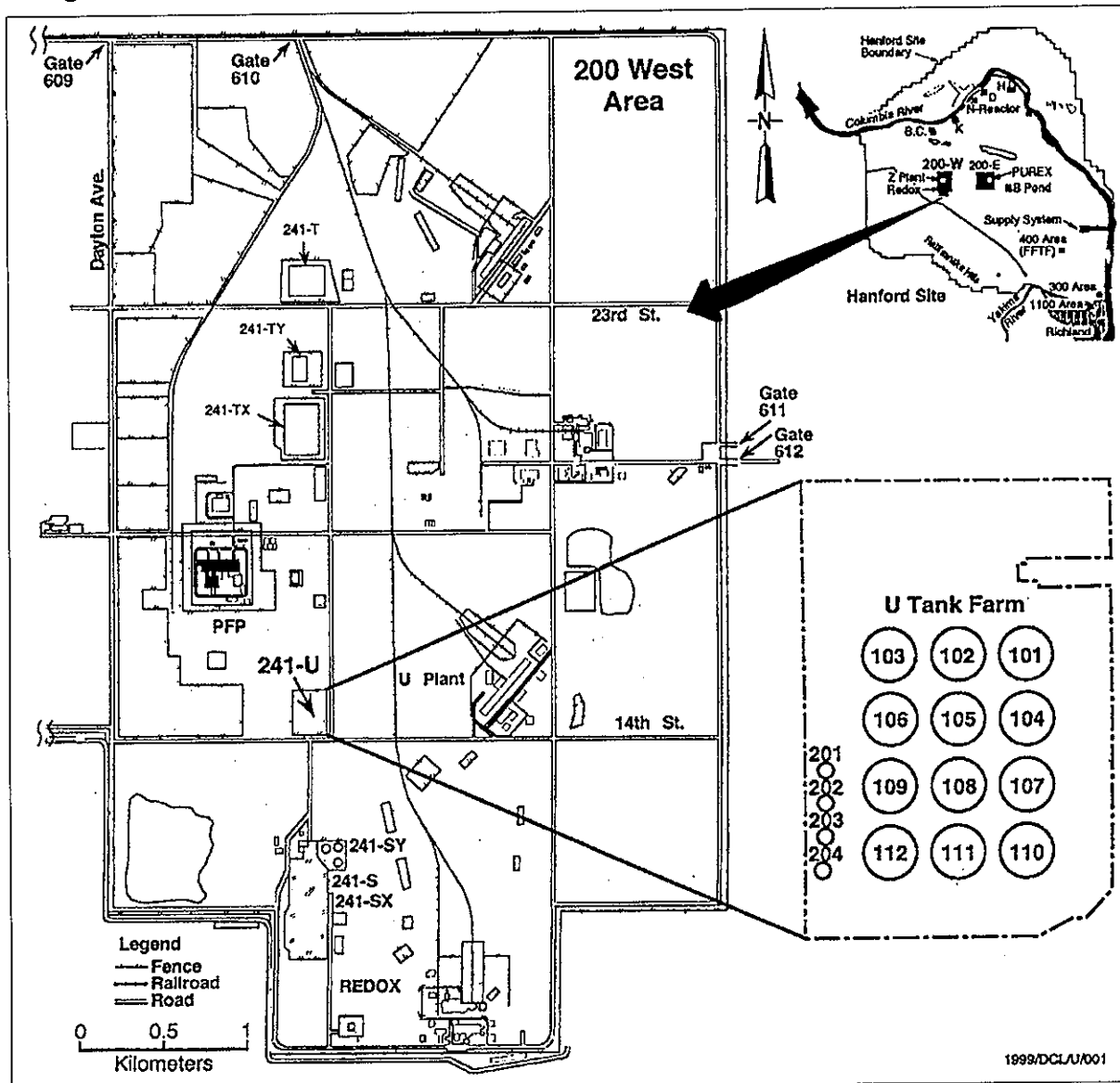
The July 1998 final report on spectral gamma logging at the C tank farm, *Vadose Zone Characterization Project at the Hanford Tank Farms: C Tank Farm Report* (GJO-HAN-18), indicates that gamma-emitting contaminants cesium-137, cobalt-60, europium-152, and europium-154 were detected in the boreholes. The network of drywells installed around each tank was intended for leak detection and was generally installed between depths of 22.8 m and 45.7 m (75 to 150 ft) bgs, thus the maximum detection depth is limited by the drywell depth.

Figure 1.1. Location Map of Waste Management Areas C and A-AX and Related Facilities



2002/DCL/A-AX-C/013 (06/10)

Figure 1.2. Location Map of Waste Management Area U and Related Facilities



The May 1997 final report on spectral gamma logging at the U tank farm, *Vadose Zone Characterization Project at the Hanford Tank Farms: U Tank Farm Report* (GJO-HAN-8), indicates that gamma-emitting contaminants cesium-137, cobalt-60, europium-154, uranium-235, and uranium-238 were detected in the boreholes. The network of drywells installed around each tank was intended for leak detection and was generally installed between depths of 22.8 and 45.7 m (75 and 150 ft) bgs, thus the maximum detection depth is limited by the drywell depth.

PNNL-13282 is a groundwater assessment monitoring report that focuses on contaminants in the underlying unconfined aquifer. The findings indicate that WMA U is a source of groundwater contamination. Based on the lack of direct evidence for a source upgradient to WMA U, it must be assumed that WMA U is a source of groundwater contamination.

Evaluation of vadose zone contamination under U tank farms by tank waste is an extension of similar activities that have been completed for several other SST farm WMAs including S-SX, B-BX-BY, T, and TX-TY. The previous investigations were initiated because the source of some nearby groundwater contamination was attributed to a tank waste source in the vadose zone underlying these WMAs. Consequently, Ecology, EPA, and DOE negotiated HFFACO Change Control Form M-45-98-03 (*Federal Facility Agreement and Consent Order Change Control Form Change No. M-45-98-03. Agreement Commitments Regarding Initial Single-Shell Tank Waste Management Area (WMA) Corrective Actions, Vadose Zone and Groundwater Characterization, Assessment, and the Integration of Vadose Zone and Groundwater Activities at Specified Associated Sites* [Ecology and DOE 2001]). The HFFACO milestones mandated a series of activities addressing these WMAs. The goal of the activities was to determine the need for corrective action to mitigate the impact of contamination from SSTs on the surrounding environment.

WMAs C, A-AX, and U were not included in this action because there was no indication that vadose zone contamination in these WMAs were a source of current nearby groundwater contamination when negotiations were being completed. However, it has become clear from previous investigations that if vadose zone contamination is present under a WMA, future groundwater contamination from these sources is plausible. To complete remediation of these WMAs, support waste retrieval, and achieve final closure of the facility, the potential environmental impacts of these sources must be evaluated. Information generated by these and future characterization activities will support waste management decisions for SST waste retrieval and SST closure.

This work plan is similar to the other work plans prepared for the corrective action program, which include the following:

- *Preliminary Site-Specific SST Phase 1 RFI/CMS Work Plan Addendum for WMA S-SX* (HNF-4380) submitted to Ecology in 1999
- *Site-Specific SST Phase 1 RFI-CMS Work Plan Addendum for WMA S-SX* (HNF-5085) submitted to Ecology in 2000

- *Site-Specific SST Phase 1 RCI/CMS Work Plan Addendum for WMA B-BX-BY* (RPP-6072) submitted to Ecology in 2000
- *Site-Specific SST Phase 1 RCI/CMS Work Plan Addendum for WMAs T and TX-TY* (RPP-7578) submitted to Ecology in 2001 and 2002.

This addendum prescribes characterization of WMAs C, A-AX, and U. All of these characterization efforts will be based on DOE/RL-99-36 and site-specific SST Phase 1 RFI/CMS work plan addenda for all four WMAs (Milestones M-45-52, M-45-53, and M-45-54).

1.2 PURPOSE AND OBJECTIVE

DOE/RL-99-36 establishes the objectives of the characterization effort for the WMAs that are a part of the RCRA corrective action process. The objectives of the investigative efforts identified in this WMAs C, A-AX, and U addendum are as follows:

- Collect data to support an improved understanding of the nature and extent of contaminants in the vadose zone from surface to maximum depth of contamination unless drilling refusal is encountered
- Collect data to support an improved understanding of vadose zone parameters affecting contaminant fate and transport required to perform risk assessments
- Provide WMA-specific information on source, nature, and extent of contamination through the planned activities listed in Section 1.3
- Provide WMA-specific characterization programs to address information gaps identified in reports RPP-14430 and *Subsurface Conditions Description of the U Waste Management Areas* (RPP-15808)
- Support the Phase 1 RFI/CMS work plan objectives.

The planning process was conducted from January 2003 through June 2003. The planning process included participation by Ecology and DOE, the Hanford Site Groundwater Protection Program and Hanford Site contractors. Meetings held as part of the planning process involved varying levels of involvement by all participants.

The planning process resulted in identification of activities (RPP-14430 and RPP-15808) to collect vadose zone data to support the objectives outlined in Section 1.3 and in this section. The process included meetings to complete a review of existing data, define the problem, identify and prioritize decisions, identify the input required to make decisions, and establish boundaries for the decisions. The meetings also addressed uncertainty and sampling and analysis alternatives. The focus of the planning process for the WMAs C, A-AX, and U addendum was on sampling and analysis alternatives. These alternatives and the decisions made by DOE based on the alternatives are documented in Section 6.0.

1.3 SCOPE OF ACTIVITIES

The characterization effort at WMAs C, A-AX and U identified in this addendum will address the following:

- Installation of four new boreholes, two in C tank farm in FY 2004 and two in U tank farm in FY 2005
- Performance of direct pushes in the area associated with an unplanned release (UPR-200-E-82) for near-surface characterization in FY 2004
- Performance of gamma surveys in the laterals under A tank farm in FY 2005
- Integration with the Hanford Site Groundwater Protection Program to collect vadose zone data from the installation of a RCRA groundwater monitoring well upgradient of WMA C.

The Tank Farm Vadose Zone Project and DOE propose four boreholes to be installed at four of these candidate sites, which are near tanks C-105, U-104, and U-112 and one north of diversion box 241-C-152 at UPR-200-E-82. Two vertical boreholes will be installed in FY 2004 in the C tank farm along with direct push technology push in the western portion of C tank farm and two vertical boreholes will be installed in FY 2005 in the U tank farm along with gamma investigation in the lateral under tanks in A tank farm. These activities support the following objectives:

- Development of a best-estimate of the concentration and distribution of contaminants of concern (CoCs) in WMAs C, A-AX, and U through soil sampling and analysis for soil remediation from four boreholes that represent known releases to the environment
- Refinement of a conceptual model for concentration, distribution, and mobility of contaminants in WMAs C, A-AX, and U for soil remediation
- Quantification of the risks posed by migration of past tank waste releases to the groundwater if no interim corrective measures (ICMs) are implemented to support waste retrieval and closure decisions
- Determination of whether interim measures or ICMs would effectively contribute to the mitigation of contaminant migration to groundwater to levels that would not pose unacceptable risk to human health and the environment before tank farm closure to support closure decisions.
- Data to support construction of ICMs, if needed, and any long-term barriers, as needed.

Risk assessments conducted in support of retrieval and closure decisions will be performed and will include the potential contribution or reduction in risk as a result of ICMs.

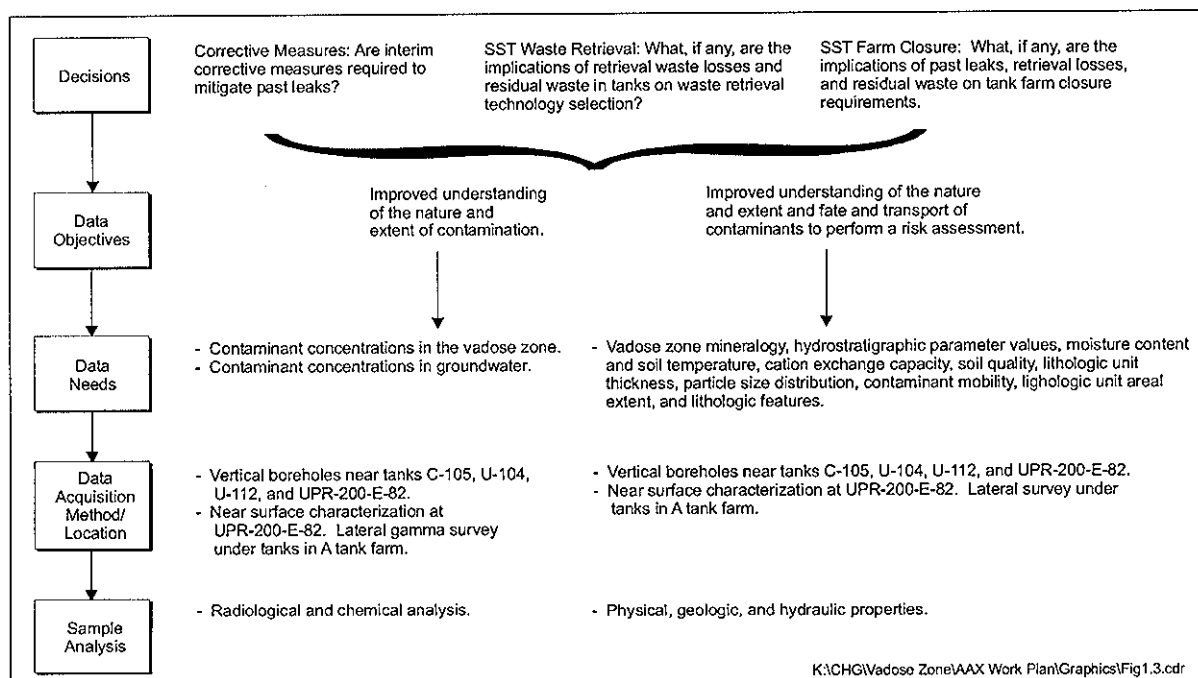
In addition to the characterization activities, a separate implementation plan is included as an appendix to DOE/RL-99-36. This implementation plan bridges the gap between the generalities

in DOE/RL-99-36 and the specifics of this addendum. The approved implementation plan provides the approach to ensuring the availability of data required to complete the analyses and evaluations that would be included in the field investigation report.

1.4 SELECTION OF FIELD ACTIVITIES

Based on input from Ecology, DOE, and other contractor participants, the characterization activities in support of the objectives and data needs for this addendum are illustrated in Figure 1.3. The meeting with Ecology resulted in a decision to characterize WMAs C, A-AX, and U with vertical boreholes, near surface characterization and lateral surveys as summarized in Figure 1.3.

Figure 1.3. Characterization Activities that Address Data Quality Objectives Process and Data Needs



- Identification of locations for new exploratory boreholes** – The subsurface condition description reports (RPP-14430; RPP-15808) resulted in the identification of several potential locations for the proposed new boreholes. Locations south of tank C-105 and northeast of diversion box 241-C-152 were selected as the highest priority locations based on spectral gamma data and historical process knowledge (RPP-14430). Drilling is scheduled for FY 2004. Lower priority boreholes will be installed in FY 2005 south of tank U-104 and northeast of tank U-112 (RPP-15808). These locations are near past leak events either from the nearby tank or from a transfer line. The new boreholes will be installed using a cable tool approach. Collection of sediment samples will be attempted from about 9 m (30 ft) bgs to maximum extent of contamination on short intervals (near continuous to 0.6 m [2 ft]) depending on the borehole. Should maximum extent of contamination go to groundwater, the water table is expected to be encountered at a depth

of 78 m (256 ft) bgs in the C tank farm (RPP-14430) and 64 m (210 ft) bgs in the U tank farm (RPP-15808). Selected portions of the samples will be analyzed for chemical, radiological, and physical characteristics. A suite of geophysical surveys (i.e., spectral gamma, gross gamma, and neutron to total depth) will be performed. The boreholes will be decommissioned in accordance with “Minimum Standards for the Construction and Maintenance of Wells” (WAC 173-160). Four locations for vertical boreholes are identified in RPP-14430 and RPP-15808. Four boreholes will be installed at the candidate sites, which are near tanks C-105, U-104, and U-112, provided that funding is available and their installation is consistent with other schedule priorities. The rationale and approach to these decisions are addressed in Section 6.0. Contamination zones exist in AX tank farm with the only large volume estimates associated with tanks AX-102 and AX-104. Despite the volume estimate associated with those tanks, no evidence supports the assumption of a potentially large contaminant inventory in the vadose zone. First, the contamination in the surrounding drywells consists of small zones of high-concentration cesium-137 and cobalt-60 in four drywells within the top 4 m (12 ft) bgs. Second, the historical record provides no corroborating information to justify the leak volume estimates. Finally, the inventory estimate for mobile radionuclides shows little total inventory from either leak (e.g., less than 1 Ci of technetium-99) (RPP-14430). Therefore, no additional vadose zone characterization efforts are recommended for the AX tank farm at this time. However, future vadose zone characterization planning activities will address the need for data from the AX tank farm. No vadose zone characterization is planned for the U tank farm in FY 2004. However in FY 2005, those areas around tanks U-104 and U-112 will be investigated.

- **Shallow vadose zone soil investigation** – This investigation will collect sediment samples via direct-push technology in the western portion of C tank farm. The shallow investigation will comprise collecting sediment samples at approximately 20 areal locations between ground surface and refusal. The main emphasis will be on characterizing unplanned releases (UPRs) within this area of concern. The areal locations will be based on 3 m (10 ft) spacing starting 15 m (50 ft) away from the centroid of the pipeline leak
- **Collection of vadose zone characterization data from proposed RCRA groundwater monitoring well** – Vadose zone samples will be collected during the installation of a proposed RCRA groundwater monitoring well planned in support of the ongoing RCRA groundwater monitoring effort (HFFACO Milestone M-24-00). The RCRA groundwater monitoring well will aid in determining groundwater flow direction in the WMA C area. Continuous drill cuttings will be collected and geologically described from these proposed wells. Selected portions of the drill cuttings will be analyzed for physical, hydraulic, and chemical properties. A detailed description of the work associated with the installation of these monitoring wells is being developed by the Hanford Site Groundwater Monitoring Project (PNNL-13024). Only details associated with the collection and analysis of drill cuttings are provided in this addendum (Sections 6.3.1 and 7.2.1).

1.5 ORGANIZATION OF THIS WASTE MANAGEMENT AREAS C, A-AX, AND U ADDENDUM

Eleven sections and one appendix are included in this WMAs C, A-AX, and U addendum. The addendum is structured to provide information necessary to initiate the field investigations at WMAs C, A-AX, and U in FYs 2004 and 2005. The sections and appendix are as follows:

- **Section 1.0** – Introduction to the WMAs C, A-AX, and U addendum that provides an overview of the issues and technical approach detailed in the remainder of the addendum.
- **Section 2.0** – Overview of the physical and environmental setting of WMAs C and A-AX in the 200 East Area.
- **Section 3.0** – Summary of the available data on potential contaminant exposure pathways that will be used to develop a conceptual exposure pathway model for WMAs C and A-AX needed to assess compliance with federal and state environmental standards, requirements, criteria, or limitations that may be considered potential corrective action requirements and potential impacts to human health and the environment.
- **Section 4.0** – Overview of the physical and environmental setting of WMA U in the 200 West Area.
- **Section 5.0** – Summary of the available data on potential contaminant exposure pathways that will be used to develop a conceptual exposure pathway model for WMA U needed to assess compliance with federal and state environmental standards, requirements, criteria, or limitations that may be considered potential corrective action requirements and potential impacts to human health and the environment.
- **Section 6.0** – Presentation of the rationale and approach for the field investigations.
- **Section 7.0** – Presentation of the tasks and activities necessary to conduct field investigations.
- **Section 8.0** – Presentation of the schedule for the site-specific investigations focused on vadose zone-related aspects of WMAs C, A-AX, and U in accordance with the tasks and activities discussed in Section 7.0.
- **Section 9.0** – Description of the project management tasks necessary to implement the field investigation activities including responsibilities, organizational structure, and project tracking and reporting procedures; interfaces with tank farm operations activities and other DOE or contractor activities planned in or surrounding the tank farm addressed in this addendum.
- **Section 10.0** – References used to develop this addendum that are cited in the main text.
- **Section 11.0** – Glossary of terms that are used in this addendum.
- **Appendix** – Sampling and Analysis Plan

2.0 C, A, AND AX TANK FARM HISTORY AND SETTING

The history of operations in relationship to the tank farm layout and physical setting provides the background for the vadose zone and groundwater characterization investigation. Information and data relevant to the RFI/CMS investigations at the C, A, and AX tank farm facilities were largely obtained from *Historical Tank Content Estimate for the Northeast Quadrant of the Hanford Site 200 East Area* (WHC-SD-WM-ER-349). This addendum updates and augments information from RPP-14430. Relevant details related to site history and physical settings are provided in Sections 2.1 and 2.2, respectively. Sections 4.0 and 5.0 provide information for WMA U.

2.1 C, A, AND AX TANK FARM HISTORY

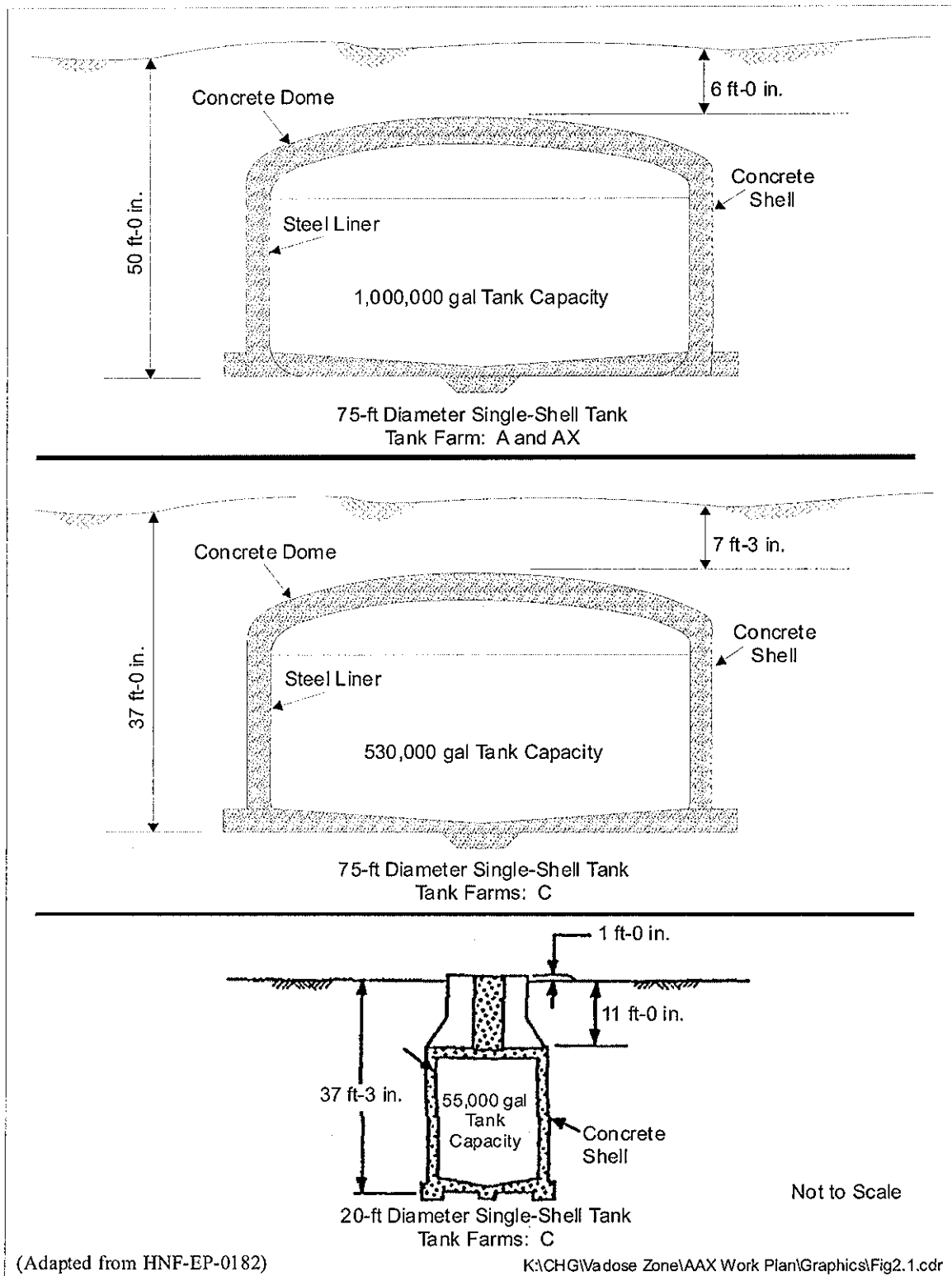
The SSTs in tank farms C, A, and AX historically received high-level radioactive waste as well as hazardous or dangerous waste. They have been out of service since 1980, or earlier, but continue to store radioactive and dangerous waste. Waste in the SSTs consists of liquid, sludges, and salt cake (i.e., crystallized salts). Over the years, much of the liquid stored in the SSTs has been evaporated or pumped to double-shell tanks. The tank farm configurations, history of operations, leak detection systems, and interaction of WMAs C and A-AX with surrounding facilities are discussed in the following subsections.

2.1.1 C, A, and AX Tank Farm Layouts

The SSTs in the C, A, and AX tank farms are 23 m (75 ft) in diameter, except for 4 SSTs in C tank farm that are 6.1 m (20 ft) in diameter. The C tank farm contains 12 SSTs each with 2,006,050-L (535,000-gal.) capacity, 4 SSTs each with 208,175-L (55,000-gal.) capacity, waste transfer lines, leak detection systems, and tank ancillary equipment (see Sections 2.1.3 and 2.1.4). The A tank farm contains 6 SSTs each with 3,780,000-L (1,000,000-gal.) capacity, waste transfer lines, leak detection systems, and tank ancillary equipment. The AX tank farm contains 4 SSTs each with 3,785,000-L (1,000,000-gal.) capacity, waste transfer lines, leak detection systems, and tank ancillary equipment. The 12 larger C tank farm SSTs are approximately 9.07-m (29.75-ft) tall from base to dome. The SSTs in A and AX tank farms are approximately 13.4 m (44 ft) tall from base to dome. The 4 smaller SSTs in C tank farm are approximately 11.4-m (37.25-ft) tall from base to dome (*Waste Tank Summary Report for Month Ending January 31, 2003* [HNF-EP-0182]).

The sediment cover from the apex of the tank domes to ground surface is 1.8 m (6.0 ft) at the A and AX tank farms and 2.2 m (7.3 ft) at the C tank farm (HNF-EP-0182). The smaller SSTs in C tank farm are approximately 3.4 m (11 ft) bgs (HNF-EP-0182). Only the tanks in the C tank farm have a dish-shaped bottom. The tanks in the A and AX tank farms have a flat bottom. The A tank farm was underlain by laterals connected to caissons as a leak detection system because the tank farm was designed to store boiling waste. The AX farm tanks included a grid of drain slots beneath the steel liner bottom and a leak detection well that could collect potential leakage. Figure 2.1 shows the general configuration of the tanks in the C, A, and AX tank farms.

Figure 2.1. General Configuration of Tanks in Waste Management Areas C and A-AX



The 23-m- (75-ft-) diameter SSTs in the C tank farm are constructed with cascade overflow lines in a 3-tank series that allowed gravity flow of liquid waste between the tanks (WHC-SD-WM-ER-349). The cascade overflow height for C tank farm SSTs is 4.78 m (15.67 ft) from tank bottom (WHC-SD-WM-ER-349). The tanks in the A and AX tank farm were connected by overflow lines but did not cascade.

2.1.2 C, A, and AX Tank Farm History of Operations

The C tank farm was built from 1943 to 1944, the A tank farm was built from 1954 to 1955, and the TY tank farm was constructed during 1963 to 1964 (WHC-SD-WM-ER-349). The C tank farm was constructed between 1943 and 1944 and first received metal waste and first cycle waste from B Plant beginning in 1946. Ultimately, tanks C-101 through C-106 received metal waste and tanks C-107 through C-112 received first cycle waste. All tanks were filled with bismuth phosphate waste by the end of 1948. The 200-series tanks also received metal waste. To free up tank space, in 1952 first cycle waste was transferred to the 242-B Evaporator.

Metal waste was also removed from C tank farm beginning in 1952 and transferred to U Plant for uranium recovery. Ancillary equipment involved in the metal waste transfer included the 244-CR vault and diversion boxes 241-CR-151, -152, and -153. Subsequently, tributyl phosphate waste, a byproduct of the uranium recovery process, was returned to C tank farm. The 244-CR vault was modified in 1955 to scavenge tributyl phosphate waste (that is, to separate cesium-137 from the supernate by precipitation) that was present in tanks C-107 through C-112. The scavenged slurry was redeposited in tanks C-109 and C-112 to settle and the resultant supernate was discharged to the BC cribs.

The A tank farm was constructed in 1955 to support the Plutonium-Uranium Extraction (PUREX) Plant operations, which ultimately produced the greatest amount of plutonium during Hanford processing history. The PUREX process produced three major waste streams, PUREX coating waste, PUREX acid waste which contained about 99% of the fission products, and organic wash waste (OWW). These wastes were neutralized, as needed, and stored in the C and A tank farms at various times. Beginning in 1956, neutralized PUREX acid waste and OWW were sent to A tank farm and PUREX coating waste was sent to C tank farm. Beginning in 1957, PUREX coating waste in C tank farm was routed to the B, BX, and BY tank farms.

AX tank farm was constructed in 1963 and received PUREX acid waste from 1965 through 1969. From 1962 until 1969, tank C-102 was designated as the receiver tank for coating waste and all coating waste from the PUREX Plant was sent there. In 1968 OWW was separated from PUREX acid waste and also sent to tank C-102. The PUREX coating waste and OWW were routed to the in-tank solidification (ITS) operations in the BY tank farm.

Both intentional and unintentional discharges to ground occurred during this time period. Tank condensate and cooling water were deliberately discharged to several cribs, ditches, french drains, and ponds beginning in 1956. Several liquid discharge facilities received enough waste to reach their radiological capacity, released contaminants to groundwater, and were decommissioned. Crib 216-A-8 was abandoned in 1958 but then reused from 1966 to 1976 when crib 216-A-24 reached its capacity and was abandoned in 1966. Crib 216-A-5 and ditch

216-A-10 received process condensate from 1956 until 1961 and from 1961 to 1978, respectively, before groundwater contamination forced their abandonment.

Several unintentional PUREX Plant waste releases to the environment occurred during this time period. In 1969, coating waste leaked from a transfer line (V051) near diversion box 241-CR-151 to which it was connected. Coating waste also leaked from a transfer line between tanks C-105 and C-108 sometime between 1956 and 1959. An estimated 190 L (50 gal.) was lost. In early 1965, a violent steam discharge event occurred in tank A-105. A 30-minute steam release was associated with this event. The initial assessment was that about 37,900 to 45,400 L (10,000 to 12,000 gal.) of waste had been lost during the event. Subsequent investigation showed a bulge in the tank liner bottom providing an estimate void volume between the liner and the concrete shell of 19,000 to 57,000 L (5,020 to 15,060 gal.). Additional leakage was noted in 1967 (UPR-200-E-126).

ISOTOPE RECOVERY PROGRAMS: By the late 1950s, it was clear that a number of SSTs had likely leaked and the long-term storage of large volumes of liquid radioactive wastes was untenable. Hanford Site contractors were directed to convert liquid radioactive waste to salt cake as soon as practicable. In the early 1960s interest developed in recovering cesium-137 and strontium-90 from PUREX wastes. As treatment processes were developed and implemented, PUREX waste streams depleted in strontium-90 and cesium-137 were stored at various times in some C farm tanks. Strontium-90 depleted PUREX acid waste was stored in tanks C-107 through C-109 after Strontium Semiworks startup in 1961. In 1963, PUREX supernate waste previously stored in tank C-103 was transferred to the 241-C-801 facility for cesium-137 removal and subsequently returned to tank C-102. Eventually, this waste and commingled coating waste in tank C-102 was transferred to the BY tank farm. From 1963 to 1967 strontium-90 recovery processes were being developed at B Plant and the depleted wastes were stored in the C tank farm and in tank AX-101.

The conversion of high-fission product radioactive waste supernates into salt cake required both a three to five year cooling-off period to allow short-lived radionuclides to decay (thus, the need for boiling waste tanks in the S, SX, A, and AX tank farms) and removal of a significant amount of the longer-lived heat-generating radionuclides such as strontium-90 and cesium-137. In 1967, B Plant was reactivated to support an isotope recovery program. Beginning in 1967, PUREX current acid wastes were processed through B Plant for cesium-137 and strontium-90 recovery, before the three to five year cooling-off period. Aged PUREX supernates and sludges were recovered from the tanks and processed through the B Plant for strontium-90 and cesium-137 recovery. The aged reduction-oxidation (REDOX) supernates were transferred to 200 East Area tanks and processed through B Plant for cesium-137 recovery. Tank C-105 was the receiver tank for all supernates going to B Plant for cesium-137 recovery. After cesium-137 removal, REDOX supernate were transferred back to the 200 West Area for salt cake production in the T and S Evaporators.

After the cesium-137 was removed (or at least greatly reduced) in the aged PUREX supernates, the wastes were transferred to various tanks in the B, BX, BY, and C farms, leading to conversion of supernates into salt cake using the BY tank farm ITS process. In the ITS process, heater units were installed in three tanks in the BY tank farm. Waste supernates were rotated through the ITS process tanks and out to the B, BX, and BY farm tanks so as to produce salt

cake. The available tank space in the B, BX, and BY farms was filled with salt cake using the ITS process in the BY tank farm.

By 1967, all cesium-137 and strontium-90 removal from PUREX supernate waste was being done at B Plant and the primary transfer sequence was initial storage of PUREX supernate waste in AX tank farm followed by transfer through tank C-105. In the late 1960s OWW was combined with coating waste and stored in tank C-102 and subsequently transferred to BX tank farm for interim tank stabilization. PUREX sludges were also sluiced from A farm tanks (tank A-101 in 1968, tank A-104 in 1969, and tank A-106 in 1970) and transferred to 244-AR vault for acidification, then to 244-CR vault as PUREX acidified sludge and B Plant. Depleted wastes from B Plant were returned to AX tank farm for storage. This cycle ran until 1978 when the last of the PUREX waste in the A and AX tank farms had been treated. Tanks deemed to be sound in the C, A, and AX tank farms (primarily tanks A-103, C-103, and C-104) stored all variety of wastes not segregated by waste type.

Intentional discharges during the waste fractionation period included slightly contaminated fluids from the 244-AR vault to crib 216-A-41 (1968 to 1974) and uncontaminated cooling water to Gable Mountain Pond. Unintentional releases included PUREX supernate waste losses from transfer lines V122 near diversion box 241-C-152 in 1970 (UPR-200-E-82) and line 812 near diversion box 241-C-151 in 1971 (UPR-200-E-86). In the AX tank farm, 3 small releases occurred surface contamination around diversion box 241-AX-151 in 1972 (UPR-200-E-42), a pump pit leak at AX-103 in 1974 (UPR-200-E-115), and a small spill created at AX-104 in 1969 created by cable movement (UPR-200-E-119).

In the mid 1970s, a decision was made put all the SSTs out of service. At the C, A, and AX tank farms, saltwell jet pumping was employed to remove much of the liquid waste present in the tanks. Tank C-103 was designated as the receiver tank for C farm and tank A-102 was designated as the receiver tank for the A and AX tank farms, and pumping began in 1976. Currently, the majority of liquid wastes have been removed from these tanks. The most recent sluicing event occurred at tank C-106 in 1999.

All C, A, and AX farm tanks have been interim stabilized except for tanks C-103, C-106, A-101, and AX-101 (HNF-EP-0182; RPP-14430). Table 2.1 lists the volume of waste currently stored in the C, A, and AX farm tanks. Previous evaluations have screened the universe of radiological and chemical constituents in the tanks and identified those constituents potentially associated with the SST system. The results of those screenings are provided in Section 3.0 of DOE/RL-99-36. DOE/RL-99-36 includes tables listing the radiological and chemical constituents that are contaminants of potential concern for the SST system. Those tables served as the starting point for defining contaminants of potential concern specific to WMAs C and A-AX and are discussed in greater detail in Section 3.0 of this addendum and in RPP-14430.

2.1.3 Vadose Zone Leak Detection Systems in C, A, and AX Tank Farms

The A tank farm has 53 leak detection drywells available for leak detection monitoring. These drywells were drilled from 1955 to 1981. The depth ranges for most of these drywells are between 24.4 m (80 ft) and 45.7 m (150 ft) bgs, except for drywell 10-06-18, which is 54.8 m (180 ft) bgs. Gamma logging data from the drywells were used from 1974 through 1993 to ascertain the integrity of the associated tanks.

The AX tank farm has 33 leak detection drywells available for leak detection monitoring and that provide access for limited vadose zone characterization (e.g., geophysical logging). These drywells were drilled from 1974 to 1981. The depth ranges for most of these drywells are between 22.9 m (75 ft) and 45.7 m (150 ft) bgs.

The C tank farm has 70 leak detection wells available for leak detection monitoring and provide access for limited vadose zone characterization (e.g., geophysical logging). These drywells were drilled from 1944 to 1982. The depth ranges for most of these drywells are between 30.5 m (100 ft) and 45.7 m (150 ft) bgs.

2.1.4 Associated Facilities

Table 2.2 shows the facilities used during C, A, and AX tank farm operations that are associated with WMAs C and A-AX. These associated facilities are located both inside and outside the WMAs C and A-AX boundaries (Figures 2.2 and 2.3). Waste discharged to or stored at these facilities may have had an effect on the groundwater contamination at WMAs C and A-AX.

A number of raw and potable water lines are also present in and around WMAs C and A-AX (*Engineering Report: Single-Shell Tank Farms Interim Measures to Limit Infiltration Through the Vadose Zone* [RPP-5002]). Leaks from these lines could have contributed to tank waste migration in the vadose zone. Historical records about leaking water lines are incomplete.

Summaries of the operation, vadose zone contamination, and groundwater contamination history for each of these associated facilities are provided in *A Summary and Evaluation of Hanford Site Tank Farm Subsurface Contamination* (HNF-2603), *Historical Vadose Zone Contamination from A, AX, and C Tank Farm Operations* (RPP-7494), and RPP-14430.

2.2 PHYSICAL SETTING

The following subsections summarize the topography, geology, hydrogeology, and surface water hydrology of WMAs C and A-AX. More detail is provided in the geology and hydrogeology summaries because of their more direct relationship to the WMAs C and A-AX field investigation. Because the meteorology, environmental resources, cultural resources, and human resources associated with WMAs C and A-AX are the same as the 200 Areas at the Hanford Site, the reader is referred to Section 3.0 of DOE/RL-99-36 for related information. Sections 2.2.2 and 2.2.3 are taken directly from RPP-14430.

2.2.1 Topography

WMAs C and A-AX lie within the east-central portion of the Hanford Site along Cold Creek bar, a large compound flood bar formed during Pleistocene Ice Age floods (*Consultation Draft Site Characterization Plan: U.S. Department of Energy* [DOE-RW-0164]; *Subsurface Conditions for B-BX-BY Waste Management Area* [HNF-5507]). The upper surface of the bar in the 200 East Area forms a broad plain extending westward for several miles. The northern boundary of the bar is defined by a series of northwest-southeast trending flood channels. WMA A-AX is near the top of the bar at an elevation of about 690 ft (210 m) whereas WMA C lies along the gently sloping, north flank of the bar at an elevation of about 650 ft (198 m). RPP-14430 provides more topographical information about WMAs C and A-AX.

Table 2.1. Current Waste Volume in C, A, and AX Farm Tanks

Tank	Total Waste Volume KL (Kgal)	Supernate KL (Kgal)	Salt Cake KL (Kgal)	Sludge KL (Kgal)
C-101	333 (88)	0 (0)	0 (0)	333 (88)
C-102	1,196(316)	0 (0)	0 (0)	1,196 (316)
C-103	344 (91)	4 (1)	0 (0)	337 (89)
C-104	980 (259)	0 (0)	0 (0)	980 (259)
C-105	500 (132)	0 (0)	0 (0)	500 (132)
C-106	136 (36)	114 (30)	0 (0)	23 (6)
C-107	939 (248)	0 (0)	0 (0)	939 (248)
C-108	250 (66)	0 (0)	0 (0)	250 (66)
C-109	242 (64)	0 (0)	0 (0)	242 (64)
C-110	674 (178)	4 (1)	0 (0)	670 (177)
C-111	220 (58)	0 (0)	0 (0)	220 (58)
C-112	394 (104)	0 (0)	0 (0)	394 (104)
C-201	4 (1)	0 (0)	0 (0)	4 (1)
C-202	4 (1)	0 (0)	0 (0)	4 (1)
C-203	8 (2)	0 (0)	0 (0)	8 (2)
C-204	8 (2)	0 (0)	0 (0)	8 (2)
A-101	1,510 (399)	0 (0)	1,495 (395)	11 (3)
A-102	151 (40)	11 (3)	140 (37)	0 (0)
A-103	1,404 (371)	19 (5)	1,378 (364)	8 (2)
A-104	106 (28)	0 (0)	0 (0)	106 (28)
A-105	140 (37)	0 (0)	0 (0)	140 (37)
A-106	299 (79)	0 (0)	110 (29)	189 (50)
AX-101	1,230 (325)	0 (0)	1,219 (322)	11 (3)
AX-102	114 (30)	0 (0)	91 (24)	23 (6)
AX-103	409 (108)	0 (0)	379 (100)	0 (8)
AX-104	26 (7)	0 (0)	0 (0)	26 (7)

Source: HNF-EP-0182.

**Table 2.2. Treatment, Storage and/or Disposal Units and
Associated Environmental Restoration Facilities at
Waste Management Areas C and A-AX (2 Sheets)**

Facility	Description	TSD or ER facility	Operable Unit	WMA
C Tank Farm (16 units)	Single-shell tanks	TSD	200-PO-3	C
241-C-151	Diversion box	TSD	200-PO-3	C
241-C-152	Diversion box	TSD	200-PO-3	C
241-C-252	Diversion box	TSD	200-PO-3	C
241-C-153	Diversion box	TSD	200-PO-3	C
241-CR-151	Diversion box	TSD	200-PO-3	C
241-CR-152	Diversion box	TSD	200-PO-3	C
241-CR-153	Diversion box	TSD	200-PO-3	C
241-C-301	Catch tank	TSD	200-PO-3	C
216-C-8	French drain	TSD	200-PO-3	C
244-CR	Vault	TSD	200-PO-3	C
2607-EG	Septic tank	TSD	200-PO-3	C
A Tank Farm (6 units)	Single-shell tanks	TSD	200-PO-3	A-AX
2607-EJ	Septic tank	TSD	200-PO-3	A-AX
AX Tank Farm (4 units)	Single-shell tanks	TSD	200-PO-3	A-AX
241-AX-151	Diversion box	TSD	200-PO-3	A-AX
241-A-152	Diversion box	TSD	200-PO-3	A-AX
241-A-153	Diversion box	TSD	200-PO-3	A-AX
241-AR-251	Diversion box	TSD	200-PO-3	A-AX
241-A-350	Catch tank	TSD	200-PO-3	A-AX
241-A-417	Catch tank	TSD	200-PO-3	A-AX
241-A-151-CT	Catch tank	TSD	200-PO-3	A-AX
241-AX-152	Diversion box	TSD	200-PO-3	A-AX
241-AX-155	Diversion box	TSD	200-PO-3	A-AX
244-AR	Vault	TSD	200-PO-3	A-AX
216-A-39	Crib	TSD	200-PO-3	A-AX
216-A-41	Crib	ER	200-PO-2	NA
216-T-1	Crib	ER	200-PO-5	NA
216-A-7	Crib	ER	200-PO-5	NA

**Table 2.2. Treatment, Storage and/or Disposal Units and
Associated Environmental Restoration Facilities at
Waste Management Areas C and A-AX (2 Sheets)**

Facility	Description	TSD or ER facility	Operable Unit	WMA
216-A-8	Crib	ER	200-PO-5	NA
216-A-24	Crib	ER	200-PO-5	NA
207-A	Retention basin	ER	200-PO-5	NA
216-A-40	Trench	ER	200-PO-2	NA
216-T-18	Trench	ER	200-PO-5	NA
216-T-19	Trench	ER	200-PO-5	NA
216-A-16	French drain	ER	200-PO-5	NA
216-A-17	French drain	ER	200-PO-5	NA
216-A-23A	French drain	ER	200-PO-5	NA
216-A-23B	French drain	ER	200-PO-5	NA
216-A-302B	Catch tank	ER	200-PO-5	NA
2607-EC	Septic tank	TSD	200-PO-3	A-AX

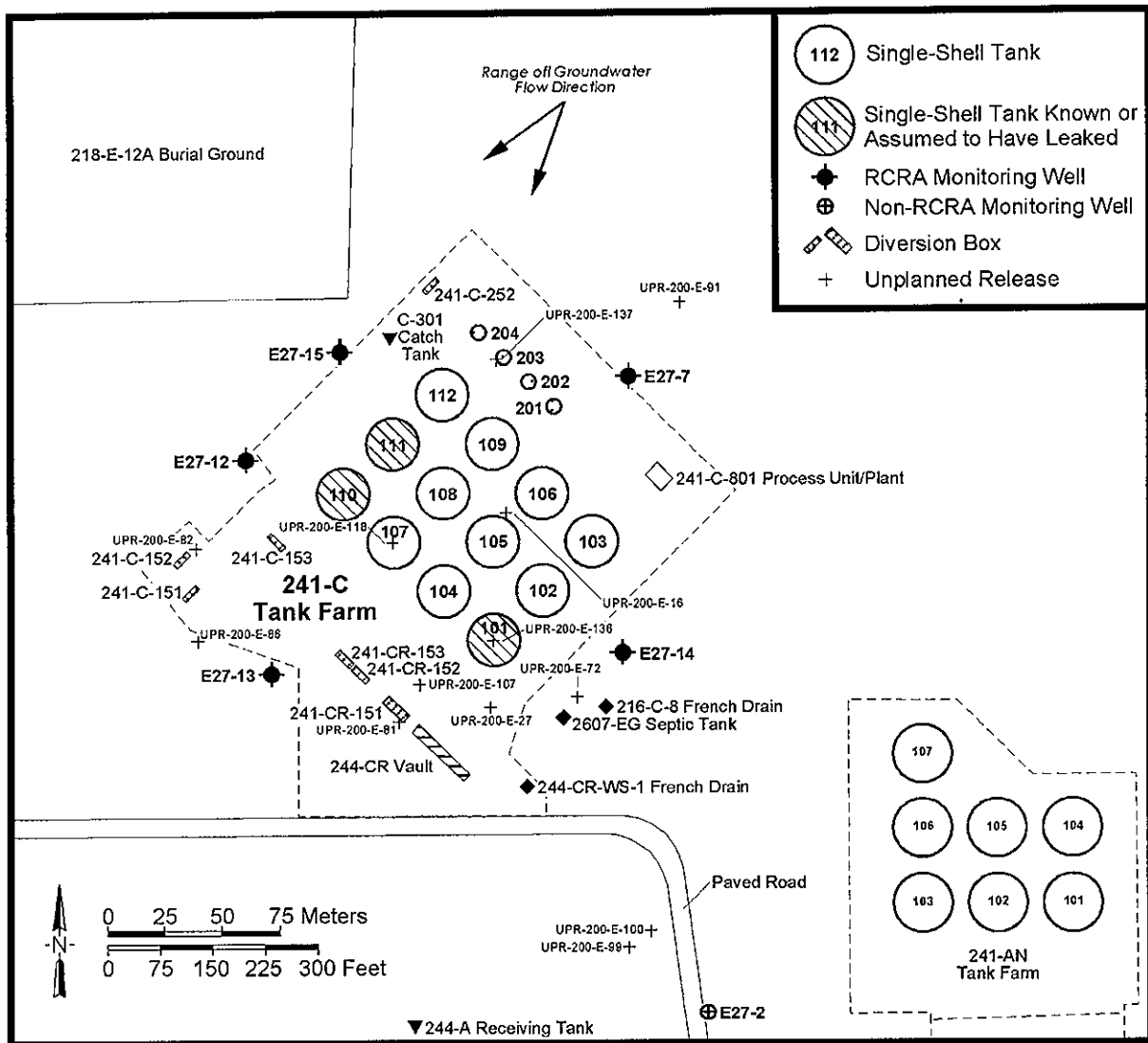
ER = environmental restoration.

NA = not applicable.

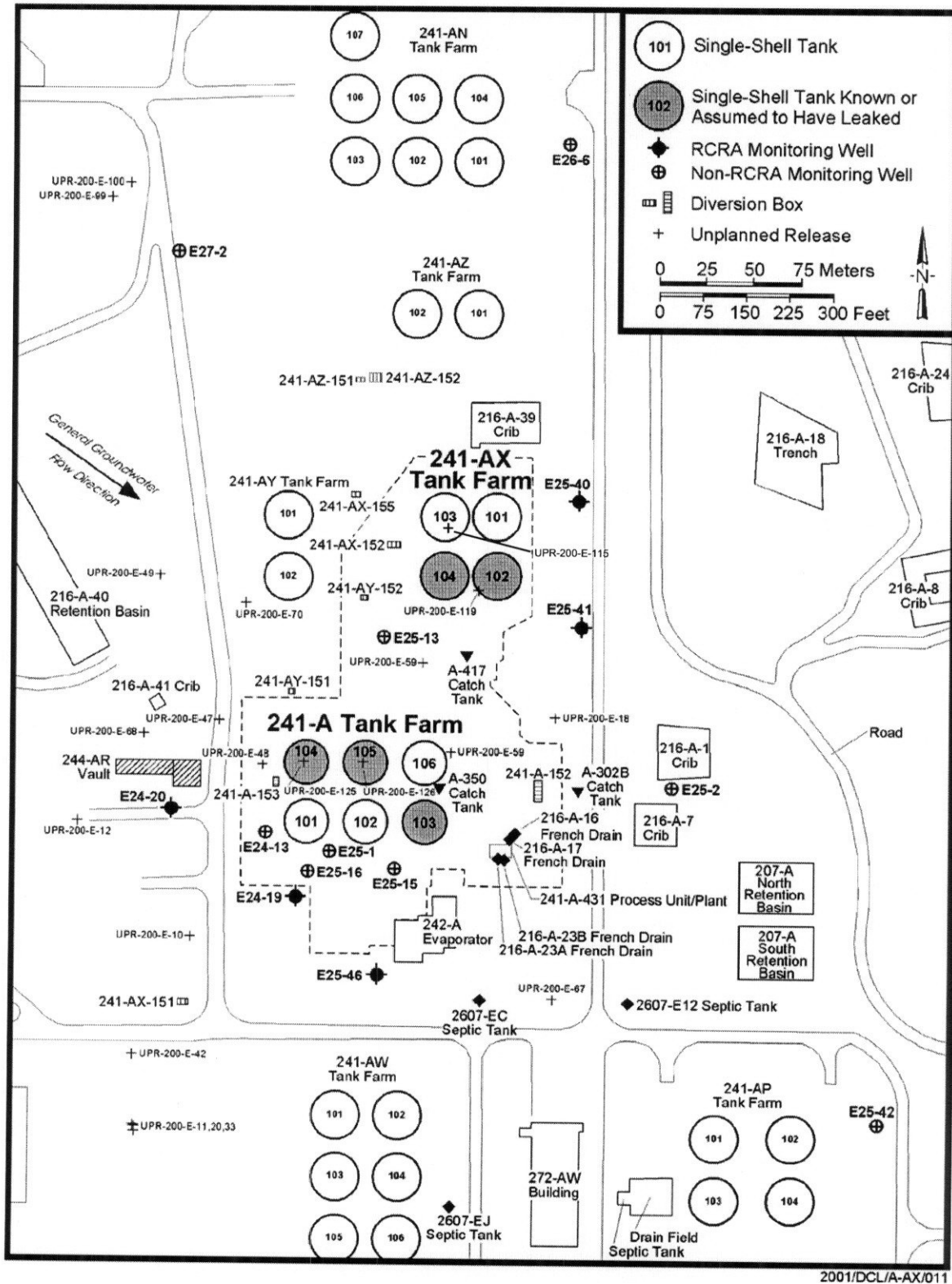
TSD = treatment, storage and/or disposal.

WMA = waste management area.

Figure 2.2. Location Map of C Tank Farm and Surrounding Facilities



2001/DCL/C/015

Figure 2.3. Location Map of A and AX Tank Farms and Surrounding Facilities

2001/DCL/A-AX/011

2.2.2 Geology

A total of seven stratigraphic units lie within WMAs C and A-AX (Figure 2.4). These units are represented on hydrogeologic cross-sections as well as isopach and structure-contour maps provided in Appendix C of RPP-14430 and include the following:

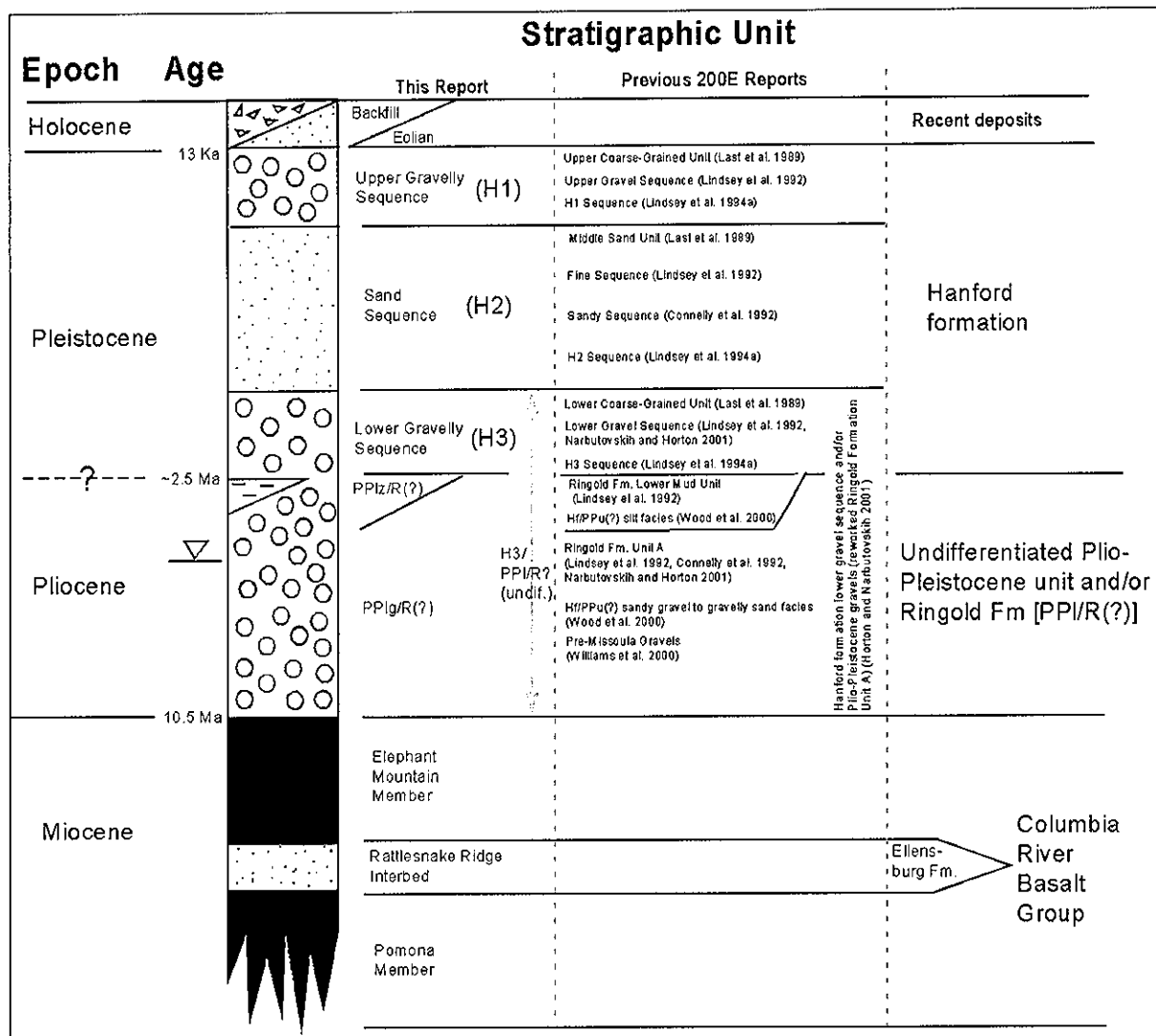
- Recent deposits
- Hanford formation – upper gravelly sequence (H1 unit)
- Hanford formation – sand sequence (H2 unit)
- Hanford formation – lower gravelly sequence (H3 unit)
- Undifferentiated Plio-Pleistocene silt (PPlz) and/or Ringold Formation mud? [PPlz/(R)?]
- Undifferentiated Plio-Pleistocene unit gravel (PPlg) and/or Ringold Formation Unit A? [PPlg/(R)?]
- Columbia River Basalt Group (CRBG).

WMAs C and A-AX were constructed in the near-surface sediments that overlie the CRBG (i.e., bedrock) on the north limb of the Cold Creek syncline. The oldest suprabasalt sediments in the vicinity of WMAs C and A-AX include (1) a gravelly sequence belonging to undifferentiated Ringold Formation member of Wooded Island (Unit A) and/or younger fluvial gravel facies of the Plio-Pleistocene unit (PPlg), referred to in this report as PPlg/R(?), overlain by (2) undifferentiated Ringold Formation mud and/or Plio-Pleistocene silt (PPlz), abbreviated here as PPlz/R(?). These deposits predate Pleistocene cataclysmic flooding, which blanketed the area with mostly coarse sand and gravel. Cataclysmic flood deposits, collectively referred to as the Hanford formation, include a lower and upper gravelly sequence, separated by a sand-dominated sequence in the study area. Recent deposits of eolian silty sand and human-made backfill locally overlie flood deposits.

The thickness of the vadose zone beneath the study area ranges from 72 m (235 ft) in the vicinity of WMA C to 90 m (295 ft) around WMA A-AX (*RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area A-AX at the Hanford Site* [PNNL-13023]; *RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area C at the Hanford Site* [PNNL-13024]). The unconfined aquifer is relatively thin (18 to 27 m [60 to 90 ft]) and resides mostly within the undifferentiated Plio-Pleistocene gravels/Ringold Formation Unit A sequence.

The vadose zone stratigraphy of the C, A, and AX tank farms is discussed in RPP-14430.

Figure 2.4. Stratigraphic Unit



2.2.2.1 Columbia River Basalt Group

The CRBG forms the bedrock base of the unconfined aquifer under WMAs C and A-AX. Sedimentary interbeds between CRBG flows belong to the Ellensburg Formation (Figure 2.4). The Elephant Mountain Member is medium to fine-grained tholeiitic basalt with abundant microphenocrysts of plagioclase (DOE/RW-0164). The Elephant Mountain Member has been dated by the K/Ar method at 10.5 Ma (“Duration and Volume of Columbia River Basalt Volcanism, Washington, Oregon, and Idaho” [McKee et al. 1977]) and consists of 2 flows beneath the 200 East Area. The Elephant Mountain Member represents the youngest basalt flows in the study area; the top of the member lies at depths between 75 and 110 m (250 and 360 ft) bgs within the study area. The top of basalt dips south toward the axis of the Cold Creek syncline (Figure 2.5) (*Hydrogeologic Model for the 200 East Groundwater Aggregate Area* [WHC-SD-EN-TI-019]). Up to 15 m (50 ft) of topographic relief exists on the basalt surface as a result of tectonic deformation and/or erosion (RPP-14430). In general, upper lava flows of the CRBG, as well as the Ellensburg Formation and overlying suprabasalt sediments, thicken to the south toward the axis of the Cold Creek syncline (DOE/RW-0164).

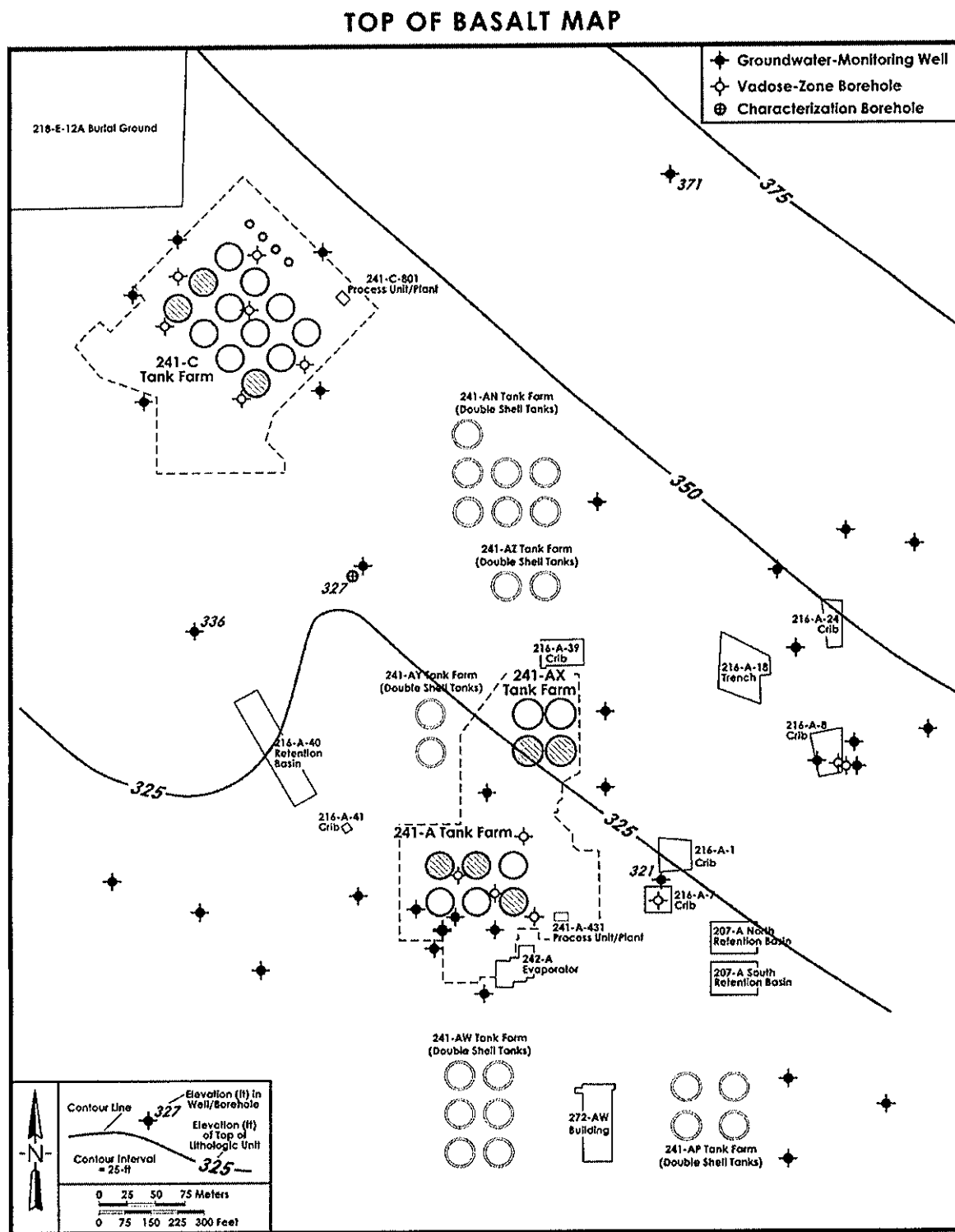
Only four boreholes (299-E25-2, 299-E26-8, 299-E27-3, and 299-E27-6) within the study area extend to the top of basalt. One borehole (299-E26-8) fully penetrated the Elephant Mountain Member and advanced through the first sedimentary interbed (Rattlesnake Ridge) into the underlying Pomona Member of the CRBG (RPP-14430). In this borehole, the Elephant Mountain Member and the Rattlesnake Ridge Interbed were 27 m (90 ft) and 15 m (50 ft) thick, respectively.

2.2.2.2 Undifferentiated Plio-Pleistocene Unit/Ringold Formation

Where not eroded away, the Ringold Formation overlies the CBRG in the central Pasco Basin (DOE/RW-0164). The Ringold Formation in this area consists of multilithic, clast-supported to matrix-supported, variably cemented and/or limonitic-stained, sandy gravel sequences. Ringold Formation gravel sequences are occasionally separated by thinner sequences of horizontally laminated, ripple laminated and/or massive, locally calcareous sand, silt, and clay in various shades of blue, olive, gray, and brown (*Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington* [BHI-00184]). Sands are generally well-sorted and predominantly quartzo-feldspathic (i.e., light colored). The gravels represent fluvial channel-fill and braidplain deposits while intervening fine-grained deposits are interpreted as lacustrine and/or fluvial overbank-paleosol deposits.

At present it is uncertain how much, if any, of the Ringold Formation is present beneath WMA C and A-AX. This area lies at or near the axis of a paleochannel that removed most or all of the Ringold Formation from the northern half of the 200 East Area (*Revised Hydrostratigraphy for the Suprabasalt Upper Aquifer System, 200 East Area, Hanford Site, Washington* [PNNL-12261]). Thus, most or all of the Ringold Formation may have been removed from beneath the study area, either by fluvial processes that post-date the Ringold Formation and/or by Ice Age cataclysmic flooding. Some previous reports, however, include erosional remnants of the Ringold Formation beneath WMAs C and A-AX (*Geology of the 200 East Area: An Update* [WHC-SD-EN-TI-012]; WHC-SD-EN-TI-019; PNNL-13023).

Figure 2.5. Structure Contour Map of the Top of Basalt



Source: RPP-14430.

The southeast-trending paleochannel underlying WMAs C and A-AX post-dates regional incision of the Ringold Formation and marks the path of the ancestral Columbia River as it flowed through a topographic low at Gable Gap starting sometime after 3.4 Ma (“Paleodrainage of the Columbia River System on the Columbia Plateau of Washington State – A Summary [Fecht et al. 1987]). The shift of the Columbia River to its present path along the north side of Gable Mountain probably occurred at the onset of the Ice Age and associated cataclysmic flooding. These floods, which began about the beginning of the Pleistocene Epoch 1.5 to 2.5 million years ago (“Long History of Pre-Wisconsin, Ice Age Cataclysmic Floods: Evidence from Southeastern Washington State” [Bjornstad et al. 2001]), led to further erosion as well as development and progradation of flood bars over the former course of the river. Before Ice Age floods, however, there was a 1- to 2-million-year period where “normal” fluvial processes might have occurred within the central basin where the ancestral Columbia River continued to flow through Gable Gap and to the southeast. It is during this period that the Plio-Pleistocene unit deposits developed locally on either the eroded Ringold Formation or directly on top of basalt bedrock within the study area.

Similar to the Ringold Formation, Plio-Pleistocene unit deposits in the central basin consist of multilithic, clast-supported sandy gravel. These deposits, previously referred to as Pre-Missoula Gravels (*Skagit/Hanford Nuclear Project, Preliminary Safety Analysis Report* [PSPL 1982]; BHI-00184), have more recently been included as a mainstream-alluvial facies of the Plio-Pleistocene unit (“Geologic Setting of the Hanford Site, South-Central Washington” [Lindsey et al. 1994]). Unlike the Ringold Formation, mainstream facies of the Plio-Pleistocene unit are generally unconsolidated, have a “whitish” or “bleached” appearance, and lack limonitic staining, characteristic of the Ringold Formation. Because mainstream facies of the Plio-Pleistocene unit consist of essentially reworked fluvial sands and gravels of the Ringold Formation, it is often difficult to distinguish the two units from one another.

Another facies of the Plio-Pleistocene unit beneath the 200 East Area consist of a well-sorted silt to fine sand, which is locally up to 10.5 m (35 ft) thick beneath the B tank farm (HNF-5507). The thickness of this unit, referred to as the Hf/PPu(?) silt by HNF-5507, appears to be too great for the Hanford formation and thus is probably entirely of Plio-Pleistocene age. A fine-grained layer, at about the same relative depth, is also present beneath most of WMA A-AX. The fine-grained layer is discontinuous between this area and northern portion of the 200 East Area; however, it is missing beneath WMA C. Some of the sample descriptions of the fine-grained unit from WMA A-AX are more like those for the lacustrine/overbank/paleosol facies of the Ringold Formation (i.e., gray, blue, or green clay). In other boreholes, however, sample descriptions are more like those for the Plio-Pleistocene silty facies (brown silt to fine sand). Therefore, it is uncertain at this time as to whether this fine-grained unit beneath WMA A-AX represents fine-grained facies of the Ringold Formation, or Plio-Pleistocene unit, or both.

Where present, the top of the fine-grained unit, near the 75 m (250 ft) depth, defines the top of the undifferentiated Plio-Pleistocene silt/Ringold Formation mud unit (PPlz/R(?)) and the base of overlying flood deposits of the Hanford formation. Below the PPlz/R(?) unit is an undifferentiated sequence of Plio-Pleistocene gravel and/or Ringold Formation Unit A, designated PPlg/R(?). Where the fine-grained layer is missing (e.g., beneath WMA C) it is not possible to differentiate between similar, coarse-grained facies of the Ringold Formation, Plio-Pleistocene unit, and flood gravels of the Hanford formation with the information available.

While these units have similar lithologic characteristics, their transport properties are believed to be very different. Whether this gravel sequence is Ringold Formation, Plio-Pleistocene unit, and/or Hanford formation has important implications for the permeability and flow rate of groundwater in the unconfined aquifer. Overall, Hanford formation gravels are significantly (10 to 100 times) more permeable than gravel sequences in the Ringold Formation. Plio-Pleistocene age gravels are probably intermediate between the Ringold Formation and Hanford formation. The differences in permeability are attributed mainly to the higher degree weathering and matrix cementation and induration common in the Ringold sediments (*Development of a Three-Dimensional Ground-Water Model of the Hanford Site Unconfined Aquifer System: FY 1995 Status Report* [PNL-10886]). Additional characterization studies, such as “geochemical fingerprinting,” might prove useful for differentiating these units.

2.2.2.2.1 Undifferentiated Plio-Pleistocene Unit Gravel and/or Ringold Formation Unit A [PPlg/R(?)]

Gravelly facies immediately overlying basalt within the study area belong to either the Ringold Formation Unit A and/or the Plio-Pleistocene unit. An exception is at the northeast in the vicinity of borehole 299-E26-8 (RPP-14430), where the top of basalt rises above the depth of post-Ringold-age scouring by Ice Age floods. It is probable that the PPlg/R(?) unit was completely removed during flooding so that flood deposits of the Hanford formation lie directly on top of basalt bedrock.

The PPlg/R(?) unit consists of predominantly sandy pebble- to cobble-sized gravel with occasional boulders. As a whole the unit shares characteristics of both coarse-grained facies of the Ringold Formation and the Plio-Pleistocene unit. In some boreholes the unit is described as tight, cemented, and brown colored with oxide coatings (characteristics of the Ringold Formation), whereas borings describe the unit as loose, caving to heaving, losing water, gray colored, and clean/unweathered (more characteristic of the Plio-Pleistocene unit). Mineralogically, the sand fraction consists of 15 to 60% basalt grains with generally less than 1 wt% CaCO₃. The total thickness of this unit is ≤ 27 m (90 ft), based on a limited number of boreholes where the upper and lower boundaries are represented. The top of PPlg/R(?) unit ranges from about 120 to 130 m (390 to 425 ft) elevation above mean sea level (amsl) (RPP-14430).

2.2.2.2.2 Undifferentiated Plio-Pleistocene Silt and/or Ringold Formation Mud? [PPlz/R(?)]

A fine-grained unit, occurring at a depth of about 75 m (250 ft), is described for most boreholes beneath WMA A-AX. The fine-grained unit is described on borehole logs of cuttings and samples as clay, silt, sandy silt, and/or silty sand. Some gross gamma-ray logs show a moderate increase in activity occasionally accompanied by an increase in moisture (Appendix). No perched water was noted on top of the sequence (*Interim Status Groundwater Monitoring Plan for the Single-Shell Tanks* [WHC-SD-EN-AP-012]), but the water table was higher in the past. Thus, the increased moisture content may be a remnant of a higher water table.

The PPlz/R(?) unit is thickest (up to 7.3 m [24 ft]) in the vicinity of WMA A -AX (RPP-14430). This unit disappears to the north and is absent beneath WMA C. Descriptions of this unit on drilling and geologic logs vary significantly, which may be due to (1) different subjective descriptions/interpretations by different drillers and geologists; (2) heterogeneities within the unit, which may include multiple lithologic units (e.g., Plio-Pleistocene unit silts overlying Ringold Formation muds); or (3) a combination of these. Where present, this fine-grained unit is described in about half the boreholes as a blue-, gray- or olive-colored clay or mud; remaining boreholes describe the unit as a tan to brown sandy silt to “heavy” silt, which may display a laminated to mottled structure. The former description fits that of Ringold Formation paleosol facies (DOE/RW-0164), whereas the latter fits descriptions for the Plio-Pleistocene silt facies (HNF-5507), interpreted as eolian-overbank in origin. Unlike most other fine-grained units in the 200 Areas, the PPlz/R(?) unit is generally noncalcareous, containing only a few weight percent or less CaCO_3 .

The top of the PPlz/R(?) unit ranges from about 121.9 to 132.6 m (400 to 435 ft) elevation amsl (RPP-14430). The top of the PPlz/R(?) unit was probably scoured and eroded during Ice Age flooding as suggested by a southeast-trending trough present at the top of this unit. The PPlz/R(?) unit may have extended further north before flooding but was subsequently removed during Ice Age flooding in the vicinity of WMA C.

2.2.2.3 Hanford Formation

The Hanford formation (informal name) overlies the Ringold Formation and consists of glaciofluvial sediments deposited by Ice Age cataclysmic floods from glacial Lake Missoula, pluvial Lake Bonneville, and perhaps other ice-margin lakes. Cataclysmic floods were released during major glacial events that occurred during the Pleistocene starting as early as 1.5 to 2.5 Ma (Bjornstad et al. 2001). The Hanford formation consists of pebble- to boulder-size gravel, fine- to coarse-grained sand, and silt (“Quaternary Geology of the Columbia Plateau” [Baker et al. 1991]). These deposits are generally divided into three facies associations: (1) gravel-dominated, (2) sand-dominated, and (3) interbedded sand and silt-dominated. The Hanford formation is present throughout the Hanford Site below elevations of about 1,000 ft (300 m). The Hanford formation reaches its maximum thickness of 300 ft (100 m) between the 200 East and 200 West Areas beneath the Cold Creek flood bar.

- **Gravel-Dominated Facies** – This facies generally consists of poorly sorted mixtures of pebble to boulder gravel, fine- to coarse-grained basaltic sand, with variable amounts of silt. Gravel-dominated facies may display massive bedding, horizontal to low-angle bedding, and/or large-scale, planar-tabular cross bedding in outcrop, as well as scour-and-fill channels. An open-framework fabric is also observed in outcrop, characterized by clast-supported basalt-rich gravel with little or no matrix-filling sand/silt. Discontinuous sand and silt beds may be interbedded throughout sequences of gravel-dominated facies. Gravel clasts are dominantly basalt with lesser amounts of reworked, Ringold Formation clasts such as granite, quartzite, and gneiss (WHC-SD-EN-TI-012). The gravel-dominated facies was deposited by high-energy floodwaters in or immediately adjacent to the main cataclysmic flood channels (Baker et al. 1991).

- **Sand-Dominated Facies** – This facies consists of fine- to coarse-grained sand and pebbly gravel. The sands typically display a high basalt content (30 to 70%) with color commonly described as black, gray, or “salt-and-pepper” like. Sand-dominated facies may contain isolated matrix-supported pebbles and rip-up clasts, as well as discontinuous beds of pebble-gravel and/or silty interbeds generally less than 3 ft (1 m) thick. The silt content of the sands is variable, but when low, the sands are clean and well-sorted. In outcrop this facies commonly displays horizontal to subhorizontal lamination and bedding. The sand-dominated facies was deposited adjacent to main flood channels during the waning stages of flooding (Baker et al. 1991). The facies is transitional between the gravel-dominated and the interbedded sand and silt-dominated facies associations.
- **Interbedded Sand and Silt-Dominated Facies** – This facies consists of thin beds of interbedded, horizontal- to ripple cross-laminated fine-coarse-grained sand and silt. Beds are typically ≤ 1 m (3 ft) thick and commonly display normally graded-bedding. Unlike the other facies associations, in outcrop, individual “rhythmite” beds may be traced laterally for hundreds of meters or more. Sediments of this facies were deposited under slack-water conditions and in back-flooded areas during cataclysmic flooding (DOE/RW-0164; Baker et al. 1991). This facies association is generally absent within WMAs C and A-AX.

Coarser-grained sand and gravel fractions of the Hanford formation generally consist of about equal amounts of basaltic and quartzo-feldspathic material (*Geology of the Separation Areas, Hanford Site, South-Central Washington* [RHO-ST-23]). This mineral assemblage gives the Hanford formation its characteristic “salt and pepper” appearance, often noted in drillers’ and geologists’ logs. The non-basaltic component consists of predominantly quartz and feldspar with some samples containing greater than 10% pyroxene, amphibole, mica, chlorite, ilmenite, and magnetite. The silt- and clay-sized fractions consist of mostly quartz, feldspar, mica, and smectite.

The Hanford formation makes up the majority of the suprabasalt sedimentary sequence beneath WMAs C and A-AX, ranging in thickness from 43 to 73 m (140 to 240 ft). The Hanford formation has been divided into three informal units (H1, H2, and H3) in the 200 East Area. The Hanford formation H1 and H3 units are gravelly units consisting of predominantly sandy gravel to gravelly sand. The H2 unit is predominantly sand, with occasional beds of slightly gravelly sand. The Hanford formation H1 and H3 units contain a higher percentage of flood gravel, associated with deposition within and along the main Ice Age flood channelways. The sand-dominated H2 unit was deposited under less-energetic currents, perhaps further away from the main channelway. The third facies association of the Hanford formation, interbedded sand and silt-dominated facies, are absent in WMAs C and A-AX.

2.2.2.3.1 Lower Gravelly Sequence (H3 Unit)

The Hanford formation lower gravelly sequence (H3 unit) locally overlies undifferentiated Plio-Pleistocene/Ringold deposits (Figure 2.4). This sequence is equivalent to the lower coarse-grained unit of the Hanford formation of *Revised Groundwater Monitoring Plan for the 200 Areas Low-Level Burial Grounds* (WHC-SD-EN-AP-015) and the lower gravel

sequence of WHC-SD-EN-TI-012, to the Hanford formation H3 sequence of *Geologic Setting of the Low-Level Burial Grounds* (WHC-SD-EN-TI-290), and to the Qfg (Quaternary flood gravels) deposits of *Geologic Map of the Priest Rapids 1:100,000 Quadrangle, Washington* (Reidel and Fecht 1994).

The H3 unit consists of predominantly gravelly facies of clast-supported, sandy, pebble to boulder gravel to matrix-supported pebbly sand. The maximum CaCO_3 measured is approximately 2.5 wt%. The sand fraction ranges from 15 to 70% basalt grains, but most often is reported as 40 to 50% basalt. This unit appears to be present everywhere except within the central and southwest portions of the study area; it is generally missing from beneath most of WMA A-AX (RPP-14430). The unit is probably absent from these areas because of lateral facies changes that take place between gravel-dominated facies to the north and sand-dominated facies to the south away from the primary flood channel that exists north and east of the study area. The greatest thickness (28.7 m [94 ft]) occurs several hundred feet east of WMA A-AX. The exact thickness of the Hanford formation H3 unit beneath WMA C, on the other hand, is uncertain because the underlying PPLz/(R)? unit, used to define the base of the unit, is missing.

A structure-contour map of the top of the Hanford formation H3 unit is provided in RPP-14430. The surface of this unit slopes to the south and west with the highest elevations occurring in the northeast and east portions of the study area. Coarser-grained facies of the Hanford formation H3 unit are more common to the north, toward the axes of flood channels (RPP-14430). About 20 m (70 ft) of relief (128 to 148 m [420 to 490 ft]) exists on the surface of the H3 unit beneath WMAs C and A-AX.

2.2.2.3.2 Sand Sequence (H2 Unit)

The Hanford formation sand sequence overlies the lower gravel sequence (H3 unit). This sand sequence is equivalent to the middle sand unit (WHC-SD-EN-AP-015), the fine sequence of WHC-SD-EN-TI-012, the sandy sequence of WHC-SD-EN-TI-019, the Hanford formation H2 sequence of WHC-SD-EN-TI-290, and to Quaternary flood sands of Reidel and Fecht (1994).

The H2 unit consists of predominantly sand-dominated facies of the Hanford formation. Fine- to coarse-grained sand dominates with lenses of silty sand to slightly gravelly sand. Minor sandy gravel to gravelly sand beds occur sporadically. Consolidation ranges from loose to compact. Cementation is very minor or absent, and total CaCO_3 content is generally only a few weight percent or less. The sand fraction ranges from 10 to 70% basalt grains but most often a basalt content of 30 to 40% is reported. Silt lenses and thinly interbedded zones of silt and sand are common but are not abundant in the Hanford formation H2 unit. These thin (< 1 ft [0.3 m]) fine-grained zones generally cannot be correlated among boreholes and are not reflected in the gross gamma-ray logs or moisture data. This is probably because moisture samples are normally collected every 1.5 m (5 ft) during drilling; this sampling interval is too large to detect most thin zones. The fine structure observed in some older gross gamma-ray logs may reflect changes in the silt content that were not detected during drilling.

The Hanford formation sand sequence (H2 unit) underlies the entire area beneath WMAs C and A-AX. The base of the Hanford formation H2 unit is identified as the top of the gravelly H3 unit or the top of the fine-grained PPlz/R(?) unit, if the H3 unit is missing. The H2 unit thickens to south and west (RPP-14430), except beneath WMA A-AX, where the upper portion may have been scoured by a southeast trending Ice Age flood channel, perhaps associated with deposition of the overlying gravelly sequence (H1 unit). This is indicated by a south to southeast-trending trough present at the top of the H2 unit (RPP-14430). Furthermore, over 30 m (100 ft) of relief exists on top of the H2 unit along this trough.

2.2.2.3.3 Upper Gravelly Sequence (H1 unit)

The Hanford formation upper gravel sequence overlies the Hanford formation sand sequence (H2 unit). This sequence is equivalent to the upper coarse-grained unit of WHC-SD-EN-AP-015, the upper gravel sequence of WHC-SD-EN-TI-012, the Hanford formation H1 unit of WHC-SD-EN-TI-290, and to Quaternary flood sands of Reidel and Fecht (1994).

The Hanford formation H1 unit consists of predominantly loose, sandy gravel to gravelly sand, with minor beds of sand to silty sand. Coarser beds may contain boulder-sized materials. Only a few weight percent or less calcium carbonate has been measured in this unit. Sand fractions range from 10 to 80% basalt, although 40 to 50% basalt is most commonly reported. The Hanford formation H1 unit consists of mostly high-energy, coarse-grained gravel and sand deposits. Occasional thin, discontinuous lenses of fine sand and silt may also be present.

The isopach map of the Hanford formation H1 unit suggests the unit thickens along a northwest-southeast trending trough, which includes WMAs C and A-AX (RPP-14430). The H1 unit appears to be missing in the northeast and extreme southwest portions of the study area. The maximum thickness (approximately 30 m [100 ft]) of the H1 unit underlies WMA A-AX. The H1 unit is thinner in the immediate vicinity of the tanks because much of the Hanford formation H1 unit was removed and replaced with backfill during tank farm operations.

2.2.2.4 Recent Deposits

Two types of recent deposits are present in WMAs C and A-AX: (1) eolian sand and silt and (2) backfill material. Fine to medium sand to silty sand naturally caps the sedimentary sequence in WMAs C and A-AX. These relatively fine-grained deposits are derived from the reworking of uppermost flood deposits by winds since the last Ice Age flood (approximately 13,000 years before present). These poorly sorted eolian deposits contain up to 10 wt% CaCO_3 associated with recent soil development.

Eolian sand and silt forms a relatively thin (6.1 m [20 ft]) blanket over the study area (RPP-14430). The thickness of the eolian deposits appears greater along a northwest to southeast trend extending from WMA A-AX toward the southeast (RPP-14430). Most or all of the eolian material has been removed and replaced with backfill in the immediate vicinity of tank farm operations. Backfill materials consist of unstructured, poorly sorted mixtures of gravel,

sand, and silt removed during tank excavation, and then later used as fill around the tanks. Backfill materials extend to depths of 15 m (50 ft) within the tank farms (RPP-14430).

2.2.2.5 Clastic Dikes

Clastic dikes are vertical to subvertical sedimentary structures that cross-cut normal sedimentary layering. Clastic dikes are a common geologic feature of the Hanford formation in the 200 Areas, especially in the sand- and silt-dominated facies. Clastic dikes are much less common in the gravel-dominated facies of the Hanford formation. While a clastic dike could increase flow rate, it is less likely to intersect large segments of leaked wastes; when it does, the cross-sectional area of the intersection is small (*TWRS Vadose Zone Contamination Issue Expert Panel Status Report* [DOE/RL-97-47]).

Clastic dikes occur in swarms and form four types of networks (*Clastic Injection Dikes of the Pasco Basin and Vicinity* [BHI-01103]):

- Regular-shaped polygonal patterns
- Irregular-shaped, polygonal patterns
- Preexisting fissure fillings
- Random occurrences.

Clastic dikes near WMAs C and A-AX probably occur randomly in the gravel-dominated facies (the Hanford formation H1 and H3 units) and as regular-shaped polygons in the sand facies (the Hanford formation H2 unit). Regular-shaped polygonal networks resemble 4- to 8-sided polygons and typically range from 3-cm to 1-m (1-in. to 3-ft) wide, from 2-m to more than 20-m (6-ft to more than 65-ft) deep, and from 1.5 to 100 m (5 to 325 ft) along their strike. Smaller dikelets, sills, and small-scale faults and shears are commonly associated with master dikes that form the polygons.

In general, a clastic dike has an outer layer of clay with coarser infilling material. Clay linings are commonly 0.03- to 1.0-mm (0.001- to 0.04-in.) thick, but linings up to about 10-mm (0.4-in.) thick are known. The width of individual in-filling layers ranges from as little as 0.01 cm to more than 30 cm (0.0004 in. to more than 12 in.) and their length can vary from about 0.2 m to more than 20 m (8 in. to more than 65 ft). In-filling sediments are typically poorly sorted to well-sorted sand but may contain clay, silt, and gravel (*Subsurface Conditions for S-SX Waste Management Area* [HNF-4936]).

2.2.3 Hydrogeology

General groundwater flow directions under WMAs C and A-AX have changed substantially because of Hanford Site operations. The flow direction in the local unconfined aquifer was from west to east before Hanford Site operations began. The water table changed significantly after waste disposal operations began in the early 1950s. The shift in discharge of large volumes of wastewater in the early 1950s to B Pond raised the water table in the vicinity of WMAs C and A-AX as much as 4.9 m (16 ft) above the pre-Hanford Site-operations level (*Hanford Site Groundwater Monitoring for Fiscal Year 1998* [PNNL-12086]). Figures 2.2 and 2.3 show the locations of wells monitored to track recent water level changes and contamination events. Water level declines have become even more pronounced since other effluent discharges

throughout the 200 Areas ceased in 1995. Water levels are expected to decline within WMAs C and A-AX region.

Currently, the water table beneath WMA C lies 122 m (400 ft) amsl with about 77 m (255 ft) of vadose zone. The aquifer thickness, based on the top of basalt at 108 m (355 ft), is approximately 13.4 m (44 ft). The aquifer materials consist dominantly of sandy gravel or silty sandy gravel. At WMA A-AX the water table lies in basal gravels currently interpreted as Ringold Formation Unit A. As explained in Section 2.2.2.2, there is some ambiguity as to the location of the Hanford/Ringold contact in this area with respect to the water table. The aquifer thickness, based on data from well 299-E25-2, which extends to basalt, is approximately 27.1 m (89 ft). The lithology within the aquifer is dominantly a sandy gravel ranging from cobble to boulder-sized clasts.

Currently, there is a discrepancy in reported hydraulic conductivity values for the area. Values are estimated between 7.3 and 33.5 m (24 and 110 ft) per day based on slug injection/withdrawal tests. Higher values of 1,981 m (6,500 ft) per day are reported based on pumping tests for the area (*Hydrologic Testing at the Single-Shelled Tanks, 1989* [WHC-SD-EN-TI-147]; WHC-SD-EN-TI-019). The hydraulic conductivity values used for WMA C were derived from pumping tests, which are considered more reliable than values derived from slug tests. Also, the pumping test values are more comparable with tracer test plume tracking results than are slug test values. Hydraulic conductivity values used for WMA C calculations are between 1,067 and 2,073 m (3,500 and 6,800 ft) per day as reported by WHC-SD-EN-TI-019.

In the FY 1992 hydrogeologic model for the 200 East Area, values of 1,889.8 to 1,982 m (6,200 to 6,500 ft) per day are reported at WMA A-AX (WHC-SD-EN-TI-019). *Unconfined Aquifer Hydrologic Test Data Package for the 200 East Groundwater Aggregate Area Management Study* (WHC-SD-EN-DP-030) reports conductivities that range from 2,518.9 m (8,264 ft) per day to 1,982 m (6,500 ft) per day for wells in the immediate area of WMA A-AX. Finally, PNNL-12086 reports hydraulic conductivities that range from 10,000 m (33,000 ft) per day to 3,000 m (9,843 ft) per day for Hanford sediments. The low results from slugs tests are likely inherent in the method. The test has a limited areal extent (i.e., interrogates a low volume), applies a limited stress to the aquifer, and is valid over a limited range of conductivities (*Summary and Evaluation of Available Hydraulic Property Data for the Hanford Site Unconfined Aquifer System* [PNL-8337]).

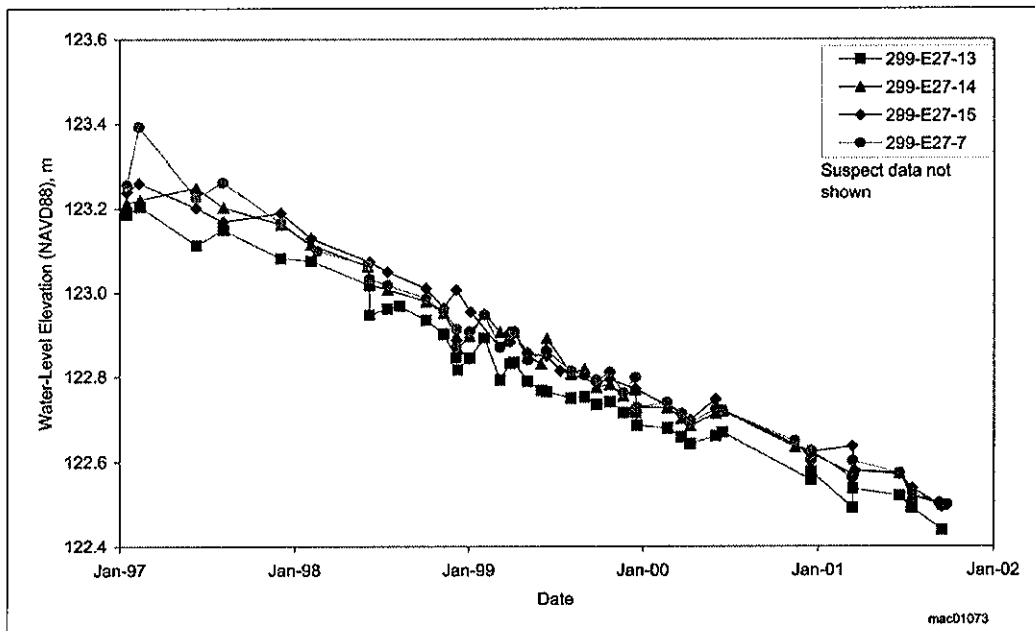
The water table is extremely flat across the 200 East Area (Figure 2.6), and in areas with flat water tables the choice of surveys may actually affect the relative position of the water elevation in a well with respect to other network wells. Because water elevations are the most common data set used at the Hanford Site to determine flow direction, a switch in the relative water elevations of wells used to determine direction could affect the interpretation of the flow direction.



The groundwater project recently switched the datum to which water levels are referenced (PNNL-12086; *Hanford Site Groundwater Monitoring for Fiscal Year 1999* [PNNL-13116]; *Hanford Site Groundwater Monitoring for Fiscal Year 2000* [PNNL-13404]; *Hanford Site Groundwater Monitoring for Fiscal Year 2001* [PNNL-13788]). In the past, water levels were referenced to the NGVD29 datum. North American Vertical Datum of 1929 (NGVD29) is the reference surface established by the US Coast and Geodetic Survey in 1929 as the datum to which elevation data were referenced. It is based on the mean sea level in the conterminous United States. North American Vertical Datum of 1988 (NAVD88) is the current official vertical datum of North America. The NGVD29 datum was chosen originally because the bulk of the wells used onsite could be referenced not only to this datum but also to a specific survey called NGVD29-2. For areas the size of a WMA, there is no effect from switching to the NAVD88 datum. However with the datum change, there was also a switch in surveys. Many wells are now referenced to one of two surveys, with elevations referenced to NAVD88, both more recent surveys than NGVD29-2.

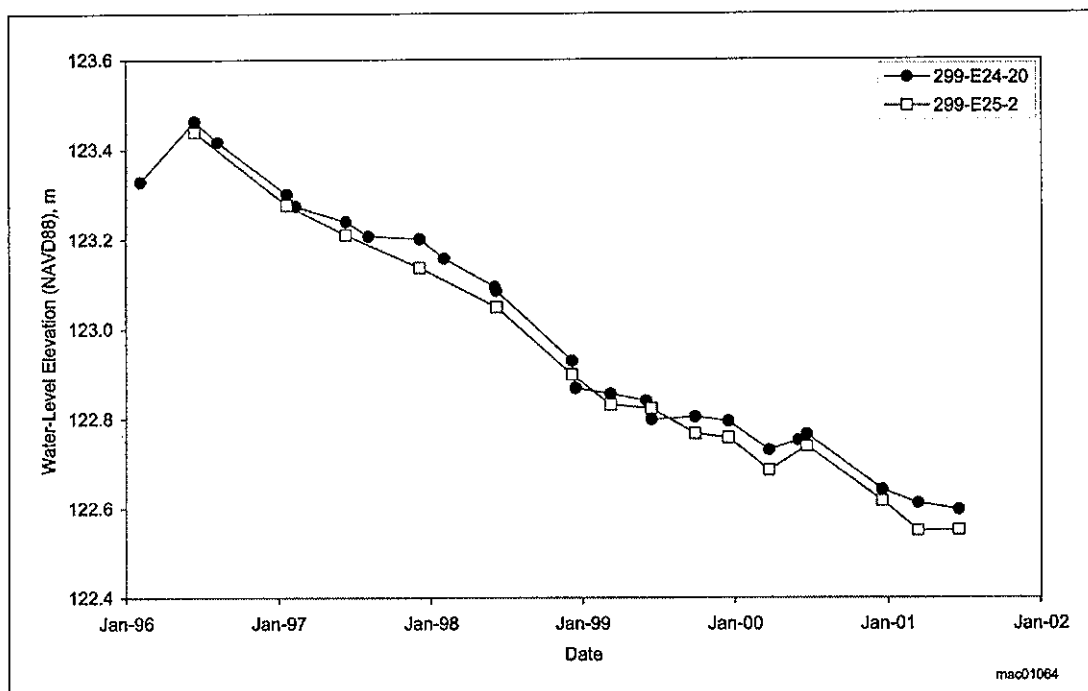
Figure 2.7 shows hydrographs for four of the five RCRA network wells that are currently used to monitor the water table at WMA C. The water level data from well 299-E27-15 had been historically inconsistent with data from the other wells in the WMA C network and with the regional water table data (PNNL-12086). Corrections to water elevations based on the recent results of gyroscope surveys at WMA C including this well provide a more consistent and thus interpretable water table surface (PNNL-13788). Water table elevations across WMA C vary from 122.62 to 122.77 m (402.3 to 402.8 ft) amsl. The local gradient between well 299-E27-7 and 299-E27-13 is 0.00021 based on June 2000 water levels.

Figure 2.7. Hydrographs for Wells in the Waste Management Area C Monitoring Network – All data referenced to the NAVD88 datum. Spurious data have been removed.



Hydrographs of the two wells at WMA A-AX give a consistent picture of relative water elevations over time (Figure 2.8). The flow direction appears to be southeast. Based on these hydrographs, well 299-E24-20 is the upgradient well, while the other four are downgradient wells. Using NAVD88-1, water elevations across WMA A-AX vary from 122.80 to 122.86 m (402.90 to 403.10 ft) or 6.1 cm (2.4 in). The local gradient between wells 299-E25-41 and 299-E24-20 is 0.000078 based on March 1999 water levels.

**Figure 2.8. Hydrographs for Two Wells in the Waste Management Area A-AX Monitoring Network – All data referenced to the NAVD88 datum.
Spurious data have been removed.**



Another well, 299-E24-19, was eliminated from the analysis because results from this well form a slight trough between wells 299-E24-20 and 299-E25-46. The water elevations in well 299-E24-19 are low regardless of which survey is used, which has confused interpretation of the flow direction in the past. Based on recent findings with vertical borehole deviations, this well may be slightly out of plumb, explaining the abnormal trough. Consequently, this well was eliminated from the network for flow direction determinations until gyroscope corrections are available.

Recent interpretations of current flow direction show a southwesterly flow from WMA C and turning more southeasterly at WMA A-AX where aquifer is more than twice as thick and the regional southeasterly flow pattern becomes dominant (PNNL-12261; PNNL-13788). These patterns are consistent with regional flow directions.

Although the predominant flow directions at these two WMAs are consistent with the regional flow directions and plume trends, as evidenced over miles, they can be misleading when determining the local flow anomalies across these small sites that are wide 152.4 m (500 ft).

Some suggestion of the complexity of flow patterns in the 200 East Area is shown by direct measurements shown in Figure 2.9. The large variation in flow directions may be somewhat exaggerated because the effects of well design and rapid changes in barometric pressure, which are not accounted for in Figure 2.9. It is known that wells south of the PUREX Plant can have large changes in flow direction in a single day because of their barometric efficiency.

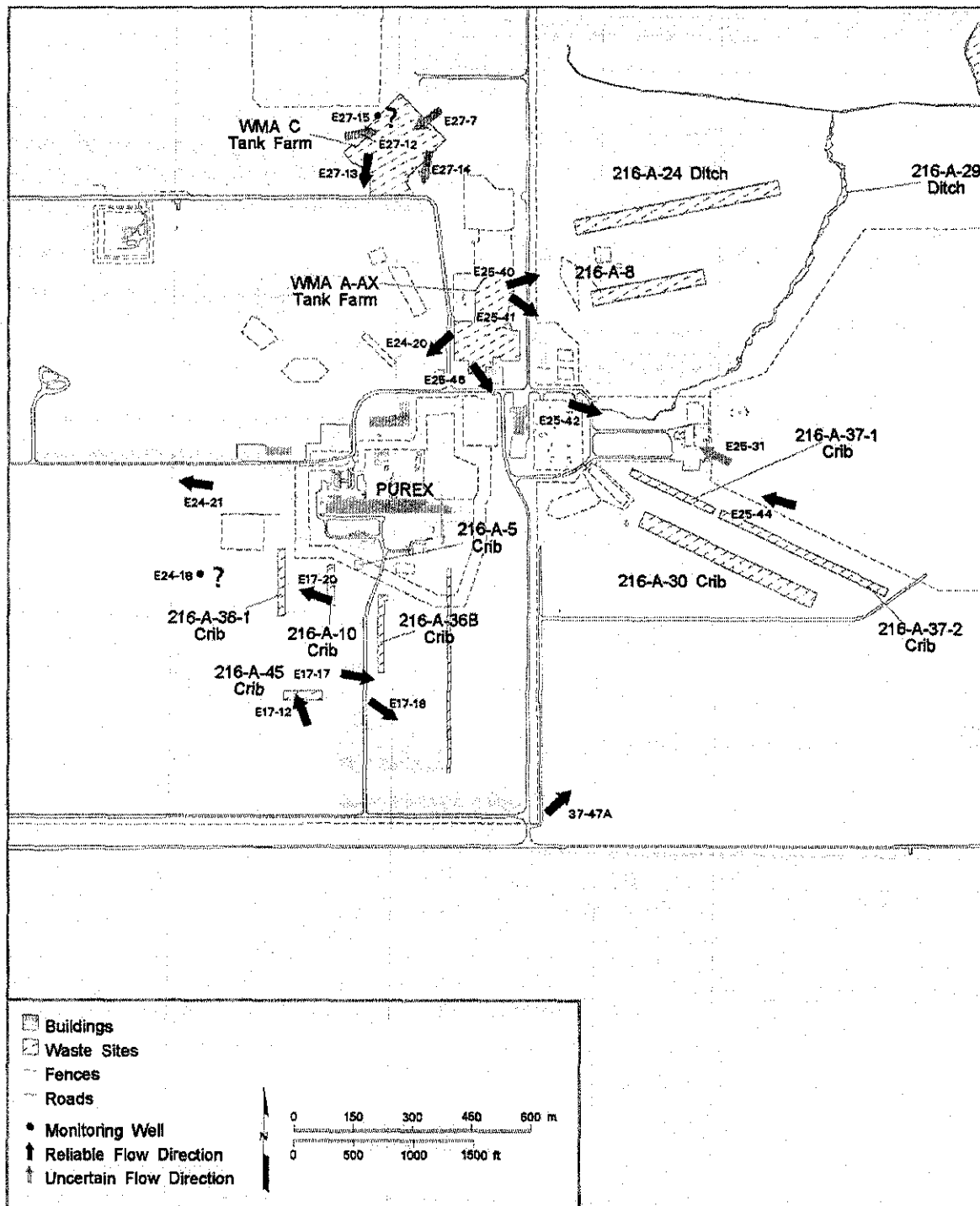
Until this year, the flow direction at these two WMAs had been determined exclusively from gradient calculations based on local water elevations. Unfortunately, across the 200 East Area, the differences in water elevation between wells are small, on the order of a few inches. The combined errors from water level measurements, survey elevations, and borehole deviations from vertical are enough to cause uncertainties in local flow direction anywhere in the 200 East Area. As reported in PNNL-13116, water level data alone are insufficient to determine flow direction in this area. Direct flow measurements were made in several wells at these tank farms to help determine flow direction and thereby minimize the uncertainty in flow direction. Also, colloidal boroscope measurements have been added at site-specific wells to improve the database for interpreting local flow directions.

Because water levels are not accurate enough to determine flow directions, instruments such as the colloidal boroscope may be employed to verify and refine flow directions and rate. The colloidal boroscope is an in situ technique developed to directly measure the flow rate and direction through a borehole (PNNL-13023). It has been demonstrated successfully twice at the Hanford Site in FY 1994 and in FY 1999. It is also an accepted method of flow direction and flow rate used increasingly in the field of groundwater studies (PNNL-13023). Results of the Hanford tests indicate that the tool can provide useful, reliable information on flow properties in the highly transmissive Hanford formation sediments (PNNL-13023).

At WMA C where barometric effects are usually minor and suspect data were intentionally avoided, the flow direction determined in well 299-E27-13 was southwest, which was measured for more than two hours, and had no significant vertical component (Figure 2.9). The similar southwest flow determined in well 299-E27-14 had similar quality, but was recorded for only 36 minutes. Therefore, the value, which is shown in gray, is accepted as valid with caution. The flow directions of the other two arrows shown in gray for wells 299-E27-7 and 299-E27-12 are very questionable because of their large vertical components.

Recent direct flow measurements with the colloidal borescope in wells 299-E27-14 (southeast of C tank farm), 299-E27-13 (southwest of C tank farm), and 299-E27-7 (northeast of C tank farm) indicate an average southwesterly flow direction of approximately 214° from true north. Actual measurements in these three wells range from 200 to 235° from true north. Only well 299-E27-12, which is located west of the C tank farm, indicates an easterly flow direction as shown in Figure 2.10. However, the two interpretable measured values in this well are suspect because they represent vertical flow, which may be related to their close proximity (i.e., less than 0.45 m [1.5 ft]) to the water table surface in the well.

Figure 2.9. Flow Direction Map of Wells in the Vicinity of Waste Management Areas C and A-AX Based on Colloidal Borescope Measurements



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According to water table elevations based on surveys referenced to NAVD88 and colloidal borescope data, the direction of flow at WMA C appears to be predominantly southwest. The current monitoring network was designed for a flow direction to the west with two upgradient wells, 299-E27-7 and 299-E27-14, and three downgradient wells, 299-E27-12, 299-E27-13, and 299-E27-15. As seen on Figure 2.10, only well 299-E27-13 is downgradient if the flow direction is southwest or south-southwest while well 299-E27-12 and 299-E27-14 are cross-gradient, providing little if any coverage of the WMA.

At WMA A-AX where barometric effects can have a more significant impact on borescope results, periods of significant barometric changes were avoided as much as possible when selecting flow direction data. Four of the five wells surveyed with the colloidal borescope near this WMA suggest an eastward to southeastward flow (Figure 2.11). The fifth well is the upgradient well 299-E24-20 that shows westerly flow, but it tends to show higher water table elevations than those wells southeast of the site. The cause of this seemingly anomalous flow direction is unknown, but may be influenced by the presence of the Plio-Pleistocene silt/Ringold Formation mud facies near the water table surface or possibly some barometric effect. A sixth well, 299-E24-19, is deviated significantly from vertical; therefore, the colloidal borescope could not be used in this well.

According to water elevations based on surveys referenced to NAVD88, the direction of flow is southeasterly. The current network was designed for a southwesterly flow direction with two upgradient wells (then 299-E25-40 and 299-E25-41) and only three downgradient wells, 299-E24-19, 299-E24-20 and 299-E25-46. However, recent measurements with the colloidal borescope in wells 299-E25-46, 299-E25-42 (both southeast of A tank farm), and 299-E25-41 (southeast of AX tank farm) confirm a southeasterly flow direction of approximately 125° from true north (Figure 2.11). Data from well 299-E25-40, which is located northeast of WMA A-AX, indicated easterly flow. The data from this well indicated primarily vertical flow, thus the flow in the well may be deviated with respect to the surrounding aquifer due to local borehole conditions. Results from well 299-E24-20 display a southwest flow, which, although southerly, does not agree as well with either the water level data or the other borescope data. The results from this well may be due to borehole effects or other perturbations in flow due to local heterogeneities of permeability at this location. As shown in Figure 2.11, only well 299-E25-41 is downgradient. Well 299-E24-20 is marginally upgradient while wells 299-E25-19 and 299-E25-46 are marginally downgradient but only for the A tank farm. This scenario results in a generally southeasterly flow across the site. This direction has been confirmed with the use of an alternative in situ method to determine flow direction. Recent direct measurements using the colloidal borescope in wells 299-E25-46 (southeast of A tank farm), 299-E25-41 (southeast of AX tank farm), and 299-E25-42 (southeast of A tank farm) indicate a southeasterly flow (Figure 2.11).

The rate of groundwater flow is calculated for a homogeneous, isotropic aquifer using the Darcy equation (*Groundwater* [Freeze and Cherry 1979]) incorporating the hydraulic conductivity, the gradient across the site and the effective porosity of the sediments in the aquifer. The current estimate is between 1.7 to 3.3 m (5.6 and 10.8 ft) per day for WMA A-AX and 0.7 and 1.4 m (2.4 and 4.8 ft) per day for WMA C (PNNL-13116; PNNL-13788).

**Figure 2.10. Flow Direction Map of Wells Around Waste Management Area C
Based on Colloidal Borescope Measurements**

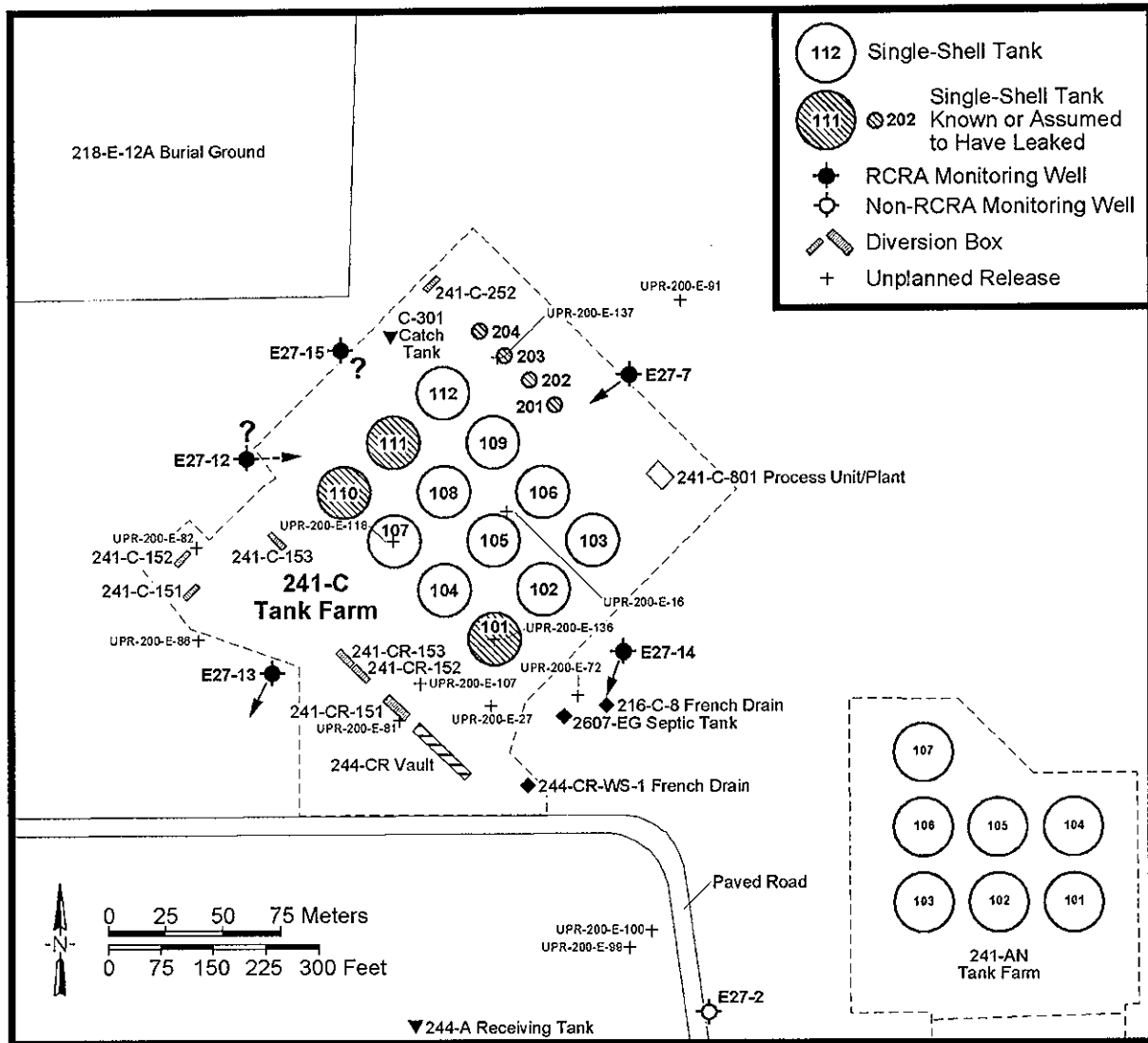
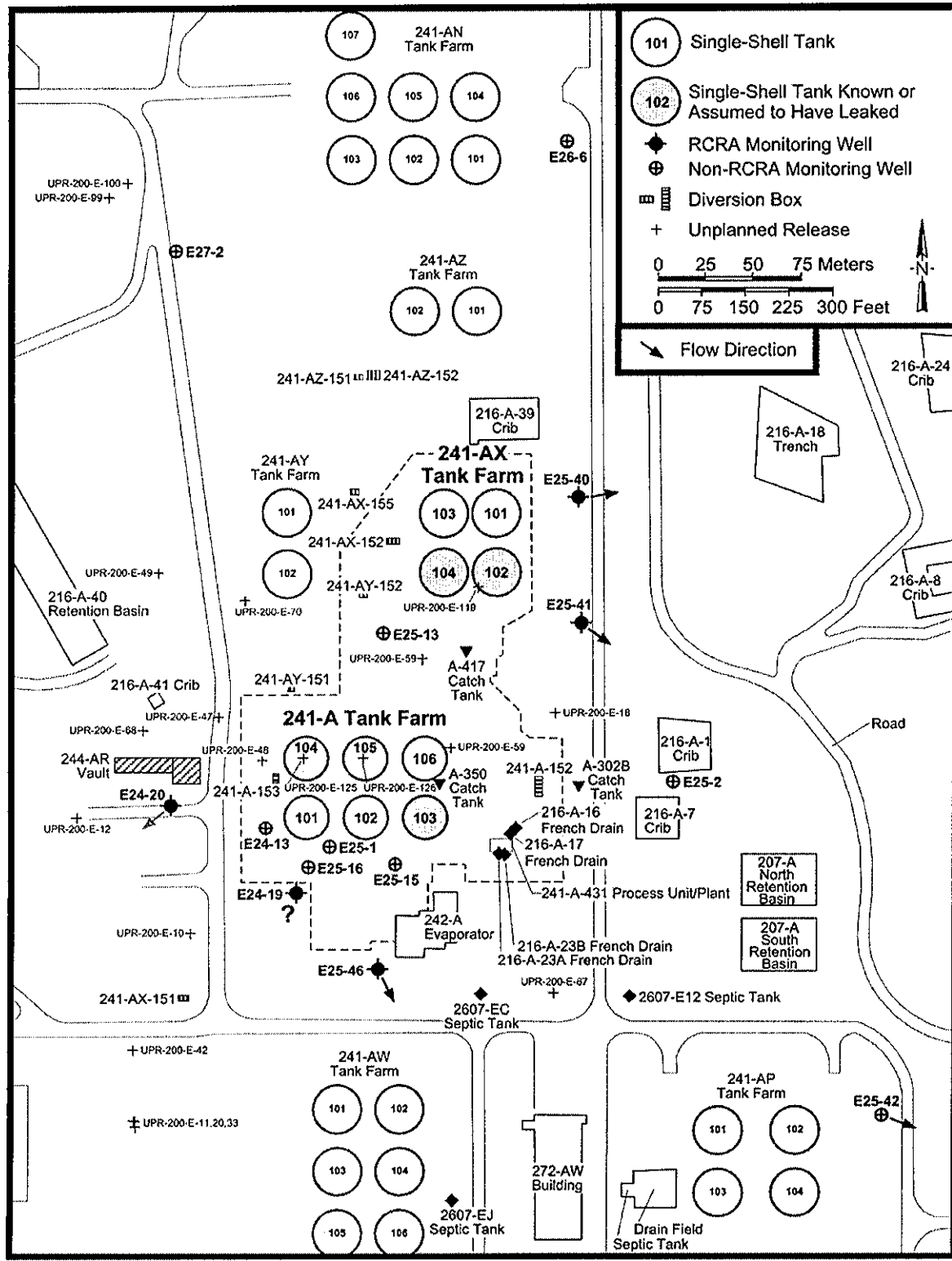


Figure 2.11. Flow Direction Map of Wells Around Waste Management Area A-AX Based on Colloidal Borescope Measurements



2001/DCL/A-AX/003

At WMA C, values obtained from wells 299-E27-13 and 299-E27-14 using the colloidal borescope, after corrections for in well flow rates, indicate flow rates in the aquifer of 1.2 to 1.9 m (4 to 6.3 ft) per day. These values for flow velocity, although higher than the current estimates of 0.7 and 1.4 m (2.4 to 4.8 ft) per day, are still within reasonable agreement with rates determined from the Darcy equation. However, in sharp contrast direct measurements of flow rates based on tracer tests and plume tracking suggest flow rates may be as high as 18 m (60 ft) per day in parts of the unconfined aquifer (PNNL-12086). The influence of the regional flow direction and velocity is demonstrated by the large tritium plume of PUREX Plant waste disposed to the PUREX cribs, the effective flow from the southeast corner of the 200 East Area is to the east and southeast at rates from 4.3 to 5.5 m (14 to 18 ft) per day (PNNL-12086). However, these values are from an area where flow velocities are expected to be higher than in WMA C because of slightly higher gradients and hydraulic conductivity southeast of WMA C as evidenced by those at WMA A-AX.

2.2.3.1 Recharge

Recharge through the vadose zone is primarily controlled by the surface sediment type, vegetation type, topography, human-made, and spatial and temporal variations in seasonal precipitation at WMAs C and A-AX. As used in this addendum, the recharge rate is the amount of precipitation that enters the sediment, is not removed by evaporation or transpiration, and eventually reaches the groundwater table. The recharge to the unconfined aquifer beneath the C, A, and AX tank farms from infiltrating precipitation is an important parameter for calculating groundwater impacts from past tank leaks, future tank waste retrieval losses, and residual tank waste currently in the SSTs. The tank farm surface characteristics and infrastructure create an environment conducive to enhanced general recharge and transient, high-intensity events.

Most of the precipitation at the Hanford Site occurs from September through February when little to no evaporation or transpiration occurs. Recharge varies temporally and spatially. The temporal variation occurs with changes in temperature, plant activity, and precipitation. Both seasonal and long-term variations, as a result of climatic change, are important. The spatial variation occurs with changes in vegetation type, surficial sediment type, and human-made structures (e.g., paved parking lots). A lag time exists between a change in recharge rate from infiltration at the surface and a change in the flow field in the vadose zone as the water infiltrates through the ground.

2.2.3.2 Natural Infiltration

No direct measurements of the natural infiltration rate under WMAs C and A-AX have been made. However, observations from similar, disturbed, gravel-covered areas at the Hanford Site indicate that as much as 10 cm (3.9 in.) can infiltrate a vegetation-free coarse gravel surface per year (“Estimating recharge Rates for a Groundwater Model Using a GIS” [Fayer et al. 1996]; “Variation in Recharge at the Hanford Site” [Gee et al. 1992]; *Estimated Recharge Rates at the Hanford Site* [PNL-10285]). That rate represents about 60% of the average annual meteoric precipitation (rainfall plus snowmelt). PNL-10285 indicates that WMAs C and A-AX are estimated to have about 5 to 10 cm (1.97 to 3.9 in.) of infiltration per year based on soil type, vegetation, and land use. Actual recharge is significantly different and not uniform because of the presence of the tanks, the disturbed soil surrounding the tanks, and no vegetative cover. Recharge is intercepted and “shed” by the tank domes and flows into the disturbed soil near the

tanks. Thus, infiltration rates near tank edges and between rows of tanks are likely manyfold higher than average areal infiltration rates.

Lysimeter data from the Field Lysimeter Test Facility located between the 200 West and 200 East Areas show that the recharge rate ranges from 24 to 66% of the annual precipitation for years 1990 to 1994 for lysimeters with gravel over sand and bare vegetation conditions, which are typical of current tank farm ground conditions (*Estimation of Natural Ground Water Recharge for the Performance Assessment of a Low-Level Waste Disposal Facility at the Hanford Site* [PNL-10508]). This is equivalent to approximately 4 to 11.1 cm (1.57 to 4.37 in.) of recharge per year based on the long-term annual precipitation rate of 16.8 cm (6.61 in.) per year (*Climatological Data Summary 1995 with Historical Data* [PNNL-11107]). However, more recent lysimeter field measurements acquired August 1995 to August 1996 from the Field Lysimeter Test Facility resulted in 16.06 cm (6.32 in.) drainage per year, which is 66% of the actual precipitation over that period. These lysimeters were designed to simulate tank farm conditions in the 200 Areas.

Rapidly melting snow is one natural event that can lead to surface flooding. This type of occurrence has been documented at the T tank farm (*Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas T and TX-TY at the Hanford Site* [PNNL-11809]), but no similar record is available for WMAs C and A-AX.

2.2.3.3 Artificial Recharge

Artificial recharge in the 200 East Area is associated with trenches, cribs, ditches, and drains that were used to dispose of waste water. Leaking water lines are another source of artificial recharge in the tank farms. Higher infiltration rates are observed around the tank farms, which are covered with gravel and kept clear of vegetation.

Waterline ruptures, such as the one in September 1996 at the S tank farm, demonstrate that surface water could enter and collect in low spots (*Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas S-SX at the Hanford Site* [PNNL-11810]). Transient saturation from runoff collecting in low spots could be a more significant driving force than average annual infiltration.

Discharges within WMAs C and A-AX were intentional and unplanned releases. Quantities are not known for many of the identified releases. Reported releases are primarily leaks from transfer pipelines, diversion boxes, and tanks. RPP-14430 provides more information on artificial recharge related to WMAs C and A-AX.

2.2.4 Surface Water Hydrology

No flood plains exist in or between the 200 Areas. Floods in Cold Creek and Dry Creek have occurred historically; however, there have been no observed flood events. Based on a probable maximum flood evaluation, no impact would occur at WMAs C and A-AX (*Hanford Site National Environmental Policy Act (NEPA) Characterization* [PNNL-6415]).

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3.0 INITIAL CONDITIONS AND CORRECTIVE ACTION REQUIREMENTS AND OBJECTIVES IN WASTE MANAGEMENT AREAS C AND A-AX

The purpose of this section is to describe what is known about confirmed or suspected contamination in the vadose zone and groundwater and identify the potential corrective action requirements and objectives. The information on known and suspected contamination is presented in Section 3.1 and RPP-14430. A summary of this information is also provided in Section 3.0 of DOE/RL-99-36. Potential corrective action requirements are provided in Section 3.2. The confirmed or suspected contamination information was used to develop the Section 3.3 discussion on the potential impacts to the public health and the environment based on potential corrective action requirements and objectives. Section 3.4 addresses preliminary corrective action objectives and alternatives with respect to Section 5.0 of DOE/RL-99-36. Additional data to support improved understanding of the nature and extent of contamination at WMAs C and A-AX will be collected during the field investigation described in this addendum.

3.1 KNOWN AND SUSPECTED CONTAMINATION IN WASTE MANAGEMENT AREAS C AND A-AX

A summary of available data and conditions is needed to effectively develop a characterization plan designed to collect data to support a determination of the presence and extent of contamination at a site caused by a given event or activity. A summary of available WMAs C and A-AX data regarding source, sediments, and groundwater contamination is presented in the following subsections and in RPP-14430.

When interpreting the data in the following subsections, it is important to note the amount of radioactive decay that has taken place since the data were gathered. For example, the half-life of cesium-137 is 30.2 years, approximately the time between 1968 and 1998. Thus, cesium-137 levels would, in 1998, have been approximately half of their 1968 values. Where possible, the dates for radionuclide inventories have been given, but calculations of the decayed inventories through the present time have not been made.

3.1.1 Sources

The source terms for WMAs C and A-AX are dependent upon nuclear and chemical aspects of the processes that generated the waste. The inventory of chemicals and radionuclides lost to the vadose zone in WMAs C and A-AX is a function of the waste types stored in the tanks over their decades of use. Because of their long operational history, the tank farms received waste generated by all of the major processes. The C tank farm initially received waste streams discharged from the bismuth phosphate process operating in B Plant. The C, A, and AX tank farm complexes received waste generated by essentially all of the major chemical processing operations that occurred at Hanford including bismuth phosphate fuel processing, uranium recovery, PUREX fuel processing, fission product recovery, and tank farm interim stabilization and isolation activities. Only C tank farm was operational during the bismuth phosphate and

uranium recovery processes. Best estimates of specific sources for each leak event are provided in RPP-14430.

The volume of waste lost from many of the C, A, and AX tanks is highly uncertain. Except for the tank A-105 leak, no detailed analyses of known or suspected leaks have been done in these WMAs. Available information on specific leak events is provided in RPP-14430.

Sources of releases include fluid discharges; tank waste through tank leaks; ancillary equipment leaks and failures (i.e., diversion boxes, transfer and cascade pipelines); and trenches and cribs (see Section 2.1.4). These releases impacted the sediments. These releases are discussed in detail in RPP-14430. Estimated releases or leaks from the tanks in WMAs C and A-AX are indicated in Table 3.1. The uncertainty associated with the leak durations is even greater than that for the estimated tank leak volumes.

Throughout the operational history of the C, A, and AX tank farms, fluids have been discharged both deliberately and inadvertently. A summary of discharge events is provided in RPP-14430. Three types of fluid discharges associated with C, A, and AX tank farm operations have occurred in and around WMAs C and A-AX. These discharges included the following:

- Periodic failure of ancillary equipment used to transfer liquids between tanks
- Deliberate collection and routing of cooling water and tank condensate to cribs
- Mechanical failure of tanks and leakage into the underlying soil column.

Leaks from ancillary equipment were observed and recorded when sufficient fluid reached the surface from the buried, but near-surface, sources. The primary parts of the ancillary equipment system responsible for the surface spills appear to be the collection points for fluids being transferred around the tank farm (e.g., diversion boxes, valve pits, and catch tanks). Numerous pipes feed into these collection points. The pipes were frequently attached, detached, and reattached as part of normal operations, because the permanent pipelines would become clogged or unusable. Plugging of underground pipelines resulted in waste escaping containment, especially transfer and cascade lines.

Most of the trenches and cribs associated with the C, A, and AX tank farms operated from the beginning of tank farm operations in 1944 until the late 1970s. RPP-14430 supplies a history of waste and its volume released to these cribs and trenches. RPP-14430 provides more information on surface and near-surface spills.

Table 3.1. Estimated Past Leak Losses from A, AX, and C Single-Shell Tanks

Tank	Listed in Hanlon	Hanlon Leak Volume (Gal)	Treated as Leaker Here	Volume Suggested
C-101	Yes	20,000	Evidence of two small leaks	
C-105	No	--	Early leak likely	Unknown but small inventory estimate assumes 1,000 gal
C-110	Yes	2,000	No evidence for leak	
C-111	Yes	5,500	No evidence for leak	
C-201	Yes	550	No evidence for leak	
C-202	Yes	450	No evidence for leak	
C-203	Yes	400	No evidence for leak	
C-204	Yes	350	No evidence for leak	
A-103	Yes	5,500	No evidence for leak	
A-104	Yes	500 to 2,500	Yes	Inventory estimate assumes 2,000 gal
A-105	Yes	10,000 to 277,000	Yes, but likely very small	Inventory estimate assumes 1,000 gal
AX-102	Yes	3,000	No evidence for leak	
AX-104	Yes	8,000*	No evidence for leak	
Totals		56,250 to 325,250		

Note: Based on RCRA corrective action program, all single-shell tank leak volume estimates in HNF-EP-0182 are currently under review and significant revisions are anticipated. There will be revision to Appendix F in HNF-EP-0182 as a better understanding of tank leak events are developed.

To convert gallons to liters, multiply by 3.785.

*Based on 19 tanks with cumulative leak volume of 150,000 gal. for an average of 8,000 gal. for each of the 19 tanks.

NA = not applicable.

RCRA = Resource Conservation and Recovery Act of 1976.

A detailed discussion of the 20 tanks (7 SSTs in C tank farm, 3 SSTs in A tank farm, and 2 SSTs in AX tank farm) that are assumed or confirmed leakers is provided in Section 3.3 of RPP-14430. The estimated volume of the leaks is provided in Table 3.1 of this addendum. Based on HNF-EP-0182, the three highest-volume releases ranked in descending order are as follows:

- Tank C-101 with an estimated 75,700 L (20,000 gal.) leaked
- Tank A-105 with an estimated range between 1,048,445 L (277,000 gal.) and 37,850 L (10,000 gal.) leaked
- Tanks A-103 and C-111 with an estimated 20,818 L (5,500 gal.) leaked.

3.1.2 Releases to Sediment

Releases of historical fluid discharges to trenches and cribs to the sediment; tank waste through tank leaks; ancillary equipment leaks; and surface spills, along with evaluation of spectral and gross gamma surveys, are of direct interest to the WMAs C and A-AX field investigation.

Detailed information about the spectral gamma surveying and historical gross gamma surveying conducted at C, A, and AX, tank farms is provided in RPP-14430. Spectral gamma logging data are available in separate reports for the C, A, and AX tank farms (GJO-HAN-12; GJO-HAN-18; GJO-HAN-23).

Because SSTs C-101, C-111, A-105, and A-103 are associated with the largest release volumes, they are discussed in more detail in the following subsections. Tanks C-105 and A-104 are also discussed because spectral gamma data indicates leaks may have occurred at these tanks of higher volume than that indicated in HNF-EP-0182. Information for other leaks that affect WMAs C and A-AX are presented in RPP-14430 and *Single-Shell Tank Leak History Compilation* (HNF-4872). The following sections are taken directly from RPP-14430.

3.1.2.1 Tank C-101

HNF-EP-0182 lists tank C-101 as a “known or suspected leaker” with a leak volume estimate of 75,700 L (20,000 gal.). Decreases in waste levels were documented in the late 1960s, a time when this tank contained aged PUREX high-level supernate. A 75,700-L (20,000-gal.) loss of this waste type would have released approximately 127,000 Ci of cesium-137 (BHI-01496), more than all of the cesium-137 projected to have been lost from all of the SX tank farm leaks (*Inventory Estimates for Single-Shell Tank Leaks in S and SX Tank Farms* [RPP-6285]).

The spectral gamma logging data from drywells around tank C-101 show little evidence of any leaks and certainly nothing of that order of magnitude. A far more likely scenario is that the liquid level drops in the late 1960s were associated with evaporation caused by the continuing high heat load of the aged PUREX high-level waste supernates. The waste loss in the late 1970s appear to have been associated with saltwell pumping (*Waste Status and Transfer Summary (WSTRS)* [LA-UR-97-311]). Although the waste transfer records indicate that tank C-101 was filled above the 2,006,050 L (530,000 gal.) fill limit from 1964 through 1969, there is no definitive evidence of leaks from the spare inlet ports in this tank.

Spectral gamma data in two drywells around tank C-101 suggest small waste loss events may have occurred. In drywell 30-01-09, a cesium-137 peak (about 600 pCi/g) occurs about 8.5 m (28 ft) bgs along with traces of cobalt-60, europium-152, and europium-154. The position of this peak suggests a small isolated leak from piping or a spare inlet port at this location. Tank waste chemistry suggests that cesium-137 in tank waste would be sorbed readily on the soil and, therefore, the leak location should be near the drywell. Because the peak value is low, it is concluded a substantial inventory was not associated with this leak. A second small tank leak may be indicated near drywell 30-01-06 where an apparent cesium-137 peak (about 50 pCi/g) around 40 ft bgs occurs, a depth that coincides with the tank bottom. *Analysis and Summary Report of Historical Dry Well Gamma Logs for 241-C Tank Farm-200 East* (RPP-8321) identifies some instability in the gross gamma logs from 1979 to 1980 in this drywell at 9 to 12.5 m (30 to 41 ft) bgs and interprets the data as an indication of cesium-137 movement.

3.1.2.2 Tanks A-103, A-104 and A-105

Spectral gamma measurements have been recorded in drywells around the A farm tanks and in laterals placed horizontally (about 3 m [10 ft] below the tank bottom) under each of the tanks. Historical reports (*Waste Storage Tank Status and Leak Detection Criteria* [WHC-SD-WM-TI-356]) identify an increase in radiation measured at the bottoms of drywells 10-03-01 and 10-03-07 (23 m [75 ft] bgs) in 1964 and at drywell 10-03-07 in 1968. Current spectral gamma data show little or no contamination at these locations. Spectral gamma data for several drywells (10-03-01, 10-03-05, 10-03-07, 10-02-03, and 10-03-11) around tank A-103 measure small amounts for cesium-137 (about 0.1 pCi/g) at 24 m (80 ft) bgs and below. All of these wells were drilled in two stages, first to 23 m (75 ft) bgs and then further down. This history combined with the very low measured values strongly indicates dragdown of any cesium-137 that might be present at depth. Given the lack of convincing evidence it is concluded that either tank A-103 did not leak or did not leak sufficiently to contaminate the vadose zone to any significant degree.

The primary evidence of tank waste leaks from tank A-104 is provided by measurements of increased radiation in two laterals under the tank in 1975, first in lateral 14-04-02 in the north central part of the tank and then in the southeast section in lateral 14-04-02. Eventually, radiation was measured in the third lateral as well. Evaluation of the gross gamma logs (RPP-8820) shows ruthenium-106 as a primary gamma emitter. The variable locations of radiation detection under the tank may indicate multiple leak locations. However, the extent of contamination that has actually entered into the vadose zone is quite limited given the lack of contamination in adjacent drywells. Spectral gamma data show no significant contamination at tank bottom depth.

Structural failure of tank A-105 is well documented (*Tank 241-A-105 Leak Assessment* [WHC-MR-0264]; *PUREX Tank-105-A Waste Storage Tank Liner Instability and Its Implications on Waste Containment and Control* [ARH-78]). In January 1965, a sudden steam release occurred in tank A-105. Steam was released from a riser on an interconnected tank, A-103. The steam release event lasted for 30 minutes. Significant damage occurred to the base of the tank during the steam release event. It was estimated that, at most, 10.2 cm (4 in.) of liquids had been lost from tank A-105. Shortly afterward, increased activity was measured in lateral 14-05-03 in two places on the east and north side of the tank. Subsequently, additional risers were drilled through the tank dome and the tank interior was inspected, revealing a

significant section of the liner floor that had bubbled up and partially separated from the sidewall. Despite the obvious liner failure, it was determined that the tank was not leaking. No significant gamma activity was measured in the surrounding drywells suggesting that the concrete tank structure provided adequate containment for the tank fluids.

The tank was closely monitored until the tank contents had aged sufficiently to allow the supernate to be sent to B Plant for cesium-137 recovery. Most of the PUREX sludge was sluiced from the tank; however, a high-heat hard heel was left in the tank. Consequently, water was added to the tank contents for cooling for the next eight years. HNF-EP-0182 lists an estimated leak volume for tank A-105 as 37,850 to 1,048,450 L (10,000 to 277,000 gal.). The 37,850 L (10,000 gal.) represents the upper limit of the volume of tank waste lost during the initial steam release event. The additional volume represents cooling water that may or may not have leaked from the tank during the eight years of water addition. The lack of significant gamma reading in nearby drywells strongly indicates the volume estimate of 37,850 L (10,000 gal.) to be extremely conservative. Liquid volume lost associated with the 30-minute steam release event is unknown but could have accounted for some or all of the liquid loss from this tank.

Over time, additional lateral measurements of increased activity did occur in other laterals, which could have indicated additional leak locations or spreading from the initial leaks. The current spectral gamma database continues to show minimal tank waste contamination in the vadose zone. Cesium-137 concentrations have been measured at several drywells (10-05-02, 10-05-05, 10-05-07, 10-05-09, 10-06-09, and 10-05-12) at the tank bottom and lower depths. However, many of these drywells were constructed in two stages and dragdown contamination is likely in most of them. One drywell (10-05-10) may contain cesium-137 contamination from the tank A-105 leak (between 23 and 26 m [75 and 86 ft] bgs) but the complicated drilling process may have shifted the cesium-137 from its original location. The historical gross gamma log shows a shift in cesium-137 contamination levels around 1978 but this is probably related to the second-stage drilling that occurred then.

3.1.2.3 Tanks C-111, C-105, and 200 Series Tanks

There are no spectral gamma data or well documented historical record data suggesting leaks occurred at primary tank C-111 and secondary tanks C-201 through C-204. WHC-SD-WM-TI-356 reported a liquid level drop in 1968 as the basis for questioning the integrity of tank C-111. However, the reliability of this claim was not well documented (GJO-HAN-18), and no spectral gamma data from drywells around the tank indicate loss of tank waste. No drywells are present near the secondary tanks; therefore, no means of identifying leaked tank waste is available. Also, no clear indication of tank leakage has been reported. However, given their small volume, it is concluded that no significant tank waste loss from this tanks has occurred.

Tank C-105 has more substantial evidence of leakage and is considered a candidate for additional characterization.

Spectral gamma data strongly indicate that tank C-105 did leak, at least temporarily and the leak event is indicated by contamination observed at drywell 30-05-07 where two high cesium-137 concentration zones occur at and below the tank bottom. Between 10 and 13 m (34 and 44 ft) bgs and 15 and 19 m (48 and 62 ft), maximum cesium-137 values (10^7 pCi/g and 10^5 pCi/g,

respectively) were recorded (*Hanford Tank Farm Vadose Zone Addendum to the C Tank Farm Report* [GJO-98-39-TARA]). The general location and profile of the spectral gamma logging data indicate that tank C-105 likely leaked near the bottom on the southwest side very near drywell 30-05-07. The gamma contamination was encountered when drywell 30-05-07 was drilled in 1974. The historical gross gamma data analysis indicates no changes in location or intensity of cesium-137 activity. Thus, if tank C-105 did leak then the leak occurred before 1974 and apparently self-sealed because tank C-105 was used as an active cesium-137 recovery feeder tank until 1974. The cesium-137 recovery wastes were aged PUREX and REDOX high-level wastes so any waste losses would have contributed radionuclides to the soil column.

Concerns about the integrity of tank C-105 are supported by the historical record of large liquid level drops (about 36 in) in tank C-105 between 1963 and 1967 (GJO-HAN-18). However, during the time tank C-105 stored aged PUREX high-level waste supernate and liquid losses to evaporation are noted in the historical records (LA-UR-97-311). The contamination in the region between tanks C-104 and C-105 has been of interest (*Assessment of Unsaturated Zone Radionuclide Contamination Around Single-Shell Tank 241-C-105 and 241-C-106* [WHC-SD-EN-TI-185]; *Analysis of the 241-C Farm* [LA-UR-93-3605]). Both cascade line and spare inlet port waste loss events have been suggested as sources of contamination in this region.

An alternate explanation for the high activity in drywell 30-05-07 has been given that cesium-137 in this drywell has origins in the cascade line between tanks C-104 and C-105 (WHC-SD-EN-TI-185; GJO-98-39-TARA). However, the likely waste, PUREX supernate, does not appear to have the appropriate chemical makeup to mobilize cesium-137 in the soil column. Therefore, a leak source at the tank wall 2 feet from the contaminated zone compared to the cascade line more than 30 feet away is much more plausible. The two high cesium-137 zones may indicate two leak events.

In addition to cesium-137 contamination at the tank bottom, isolated occurrences of cobalt-60, europium-152, and europium-154 are present. The true extent of these contaminants at this drywell location is difficult to determine. The very high cesium-137 concentrations may mask the occurrence of these isotopes at the same depth. Also, the drywell ends at about 21 m (68 ft) bgs and additional contamination at greater depth cannot be determined.

Two other drywells may indicate the outer edges of the proposed tank C-105 leak. In drywell 30-05-05 just south of drywell 30-05-07, a cesium-137 peak (about 70 pCi/g) occurs between 60 and 65 ft (18 and 19 m) bgs and a cobalt-60 peak occurs at 70 ft (21 m) bgs. Proximity of the two drywells and consistent cesium-137 peaks with depth suggest the same leak source. Similarly, a cesium-137 peak (15 pCi/g) occurs at 47 ft (14 m) bgs in drywell 30-05-08. Cobalt-60 is also present between 35 and 50 ft (11 and 15 m) bgs.

RPP-7494 identifies a number of unintentional near-surface losses and windblown contamination events in the C tank farm. The Waste Information Database System summarizes these events, also known as unplanned releases, and *Handbook 200 Area Waste Sites* (RHO-CD-673) also discusses some events. Two of the UPRs (UPR-200-E-82 and UPR-200-E-86) involved PUREX high-level waste supernate and contributed significant inventory to the soil column. A third UPR involved the loss of PUREX aluminum cladding waste. These three events occurred on the

southwest side of the C tank farm and made relatively significant contributions to vadose zone contamination. The Waste Information Database System also identifies a number of other waste loss events but these involve either small (less than 379 L [100 gal.]) volume losses, airborne contamination spreads, or tank leak information mirroring the information in the monthly Hanlon report (HNF-EP-0182). There is small overland piping leak (189.25 L [50 gal.]) involving the loss of PUREX cladding waste between tanks C-105 and C-108, documented in UPR-200-E-16. The spectral gamma logging data (GJO-HAN-18) for the C tank farm indicates widespread low-level cesium-137 contamination across much of this farm.

Report UPR-200-E-81 describes a 1969 waste loss event that occurred near the 241-CR-151 diversion box and involved the loss of 136,000 L (36,000 gal.) of PUREX cladding waste (RPP-7494; RHO-CD-673). A puddle of contaminated liquid measuring 1.8 by 12.2 m (6 by 40 ft) was formed. The puddle was backfilled with clean dirt in 1969. The PUREX cladding waste was a reasonably low-activity waste stream produced from the caustic dissolution of the aluminum fuel rod cladding. The origin of the radioactive contamination in this waste stream was congruent dissolution of the uranium fuel during the de-cladding operation. It was estimated that 720 Ci of cesium-137 were lost to the soil.

Report UPR-200-E-82 describes the loss of cesium-137 recovery process feed solution being pumped from tank C-105 to the B Plant. The leak occurred near the 241-C-152 diversion box and involved the loss of approximately 9,841 L (2,600 gal.) of liquids (ARH-1945). Approximately 379 L (100 gal.) of this fluid surfaced. Surface contamination was covered with clean gravel in 1969. This waste loss event was investigated and results are available (ARH-1945). It was estimated that 11,300 Ci of cesium-137 were lost to the soil. Additional inventory estimates of vadose contamination from this event are discussed in Section 4 of RPP-14430.

Report UPR-200-E-86 describes a waste loss event associated with a pipeline break near the southwest corner of the C tank farm. Fluids were being pumped from the 244-AR vault to the C tank farm. Approximately 17,400 gal. of fluid that contained approximately 21,000 Ci of cesium-137 were lost to the soil (RHO-CD-673). Based on the ratio of technetium-99 to cesium-137 in the irradiated fuel (approximately 3×10^{-4} Ci technetium-99/Ci cesium-137), approximately 6 Ci of technetium-99 were lost. This waste stream most likely originated from the water washing of PUREX sludge intended to remove cesium-137 (and other waste soluble components) from the sludge before acidification and strontium-90 recovery.

Additional information is presented in RPP-14430.

3.1.3 Intentional Liquid Waste Disposals to Surrounding Cribs and Trenches

Numerous cribs, trenches, tile fields, and retention basins surround WMAs C and A-AX (see Figure 2.2). Throughout the operational history of the C, A, and AX tank farms, fluids were discharged to the ground, both deliberately and inadvertently. A list of intentional discharge sites and UPRs with descriptive information is provided in Appendix A of RPP-14430 and in RPP-7494.

The total liquid amounts released to the ground within WMAs C and A-AX from UPRs are not well quantified, except for UPR-200-E-82 and UPR-200-E-86. However, the descriptions

indicate that these releases were uniformly small (no more than a few gallons) within WMAs C and A-AX, with the possible exception of UPR-200-W-82, the underground pipe leak between tank C-105 and Building 221-B. This unplanned release is unusual and may have been a relatively large leak. In 1969, an underground pipe leak of cesium nitrate waste between tank C-105 and Building 221-B (UPR-200-E-82) was detected by the discovery of surface contamination. Clean soil was placed over the contaminated area.

3.1.4 Groundwater

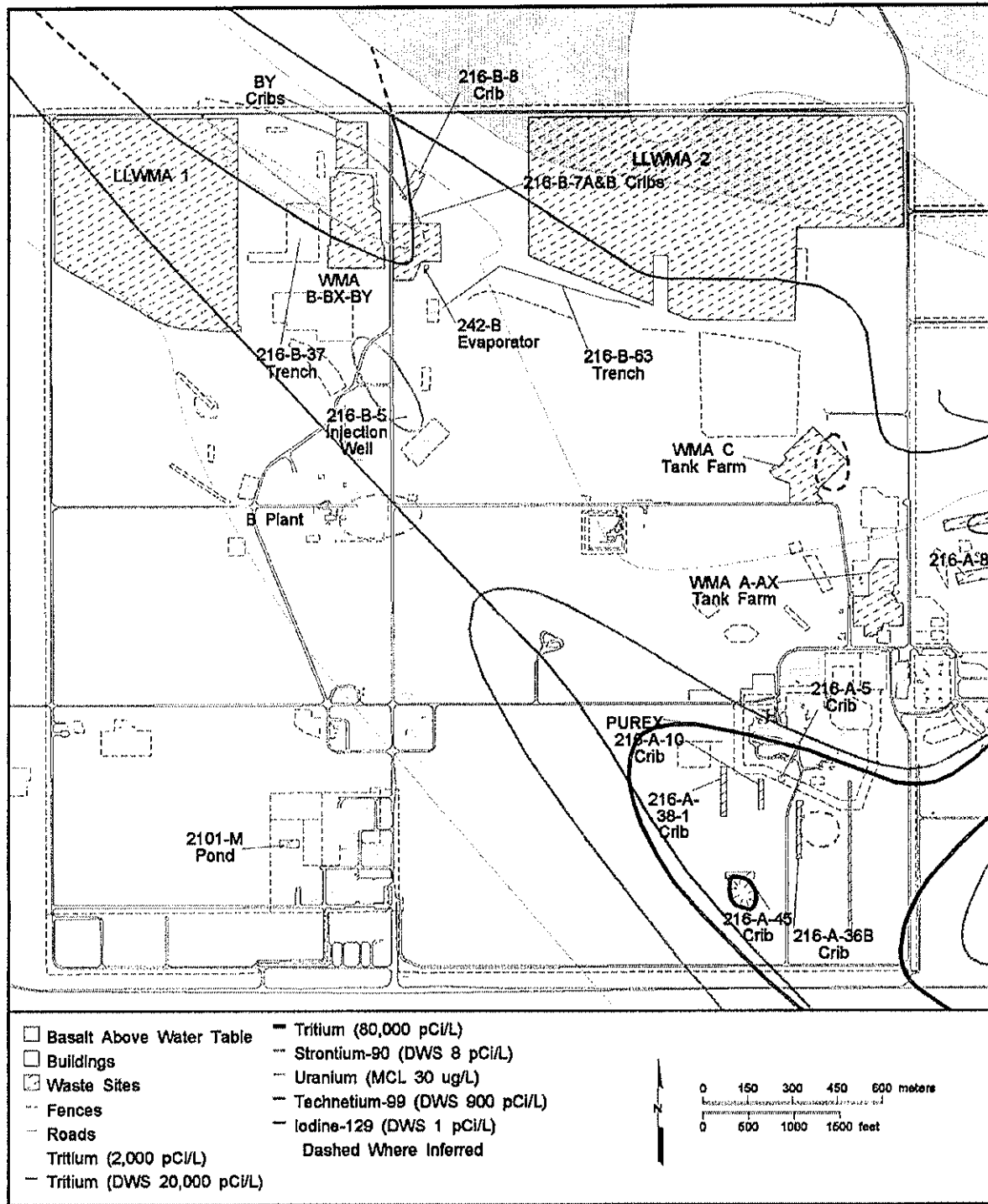
This section covers the current state of contamination surrounding WMAs C and A-AX, including historic constituent trends that depict the temporal and spatial distribution of contaminants. Several distinct suites of contaminants are recognized, based on spatial relationships and on identifying associations of co-contaminants or aqueous chemical parameters. Given the complicated history of waste discharge to the subsurface in the last 50 years combined with artificial reversals in the natural flow direction and the ambiguities and dynamics in the current flow direction, identifying sources at this time is not possible. The current distribution of radionuclides (i.e., tritium, strontium, uranium, technetium, and iodine) in the groundwater in the 200 East Area is shown in Figure 3.1, and the nitrate and chromium distribution is shown in Figure 3.2.

3.1.4.1 Groundwater Contamination at C Waste Management Area

During FY 2001, critical means (or range for pH) were not exceeded for the three indicator parameters of pH, total organic carbon, and total organic halides. However, the critical mean for conductivity (553.3 $\mu\text{S}/\text{cm}$) was exceeded in well 299-E27-14 at the end of FY 2001 (Figure 3.3). An averaged value of 614 $\mu\text{S}/\text{cm}$ was reported for this cross gradient well for the September 2001 sampling event. The increase in conductivity is due primarily to rising sulfate and calcium along with nitrate and chloride (Figure 3.4). Sulfate was 135 mg/L while nitrate was 29 mg/L for July 2001. The September 2001 sulfate data is abnormally low and is under review. The nitrate value for September 2001 is 43.8 mg/L, very close to the drinking water standard (DWS) of 45 mg/L.

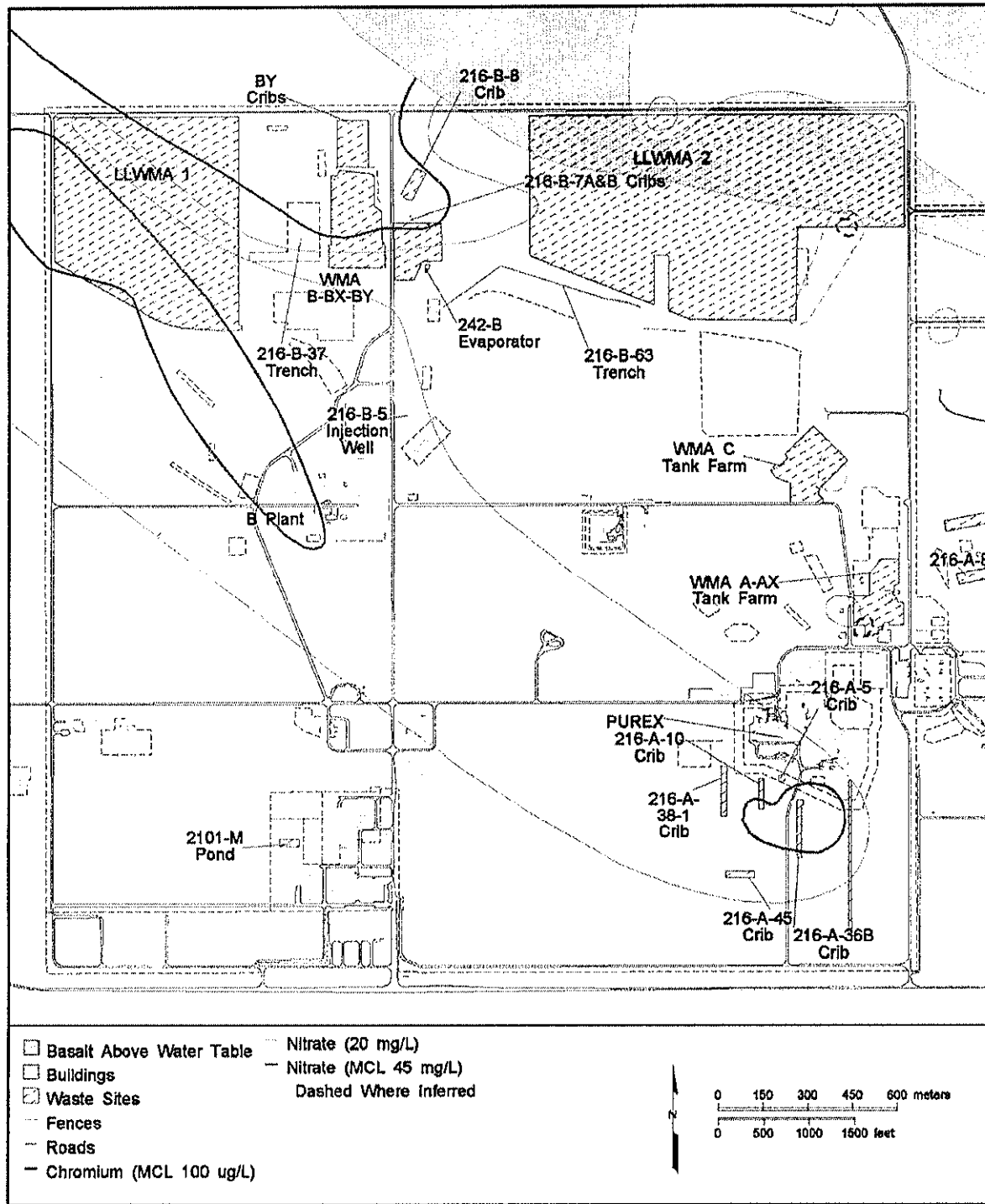
Technetium-99 concentrations continue to increase in all wells at WMA C (Figure 3.5). This technetium-99 contamination correlates to the rising anionic chemistry. Although downgradient well 299-E27-13 had a pulse of technetium-99 (487 pCi/L) seen in 1998, the recent technetium-99 contamination began to increase in the mid-1990s in well 299-E27-14, to a value of 1,190 pCi/L in July 2001. The greatest increase in FY 2001 was detected in well 299-E27-7, which had a maximum value of 2,190 pCi/L in July 2001 (DWS 900 pCi/L). The correlation of the nitrate to the technetium-99 is shown in Figure 3.6. As can be seen, nitrate is greater in well 299-E27-14 while technetium-99 is higher in well 299-E27-7. These differences in concentration levels may be due to chemical differences within a larger, regional plume.

**Figure 3.1. Distribution of Radionuclides in the
Unconfined Aquifer in 200 East Area**



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**Figure 3.2. Distribution of Chromium and Nitrate
in the Unconfined Aquifer in 200 East Area**



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Figure 3.3. Trend Plots of Specific Conductance for Waste Management Area C

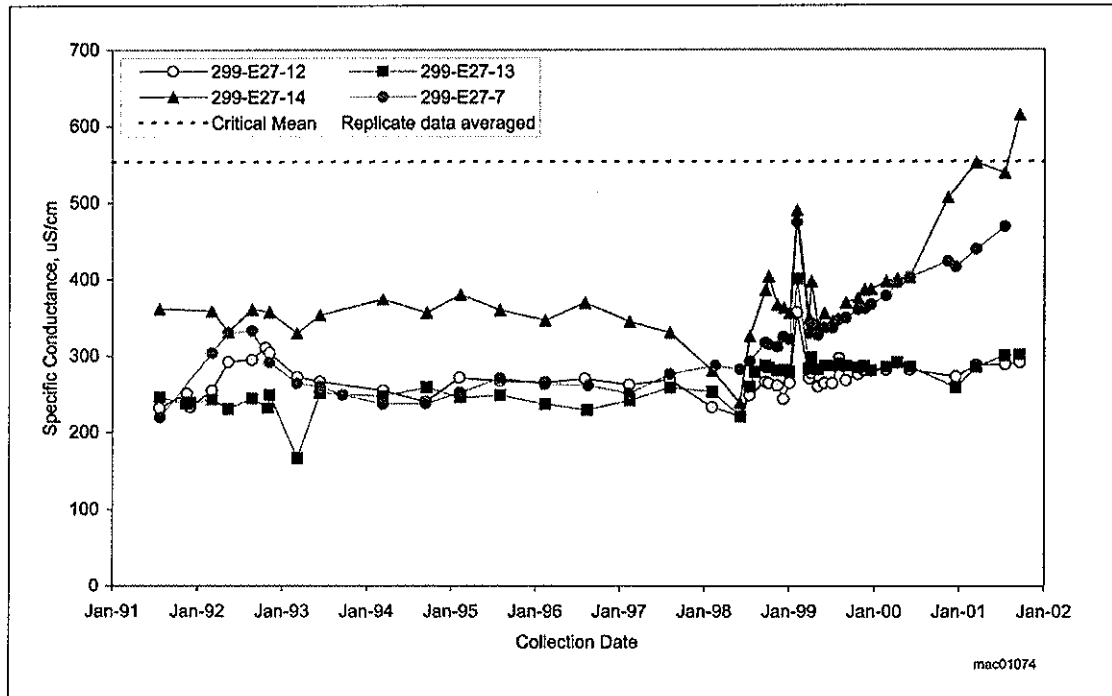


Figure 3.4. Trend Plots of Specific Conductance, Cations and Anions for Well 299-E27-14

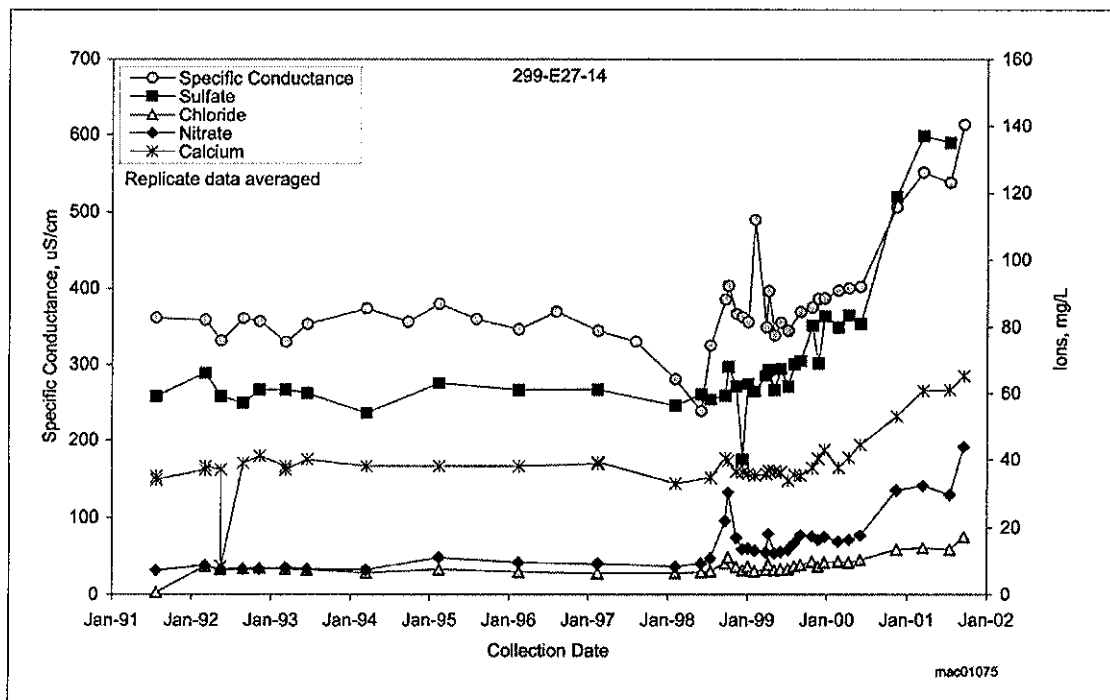


Figure 3.5. Trend Plots of Technetium-99 for Waste Management Area C

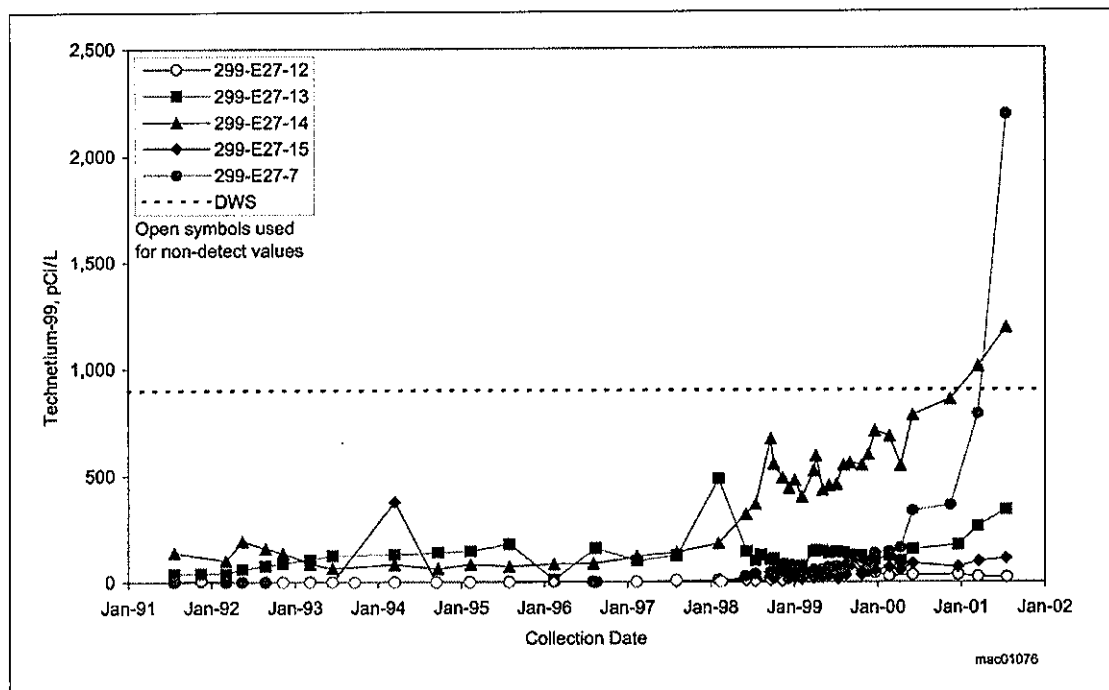
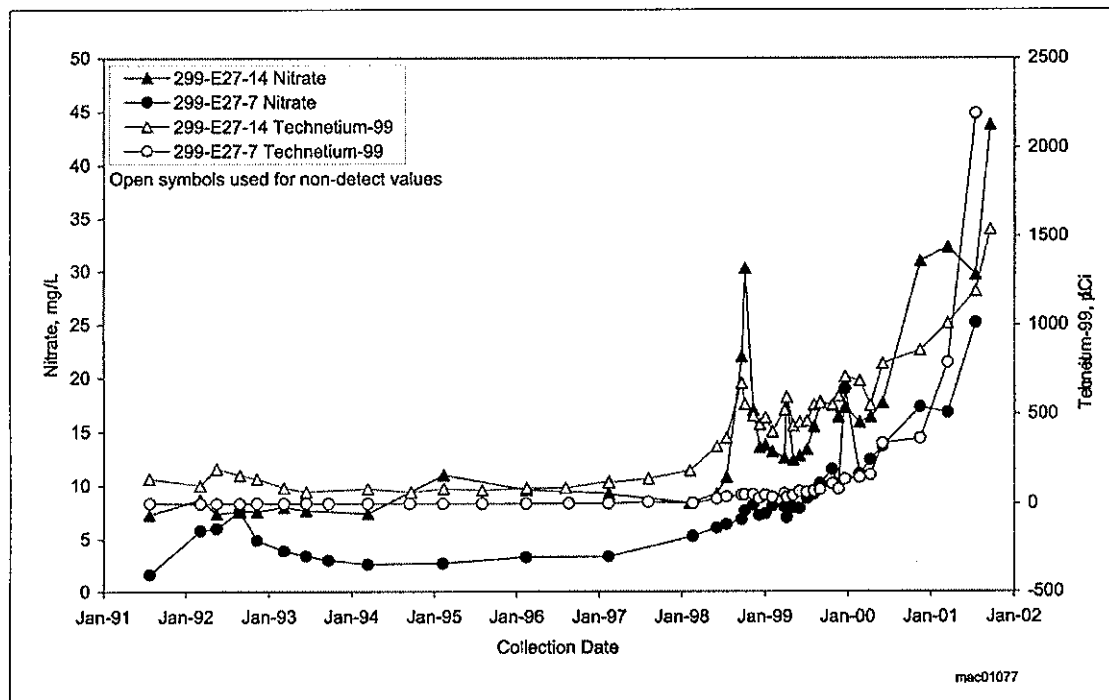


Figure 3.6. Trend Plots of Nitrate and Technetium-99 for Waste Management Area C



These increases in well 299-E27-14 are part of a contaminant plume that may be moving into the area from upgradient areas in recent years (1995 to the present). Although the source of this contamination is presently unknown, it may be related to past discharges that moved through the area when the B Pond was in full operation or from the upgradient 216-B-3-1 ditch. As part of a continuous ditch system connected to the 216-B-63 trench, this ditch was decommissioned in 1964 after an accidental release of mixed fission products from the PUREX Plant was discharged directly to the 216-B-3-1 ditch (*PUREX 216-B-3 Pond System Closure/Post Closure Plan* [DOE/RL-89-28]).

The technetium-99 level in well 299-E27-7 has risen sharply, indicating a short travel time and thus a short travel distance in the groundwater from the point of entry into the groundwater to the well. Therefore, the 216-B-3-1 ditch is probably not the source of this groundwater contamination. Results from well 299-E27-7 have, in the past 2 years, shown low levels of cyanide with a maximum value of 17 µg/L in June 2000. Ferrocyanide scavenging was conducted in the 244-CR vault with storage in selected tanks at WMA C (*Standard Inventories of Chemicals and Radionuclides in Hanford Site Tank Wastes* [HNF-SD-WM-TI-740]). Although well 299-E27-7 is the upgradient well for this WMA, the only known source for cyanide is the waste stored in the C tank farm. However, cyanide concentrations decreased during FY 2001, and presently it is not detected in this well or any other network monitoring well.

There does not appear to be other tank-related waste in the groundwater at WMA C. Tritium levels are low, generally less than 1,500 pCi/L, except at well 299-E27-7 where values rose from about 600 to 2,500 pCi/L during the late 1990s. Currently, the trend remains steady near 2,480 pCi/L.

3.1.4.2 Groundwater Contamination at Waste Management Area A-AX

Although concentrations of indicator parameters, conductivity, total organic carbon, and total organic halides have not exceeded the critical means at WMA A-AX since 1992, the pH fell below the critical range (6.89 to 9.24) in well 299-E24-19 in July 2001. This well is, at best, cross-gradient because it is located on the southwest side of the WMA (see Figure 2.3). Verification sampling was conducted in October 2001 resulting in a pH value of 7.13. Causes for the low pH are discussed below in relation to the elevated chromium found in the groundwater at this location. Groundwater monitoring to date provides no evidence that the site has contaminated groundwater.

Specific conductance values generally ranged from 261 to 374 µS/cm during FY 2001 (Figure 3.7), reflecting changes in sulfate and nitrate concentrations. The primary cation is calcium. These specific conductance values are well below the critical mean of 534.9 µS/cm. Figures 3.8 and 3.9 show trend plots for sulfate and nitrate, comparing contaminant levels in WMA network groundwater monitoring wells. The specific conductance changes that occurred at WMA A-AX are generally dominated by sulfate except for well 299-E24-20 (maximum contaminant level 250 mg/L). Although sulfate appears to be increasing in wells on the southwest side of the WMA, sulfate concentration ranges from 37 to 48 mg/L, which is within the Hanford Site background values reported in *Westinghouse Hanford Company Operational Groundwater Status Report 1990-1992* (WHC-EP-0595) (approximately 14 to 60 mg/L). Although in the past

sulfate concentrations above background values were identified in two wells, 299-E25-40 and 299-E25-41, the recent trend appears to be decreasing to values of 55 to 57 mg/L.

Nitrate values currently range from approximately 4 to 12 mg/L, which falls within the ranges of background values of 3 to 12 mg/L for the Hanford Site (WHC-EP-0595) except for one well. Nitrate concentrations in well 299-E24-20 are approximately 36 mg/L, which is above the maximum background value of 12 mg/L (see Figure 3.9). This well is located south of the 244-AR vault and is the upgradient well for WMA A-AX. Nitrate values rose from 6 mg/L in February 1996 to 38 mg/L in June 2000.

**Figure 3.7. Trend Plots of Specific Conductance for
Waste Management Area A-AX**

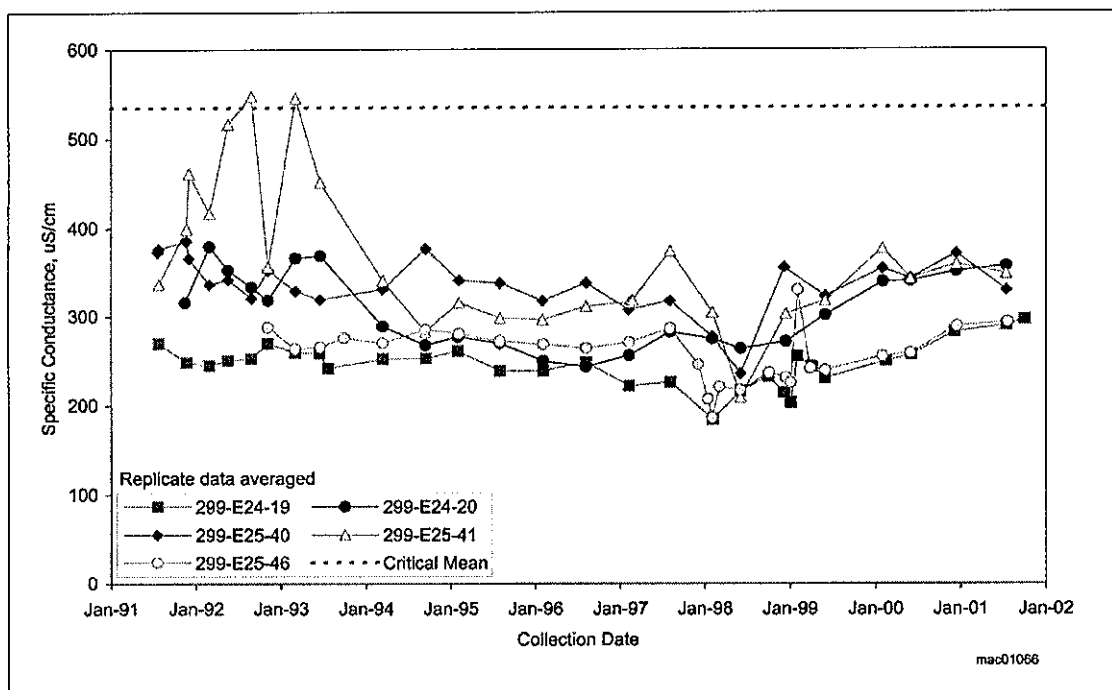


Figure 3.8. Trend Plots of Sulfate for Waste Management Area A-AX

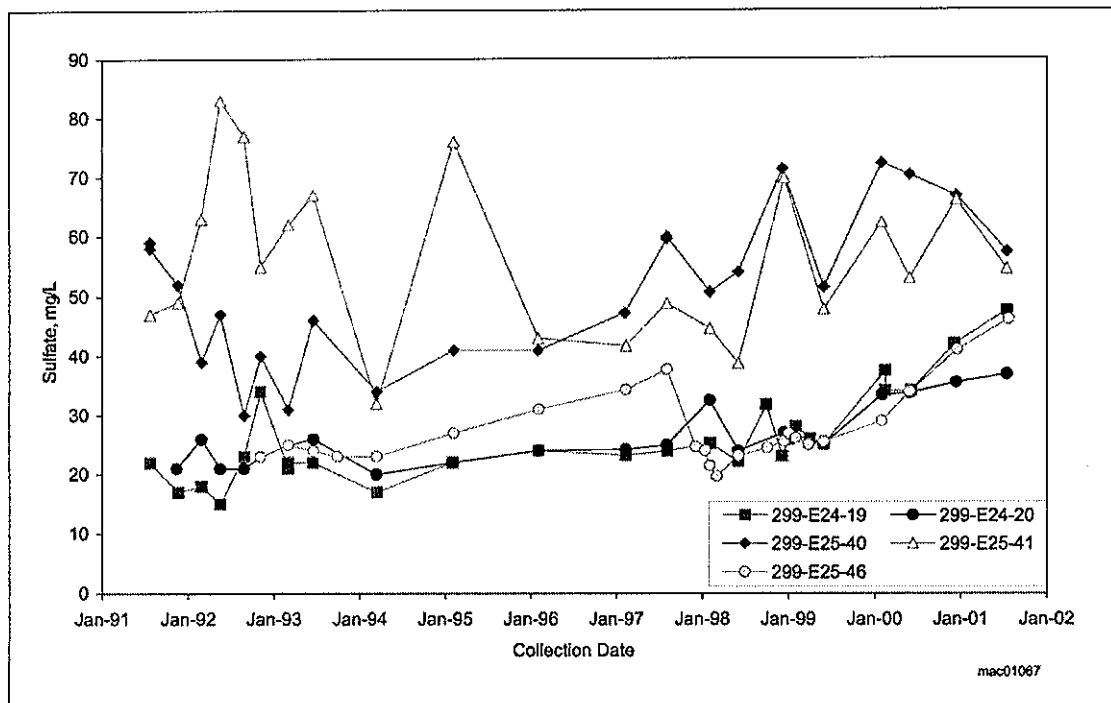
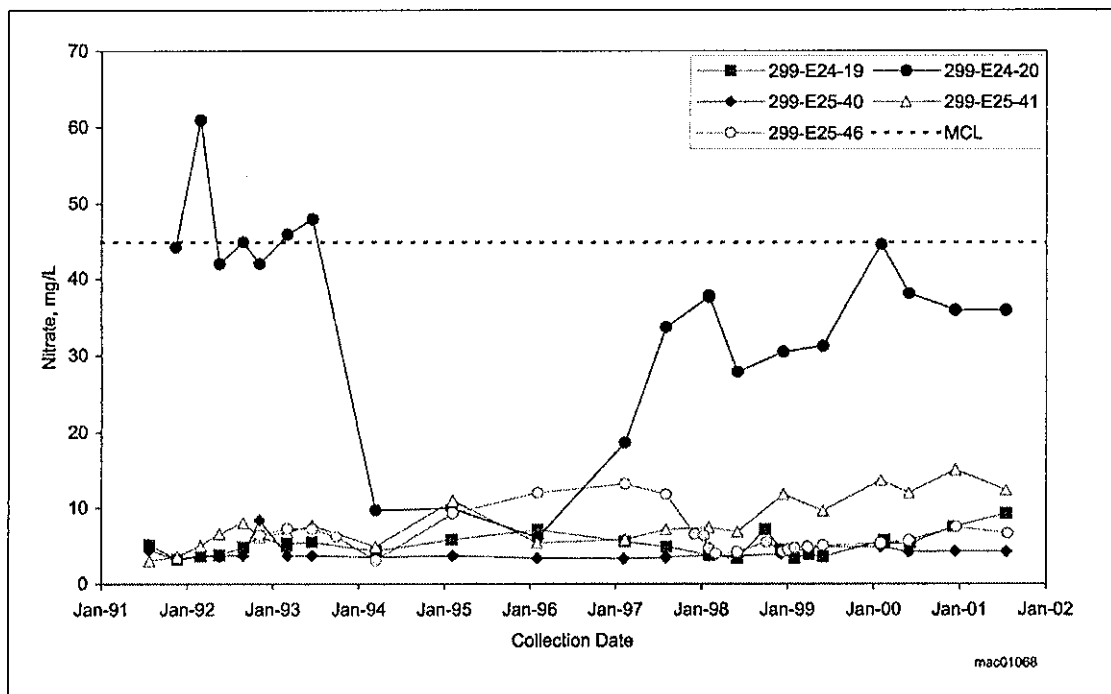
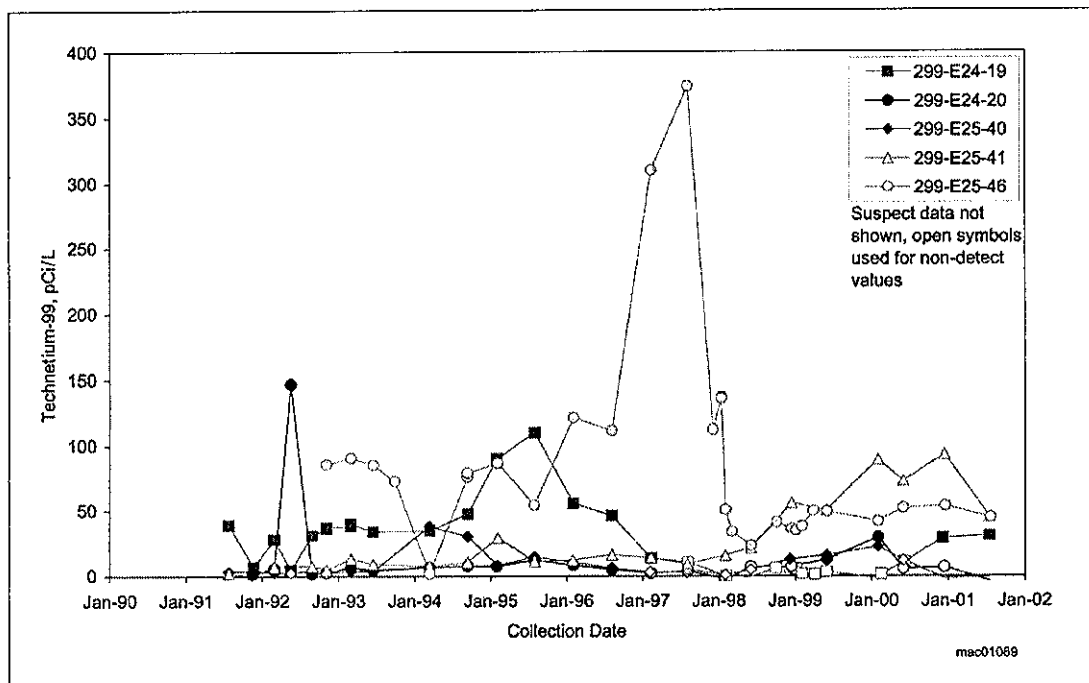


Figure 3.9. Trend Plots of Nitrate for Waste Management Area A-AX



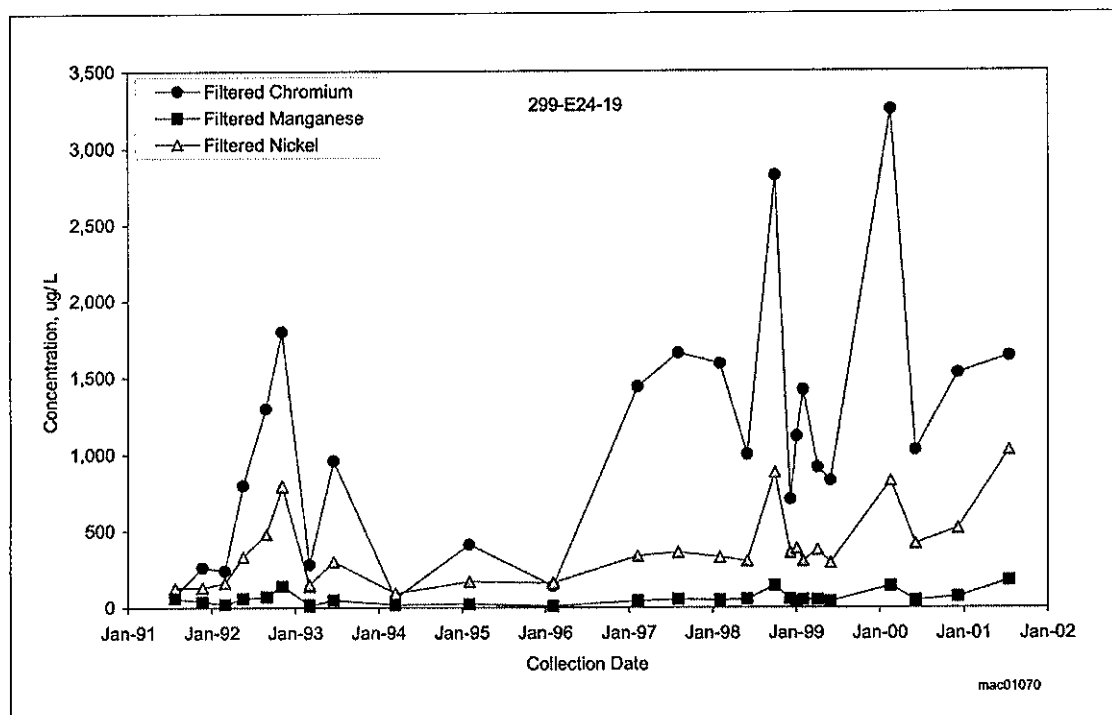
Technetium-99 concentrations are low (Figure 3.10) at WMA A-AX; thus, there is no correlation between nitrate and technetium-99. There is, however, a distinct correlation of nitrate with tritium, which remained the same from approximately 9,200 pCi/L in February 2000 to 9,170 pCi/L in December 2000. Most tritium values in other wells at the WMA range from 3,530 to 5,000 pCi/L. The drinking water standards for tritium and nitrate are 20,000 pCi/L and 45 mg/L, respectively. This local region had extremely high values of tritium (over 200,000 pCi/L) in the late 1960s when the PUREX Plant was operating. Also, nitrate concentrations in this well were above 60 mg/L in early 1992. The current elevated nitrate may be this same pocket of nitrate moving back through the well.

Figure 3.10. Trend Plots of Technetium-99 for Waste Management Area A-AX



In filtered samples from well 299-E24-19, chromium continues to be detected at values above the DWS of 100 µg/L. The current value in July 2001 is 1,640 µg/L (Figure 3.11). This well historically has high concentrations of chromium, nickel, and manganese. The maximum contaminant level for nickel is 100 µg/L and 50 µg/L for manganese. Further tests were conducted in FY 2001 to verify that local corrosion of the screen is the cause of the elevated metals concentrations.

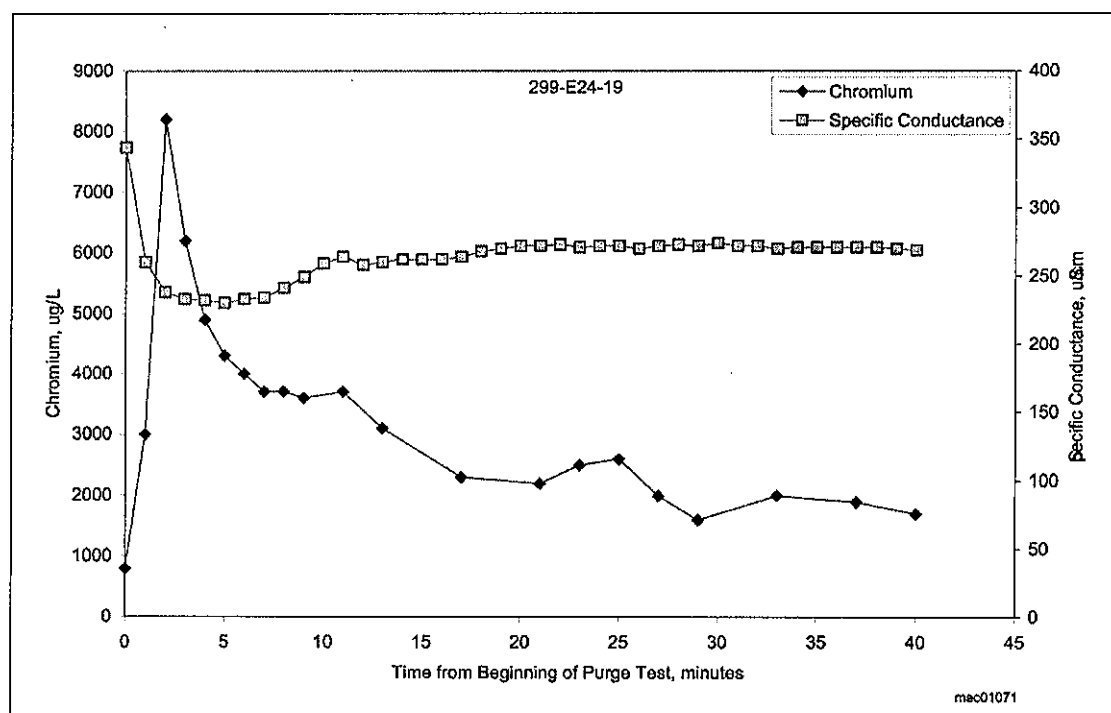
Figure 3.11. Trend Plots for Filtered Chromium, Nickel, Manganese, and Iron for Well 299-E24-19



Note: These data are from filtered samples.

Comprehensive purge sampling was conducted during December 2000. Chromium concentrations, conductivity, and pH were monitored during an extensive purge from the first borehole water removed from the well for over 40 minutes at a pumping rate of 11.4 L (3 gal.) per minute. Plots of the chromium concentration versus conductivity and pH are shown in Figure 3.12. The results show, as purging began, the chromium content rapidly increased to a maximum of 8,200 $\mu\text{g/L}$ between 2 and 4 minutes. As the purge continued, the chromium concentration sharply declined.

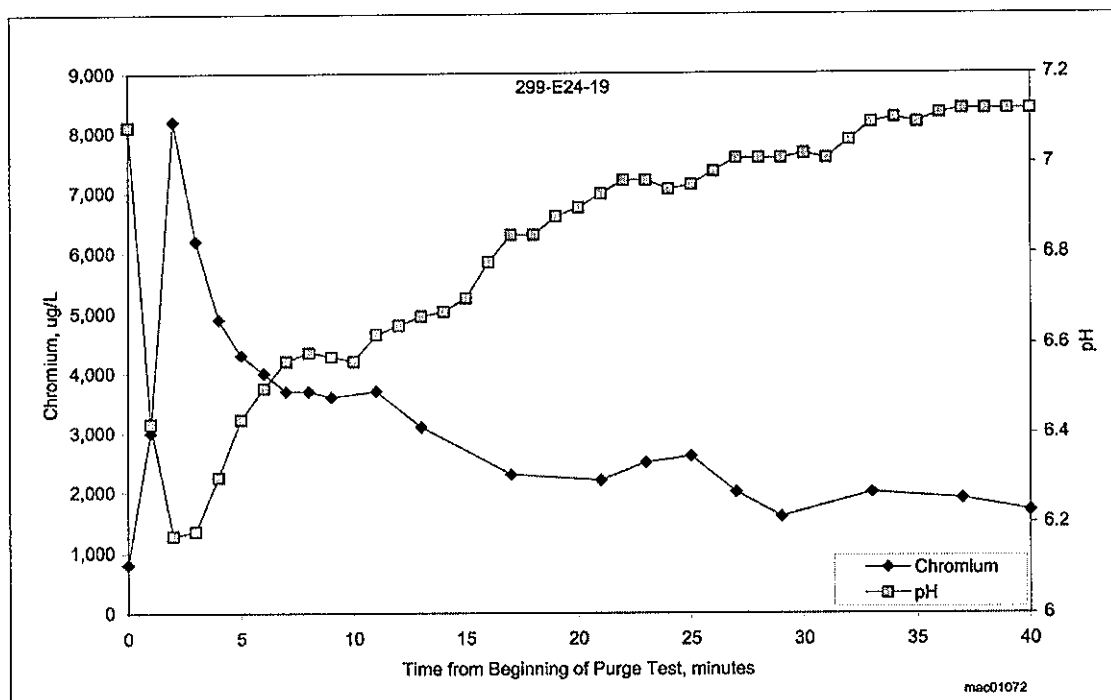
Figure 3.12. Trend Plots for Filtered Chromium and Specific Conductance for Well 299-E24-19. These data are from filtered samples.



Although it initially dropped, conductivity stayed relatively constant ranging from 230 to 274 $\mu\text{S}/\text{cm}$, indicating that the changes in chromium are not associated with anionic groundwater chemistry.

Figure 3.13 shows the same chromium data compared to pH. As the chromium rose sharply, the pH fell from an initial value of 7.08 to a low of 6.17 and then increased as the chromium concentration continued to decrease. During the corrosion of steel, a REDOX reaction is set up whereby free hydronium ions are produced in the aqueous environment. Thus the pH is decreased as the metal content is increased, explaining the drop in pH below the critical range for the site. It is important to note that if the chromium flowed with the groundwater over an extended distance from the well screen, the chromium content would not have decreased as the purge progressed. This study provides further support for the premise that the elevated metals historically found in the groundwater at this well are related to corrosion of the screen.

**Figure 3.13. Trend Plots for Filtered Chromium
and pH for Well 299-E24-19**



Note: These data are from filtered samples.

3.1.5 Surface Water and River Sediment

Based on contaminant plume maps in PNNL-13788, surface water and river sediment contamination has not occurred related to contamination releases associated with WMAs C and A-AX.

3.2 POTENTIAL CORRECTIVE ACTION REQUIREMENTS

WMAs C and A-AX were not included in RCRA corrective action because there has been no indication that vadose contamination in these WMAs is a source of current nearby groundwater contamination. However, it has become clear from previous investigations that if vadose zone contamination is present under a WMA, future groundwater contamination from these sources is plausible. To complete remediation of these WMAs and achieve final closure of the facility, the potential environmental impacts of these sources must be evaluated. Information generated by these and future characterization activities will support waste management decisions for SST waste retrieval and SST closure.

3.3 POTENTIAL IMPACTS TO PUBLIC HEALTH AND THE ENVIRONMENT

This section presents a preliminary conceptual model of the vadose zone portion of the groundwater exposure pathway because the vadose zone is the focus of this addendum. The vadose zone conceptual model is a set of working hypotheses made up of elements of tank

waste characteristics, past leak characteristics, geology, hydrogeology, and driving forces that include infiltration from precipitation and human sources of water. The data, both existing and to be collected, will be used to test these hypotheses. If the hypotheses are consistent with the data, then that consistency would initially be deemed an endorsement. If the hypotheses are not consistent, then the hypotheses will be revised in an effort to refine and improve the conceptual model.

DOE/RL-99-36 focuses on all potential exposure pathways, including groundwater in accordance with approved M-45-98-03 Change Package (Ecology and DOE 2001). The conclusions in the following subsections are based on preliminary data and are tentative; they will be subject to refinement as data are gathered during the RFI/CMS process.

This section presents a preliminary vadose zone conceptual model for WMAs C and A-AX. The conceptual model is based on information presented in Section 2.0 and Section 3.1 of this addendum and is, therefore, intended to be preliminary. The exposure pathway in this conceptual model is limited to near-surface releases associated with the waste tanks and transport in the vadose zone. A generic set of release and migration processes are shown conceptually in Figure 3.14. Through the corrective action process, the concepts illustrated in Figure 3.14 must ultimately be confirmed, disproved, or shown to be inconsequential in the context of retrieval and closure, including the WMAs C and A-AX endstate. A generalized conceptual model is provided in Section 4.0 of DOE/RL-99-36 and identifies the preliminary conceptual model of this addendum.

The data and evaluations previously discussed are integrated and summarized in this section in the form of a preliminary vadose zone conceptual model. The conceptual model is a preliminary working effort because the data are not complete, not all the data have been evaluated, and in many cases, the data are not validated. The purpose of the vadose zone conceptual model is to help focus the preliminary field data collection. The vadose zone conceptual model will be refined in the site-specific Phase 1 RFI/CMS field investigation report for WMAs C, A-AX, and U based on evaluation of the data collected under the guidelines in this addendum and the continued evaluation of existing data.

The contaminant sources, mechanisms for these contaminants to be released into other environmental media, potential types of movement through the vadose zone, and one type of potential receptor are shown conceptually in Figure 3.14. The schematic illustrated on Figure 3.14—together with estimates of values for key parameters (e.g., contaminant concentrations)—are a part of the basis for assessing initial human health risks associated with the various contaminants and receptors.

The results of the human health risk assessment will be provided in the site-specific Phase 1 RFI/CMS field investigation report for WMAs C, A-AX, and U. The vadose zone conceptual model is used in this addendum to qualitatively express the current understanding of the following:

- Pathways that contaminants may follow to the groundwater based on the integration of contaminants, hydrochemical, hydrogeologic, and geologic data (inferences are made on relatively sparse and unevenly distributed data)

- Contaminant sources with most of the available data for source locations for the upper 40 m (130 ft) of the vadose zone (inference is made to the presence of contaminants in the lower vadose zone based on groundwater contamination and historic records of water levels).

Key aspects of the WMAs C and A-AX vadose zone conceptual model required to support this addendum are summarized in the following subsections.

3.3.1.1 Sources

3.3.1.1.1 Chemical Processing

Irradiated nuclear fuel from the Hanford Site plutonium production reactors contained fission products and lesser amounts of neutron activation products as well as the unreclaimed uranium and transuranic radionuclides. Plutonium was chemically extracted from the fuel matrix at T Plant and S Plant in the 200 West Area and B Plant and A Plant in the 200 East Area.

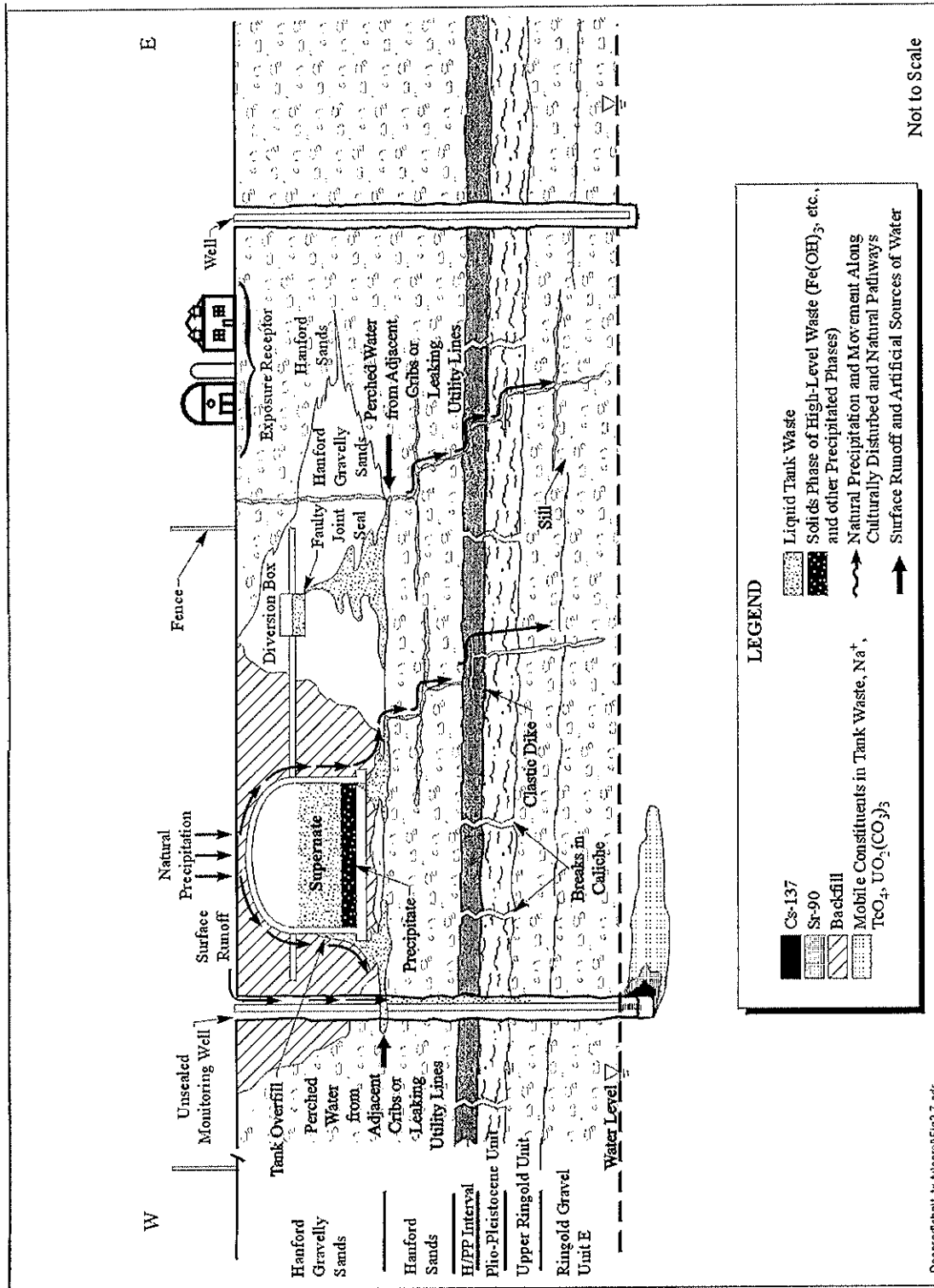
The C, A, and AX tank farms received waste generated by a variety of major chemical processing operations. The C, A, and AX tank farms contain aqueous waste generated from four different operations: post-war bismuth phosphate operation (1946-1956), uranium recovery and scavenging (1952-1958), ITS (1960-1974), and interim stabilization and isolation (1975-present) (RPP-7494).

3.3.1.1.2 Tank-Related Considerations

The SSTs are constructed of a single layer of carbon steel surrounded by a layer of reinforced concrete, which forms the roof and sidewall support. The tanks declared leakers in the C, A, and AX tank farms (Section 3.1.1) apparently failed because of waste transfer leaks and/or accelerated corrosion of the steel liner and leaked through the reinforced concrete.

The vadose zone conceptual model for this addendum focuses on those contamination sources in the vicinity of the SSTs in WMAs C and A-AX. As discussed in Section 3.1 and RPP-14430, one hypothesis for the observed contaminants in the RCRA groundwater monitoring wells is that contaminants from tank leaks have migrated downward through the vadose zone and then traveled in a direction consistent with the local groundwater flow. Releases from the SSTs in WMAs C and A-AX could represent a significant present contamination source in the vadose zone. It is certain that the leaks from those tanks contained several radioisotopes and chemicals commonly found in tank waste (e.g., cesium-137, technetium-99, sodium, chromium, and nitrate). Thus, contaminants (i.e., technetium-99, chromium, and nitrate) that are remnants of these past leaks are likely present in the vadose zone, especially within the finer-grained sediments of the Hanford formation. RPP-14430 provides a discussion of the contaminated areas in WMAs C and A-AX.

**Figure 3.14. Preliminary Generalized Waste Management
Areas C and A-AX Vadose Zone Conceptual Model**



3.3.1.2 Geologic Conceptual Model

The geology of the C, A, and AX tank farms was documented after the drywell boreholes were completed in the early 1970s (*Geology of the 241-A Tank Farm* [ARH-LD-127]; *Geology of the 241-AX Tank Farm* [ARH-LD-128]; and *Geology of the 241-C Tank Farm* [ARH-LD-132]). The major stratigraphic units of the suprabasalt sediments present beneath WMAs C and A-AX are the undifferentiated Plio-Pleistocene unit/Ringold Formation, and the Hanford formation (in ascending order) (see Section 2.2). Several sources of data were included in evaluating valid conceptual model(s) for the C, A, and AX tank farms geology (ARH-LD-127; ARH-LD-128; ARH-LD-132; BHI-00184; HNF-2603; PNNL-13023; PNNL-13024; RPP-14430; WHC-SD-EN-TI-012). Potential geologic control or influence on contaminant migration in the vadose zone is of particular interest. Elevation maps of the basalt are presented in Figure 2.5 and for the other stratigraphic units in RPP-14430 and will be used as a source for this information.

Clastic dikes, illustrated conceptually in Figure 3.14, are lenses or tabular bodies, relatively narrow at 18 to 38 cm (7 to 15 in.) (*Geologic Field Inspection of the Sedimentary Sequence at the Environmental Restoration Disposal Facility* [BHI-00230]; BHI-01103), with textural characteristics typically comprised of clay and sand. The presence of clastic dikes has been observed in these WMAs. The localized effect of the dikes on contaminant movement may occur over the scale of a few meters, but no direct indication of this movement has been measured. Among potential preferential pathways, the probability of a tank encountering a clastic dike is substantial. For example, numerous clastic dikes occur at the US Ecology site southwest of the 200 East Area that may serve as conduit for preferential flow. While a clastic dike could increase flow rate, it is less likely to intersect large segments of leaked wastes, and when it does the cross-sectional area of the intersection is small (DOE/RL-97-47). Therefore, presence of clastic dikes in unsaturated media appears unlikely to contribute much to the transport to groundwater of the bulk quantity of leaked tank wastes. The geologic cross-sections provided in RPP-14430 represent the preliminary working geologic conceptual model for this work plan.

3.3.1.3 Hydrologic Properties

Preliminary hydrologic property values will be provided in the site-specific Phase 1 RFI/CMS field investigation report for WMAs C and A-AX that will be prepared.

3.3.1.4 Receptors

Receptors are organisms with the potential for exposure to the released contaminants and include both biota and humans. A likely point of exposure for terrestrial biota is in the plant root zone where flora could absorb buried contaminants. Terrestrial animals (especially burrowing animals) may be exposed by direct contact, inhalation, and ingestion of contaminated sediment, water, plants, and animals.

For the receptors, the site-specific Phase 1 RFI/CMS field investigation report for WMAs C, A-AX, and U will use “Model Toxics Control Act Cleanup Regulation” (WAC 173-340) Methods B and C exposure scenarios at these WMA boundaries to evaluate human health risks for the chemicals, the Hanford Site risk assessment methodology (*Hanford Site Baseline Risk Assessment Methodology* [DOE/RL-91-45]) and the 15 mrem/yr dose above background standard (*Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination*

[EPA OSWER Directive No. 9200.4-18]) as stated in RPP-7455 to evaluate human health risks from radionuclides.

The Model Toxics Control Act Method B (defined in WAC 173-340-705) residential scenario is a combination of the risk equations specified in WAC 173-340-720 through 173-340-750 inclusive of sections 173-340-7490 through 173-340-7494. The Model Toxics Control Act Method C (defined in WAC 173-303-706) industrial scenario is a combination of the risk equations specified in WAC 173-340-720 through 173-340-750 inclusive of sections 173-340-7490 through 173-340-7494. WAC 173-340-730 is not applicable to either scenario as it is not expected that WMAs C and A-AX or any remedial activity under consideration will impact surface water.

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4.0 U TANK FARM HISTORY AND SETTING

The history of operations in relationship to the tank farm layout and physical setting provides the background for the vadose zone and groundwater characterization investigation. Information and data relevant to the RFI/CMS investigations at the U tank farm facilities were largely obtained from *Historical Tank Content Estimate for the Southwest Quadrant of the Hanford 200 West Area* (WHC-SD-WM-ER-352). This addendum updates and augments information from RPP-15808. Relevant details related to site history and physical settings are provided in Sections 4.1 and 4.2, respectively. Sections 2.0 and 3.0 provide information for WMAs C and A-AX.

4.1 U TANK FARM HISTORY

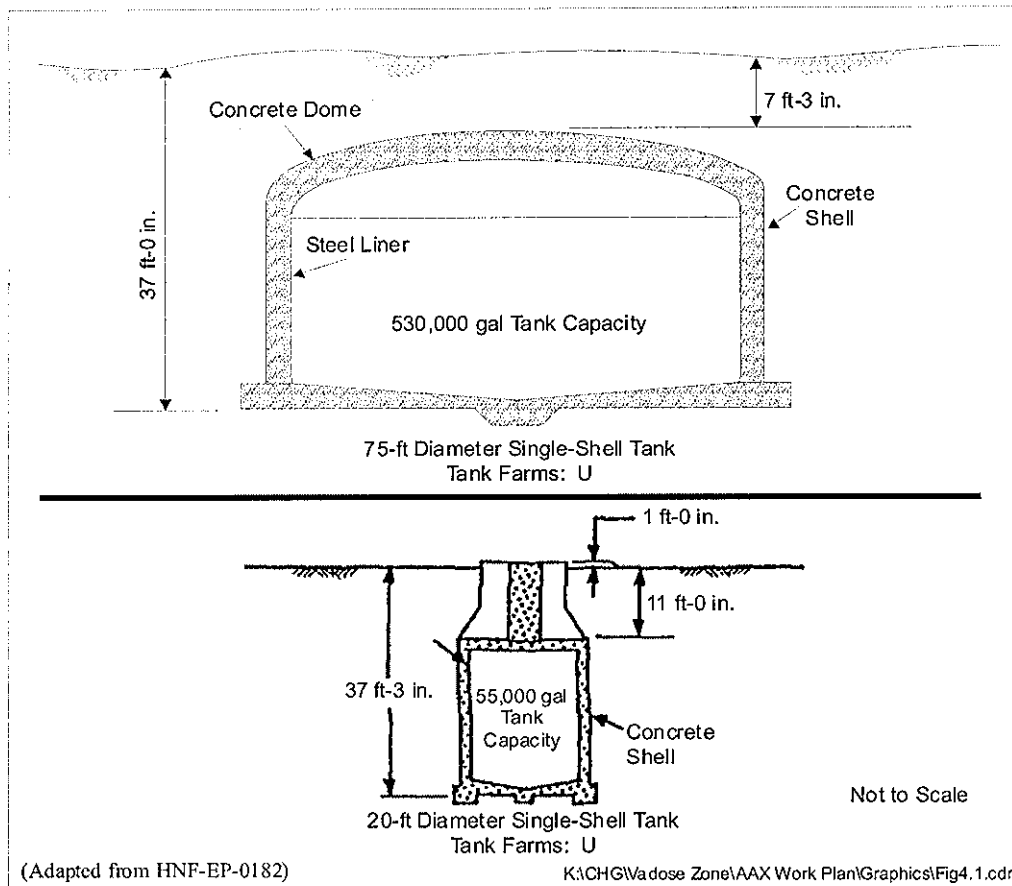
The SSTs in the U tank farm historically received high-level radioactive waste as well as hazardous or dangerous waste. They have been out of service since 1980, or earlier, but continue to store radioactive and dangerous waste. Waste in the SSTs consists of liquid, sludges, and salt cake (i.e., crystallized salts). Over the years, much of the liquid stored in the SSTs has been evaporated or pumped to double-shell tanks. The tank farm configurations, history of operations, leak detection systems, and interaction of WMA U with surrounding facilities are discussed in the following subsections.

4.1.1 U Tank Farm Layout

The SSTs in the U tank farm are 23 m (75 ft) in diameter, except for 4 SSTs that are 6.1 m (20 ft) in diameter. The U tank farm contains 12 SSTs each with 2,006,050-L (535,000-gal.) capacity, 4 SSTs each with 208,175-L (55,000-gal.) capacity, waste transfer lines, leak detection systems, and tank ancillary equipment (see Sections 4.1.3 and 4.1.4). The 12 larger U tank farm SSTs are approximately 9.07-m (29.75-ft) tall from base to dome. The 4 smaller SSTs in U tank farm are approximately 11.4-m (37.25-ft) tall from base to dome (HNF-EP-0182).

The sediment cover from the apex of the tank domes to ground surface is 2.2 m (7.3 ft) at the U tank farm (HNF-EP-0182). The smaller SSTs in U tank farm are approximately 3.4 m (11 ft) bgs (HNF-EP-0182). The tanks in U tank farm have a dish-shaped bottom. Figure 4.1 shows the general configuration of the tanks in the U tank farm.

The 23-m- (75-ft-) diameter SSTs in the U tank farm are constructed with cascade overflow lines in a 3-tank series that allowed gravity flow of liquid waste between the tanks (WHC-SD-WM-ER-352). The cascade overflow height for U tank farm SSTs is 4.78 m (15.67 ft) from tank bottom (WHC-SD-WM-ER-352). The U tank farm also contains an assortment of ancillary equipment used to move tank waste during operations. These include six diversion boxes, the 271-UR control house, the 244-UR process vault, the 244-U double-contained receiver tank, and waste transfer lines.

Figure 4.1. General Configuration of Tanks in Waste Management Area U

4.1.2 U Tank Farm History of Operations

The U tank farm was constructed between 1943 and 1944 and first received metal waste and first cycle waste generated by the bismuth phosphate process from T Plant beginning in 1946 (WHC-SD-WM-ER-352). Ultimately, tanks U-101 through U-109 received metal waste and tanks U-110 through U-112 received first cycle waste (WHC-SD-WM-ER-352). All tanks were filled with bismuth phosphate waste by the end of 1948. Subsequently, a decision was made to recover the uranium present in the metal waste. Therefore, the stored metal waste was removed from the U tank farm beginning in 1952 and transferred to U Plant for uranium recovery. Ancillary equipment involved in the metal waste transfer included the 271-UR control house, the 244-UR vault and diversion boxes 241-UR-151, -152 -153 and -154. Subsequently, tributyl phosphate waste, a byproduct of uranium recovery was returned to several tank farms, but not U farm. Uranium recovery operations concluded in 1957.

Both intentional and unintentional discharges to ground occurred during these two major operations. Uncontaminated and slightly contaminated water from facilities outside the U tank farm were discharged to several nearby ditches, particularly 216-U-14.

Several unintentional bismuth phosphate process waste releases to the environment occurred during this time period. In 1950 during construction at diversion boxes 241-U-151 and 241-U-152, a leak occurred whose source and volume were unspecified (UPR-200-W-6). In 1953, metal waste spray was ejected from a riser in the 244-UR vault created by a violent chemical reaction in the vault (UPR-200-W-24). The geyser rose about 30 ft (9 m) into the air for 30 seconds. The volume of waste released was unspecified but should not have exceeded the 56,800-L (15,000-gal.) storage capacity of the vault. The contamination spread to the southeast covering the eastern half of the tank farm. Finally, in 1956, two events occurred. One thousand nine hundred liters (500 gal.) of metal waste overflowed from the 241-UR-151 diversion box at the northeast corner of the U tank farm (UPR-200-W-132) and tank U-104 leaked an estimated 208,000 L (55,000 gal.) of metal waste (UPR-200-UW-155).

Before the uranium recovery program was completed in 1957, the REDOX plutonium and uranium separations process was implemented in 1952. By 1954 waste generated by this process was transferred to tanks U-110, U-111, and U-112. Two kinds of waste were mixed in this stream including high-level waste, which contained most of the fission products and aluminum nitrated, and coating waste. Because the waste was self-boiling a reflux condenser was added to tank U-110 and tank condensate was transferred to the 216-U-3 french drain (identified as the 216-U-3 crib in Figure 4.1) until the tanks stopped boiling. In 1954 and 1955 about 791,000 L (209,000 gal.) were discharged to this facility. Additional REDOX waste was transferred to the U tank farm in 1956 and 1957 with tanks U-101, U-102 and U-103 receiving high-level waste and tanks 107, -108, and -109 receiving coating waste (*Historical Vadose Zone Contamination from U Tank Farm Operations* [RPP-7580]).

The last major stage of U tank farm activity was the removal of waste by supernate pumping and saltwell pumping of interstitial liquids, which started in 1972. This process has occurred intermittently and is nearing completion.

All U tanks have been interim stabilized except for tanks U-107, U-108, and U-111 (HNF-EP-0182; RPP-15808). Table 4.1 lists the volume of waste currently stored in the U farm tanks. Previous evaluations have screened the universe of radiological and chemical constituents in the tanks and identified those constituents potentially associated with the SST system. The results of those screenings are provided in Section 3.0 of DOE/RL-99-36. DOE/RL-99-36 includes tables listing the radiological and chemical constituents that are contaminants of potential concern for the SST system. Those tables served as the starting point for defining contaminants of potential concern specific to WMA U and are discussed in greater detail in Section 5.0 of this addendum and in RPP-15808.

Table 4.1. Current Waste Volume in U Farm Tanks

Tank	Total Waste Volume KL (Kgal)	Supernate KL (Kgal)	Salt Cake KL (Kgal)	Sludge KL (Kgal)
U-101	91 (24)	0 (0)	0 (0)	91 (24)
U-102	1,238 (327)	4 (1)	1,072 (283)	163 (43)
U-103	1,578 (417)	4 (1)	1,533 (405)	42 (11)
U-104	462 (122)	0 (0)	0 (0)	462 (122)
U-105	1,336 (353)	0 (0)	121 (32)	1,215 (321)
U-106	651 (172)	11 (3)	640 (169)	0 (0)
U-107	1,188 (314)	0 (0)	1,132 (299)	57 (15)
U-108	1,544 (408)	0 (0)	1,435 (379)	110 (29)
U-109	1,518 (401)	0 (0)	1,385 (366)	132 (35)
U-110	666 (176)	0 (0)	0 (0)	666 (176)
U-111	965 (255)	0 (0)	867 (229)	98 (26)
U-112	170 (45)	0 (0)	0 (0)	170 (45)
U-201	19 (5)	4 (1)	0 (0)	15 (4)
U-202	19 (5)	4 (1)	0 (0)	15 (4)
U-203	19 (5)	4 (1)	0 (0)	15 (4)
U-204	15 (4)	4 (1)	0 (0)	11 (3)

Source: HNF-EP-0182.

4.1.3 Vadose Zone Leak Detection Systems in U Tank Farm

The U tank farm has 59 leak detection drywells available for leak detection monitoring. These drywells were drilled from 1944 to 1979. The depth ranges for most of these drywells are between 24.4 m (80 ft) and 45.7 m (150 ft) bgs. Gamma logging data from the drywells were used from 1974 through 1993 to ascertain the integrity of the associated tanks.

4.1.4 Associated Facilities

Table 4.2 shows the facilities used during U tank farm operations that are associated with WMA U.

Table 4.2. Treatment, Storage, and/or Disposal Units and Associated Environmental Restoration Facilities at Waste Management Area U

Facility	Description	TSD or ER facility	Operable Unit	WMA
U Tank Farm (16 units)	Single-shell tanks	TSD	200-UP-3	U
241-UR-151	Diversion box	TSD	200-UP-3	U
241-UR-152	Diversion box	TSD	200-UP-3	U
241-U-252	Diversion box	TSD	200-UP-3	U
241-UR-153	Diversion box	TSD	200-UP-3	U
241-UR-154	Diversion box	TSD	200-UP-3	U
241-U-151	Diversion box	TSD	200-UP-3	U
241-U-152	Diversion box	TSD	200-UP-3	U
241-U-153	Diversion box	TSD	200-UP-3	U
244-U-DCRT	Catch tank	TSD	200-UP-3	U
241-U-301	Catch tank	TSD	200-UP-3	U
216-U-3	French drain	ER	200-UP-2	U
216-U-13	Trench	ER	200-UP-2	
216-U-14	Ditch	ER	200-UP-2	
216-Z-11	Ditch	ER	200-UP-2	
216-Z-19	Ditch	ER	200-UP-2	
216-Z-20	Ditch	ER	200-UP-2	
207-U	Retention pond	ER	200-UP-2	
244-UR	Vault	TSD	200-UP-3	U
2607-WUT	Septic tank	TSD	200-UP-3	U

DCRT = double-contained receiver tank.

ER = environmental restoration.

NA = not applicable.

TSD = treatment, storage, and/or disposal.

WMA = waste management area.

These associated facilities are located both inside and outside the WMA U boundaries (Figure 4.2). Waste discharged to or stored at these facilities may have had an effect on the groundwater contamination at WMA U.

A number of raw and potable water lines are also present in and around WMA U (RPP-5002). Leaks from these lines could have contributed to tank waste migration in the vadose zone. Historical records about leaking water lines are incomplete.

Summaries of the operation, vadose zone contamination, and groundwater contamination history for each of these associated facilities are provided in HNF-2603, RPP-7580, and RPP-15808.

4.2 PHYSICAL SETTING

The following subsections summarize the topography, geology, hydrogeology, and surface water hydrology of WMA U. More detail is provided in the geology and hydrogeology summaries because of their more direct relationship to the WMA U field investigation. Because the meteorology, environmental resources, cultural resources, and human resources associated with WMA U are the same as the 200 Areas at the Hanford Site, the reader is referred to Section 3.0 of DOE/RL-99-36 for related information. Sections 4.2.2 and 4.2.3 are taken directly from RPP-15808.

4.2.1 Topography

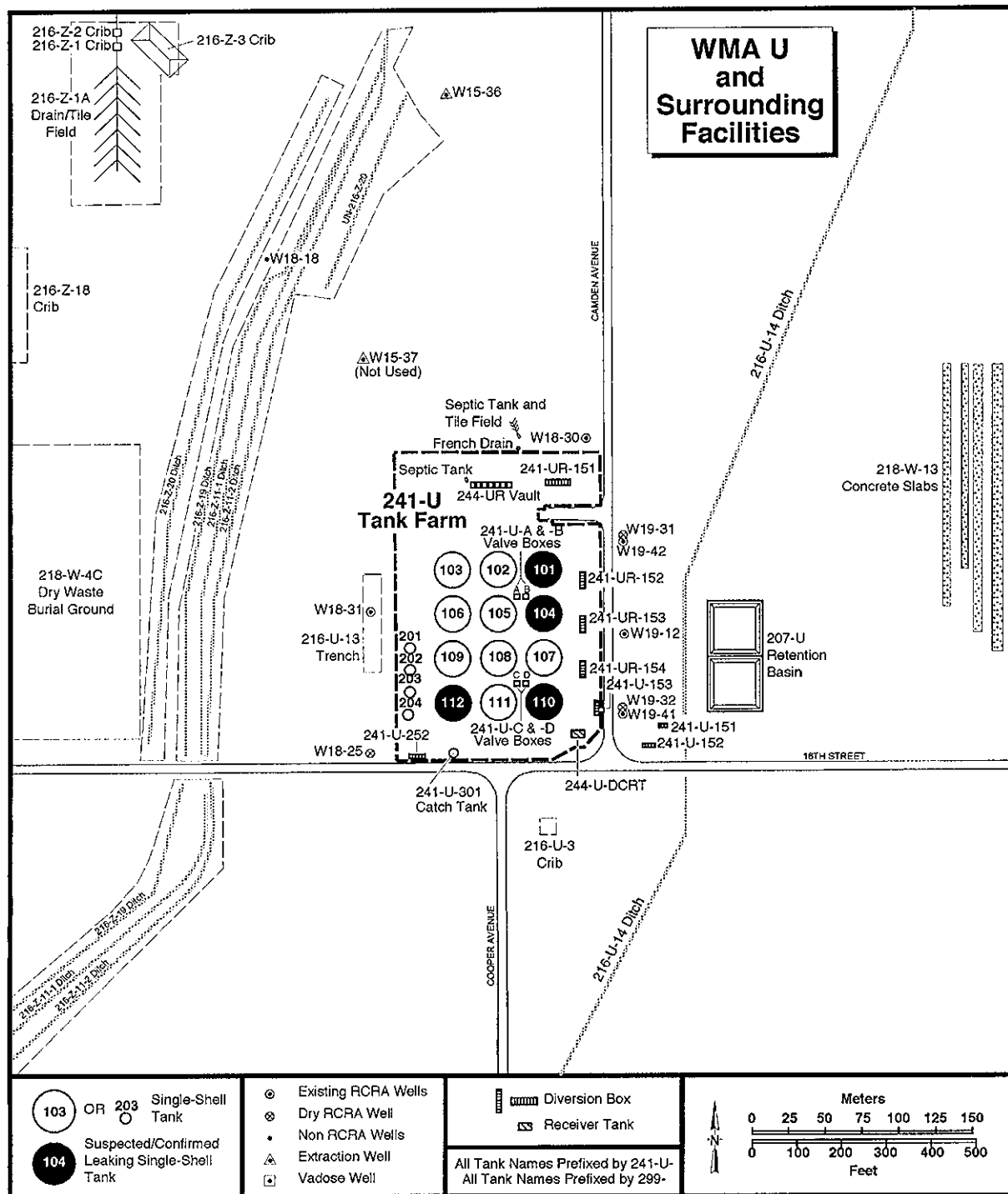
WMA U lies within a shallow, north to south-oriented topographic low. This low formed within the southwestern extent of a flood bar deposit known as the Cold Creek bar and likely represents a braided stream channel that cut across the bar. Within the U tank farm, isolated human-made topographic depressions occur just southwest of tank U-110 and northwest of tank U-109. Until runon and runoff controls were recently constructed around the site, these depressions were conducive to the collection and subsequent infiltration of surface runoff. RPP-15808 provides more topographical information about WMA U.

4.2.2 Geology

WMA U is located on a sequence of sediments that overlie the CRBG on the north limb of the Cold Creek syncline. The syncline axis runs generally northwest to southeast just south of the 200 West Area; the CRBG dips slightly to the southwest. The sediments include the upper Miocene to Pliocene age Ringold Formation, the Plio-Pleistocene unit or Cold Creek unit, the Pleistocene cataclysmic flood gravels and slack water sediments of the Hanford formation and Holocene eolian deposits (Figure 4.3). The sediment sequence is about 170 m (560 ft) thick at WMA U and the individual strata are relatively uniform in their thicknesses. A more detailed description of these is provided in the following sections.

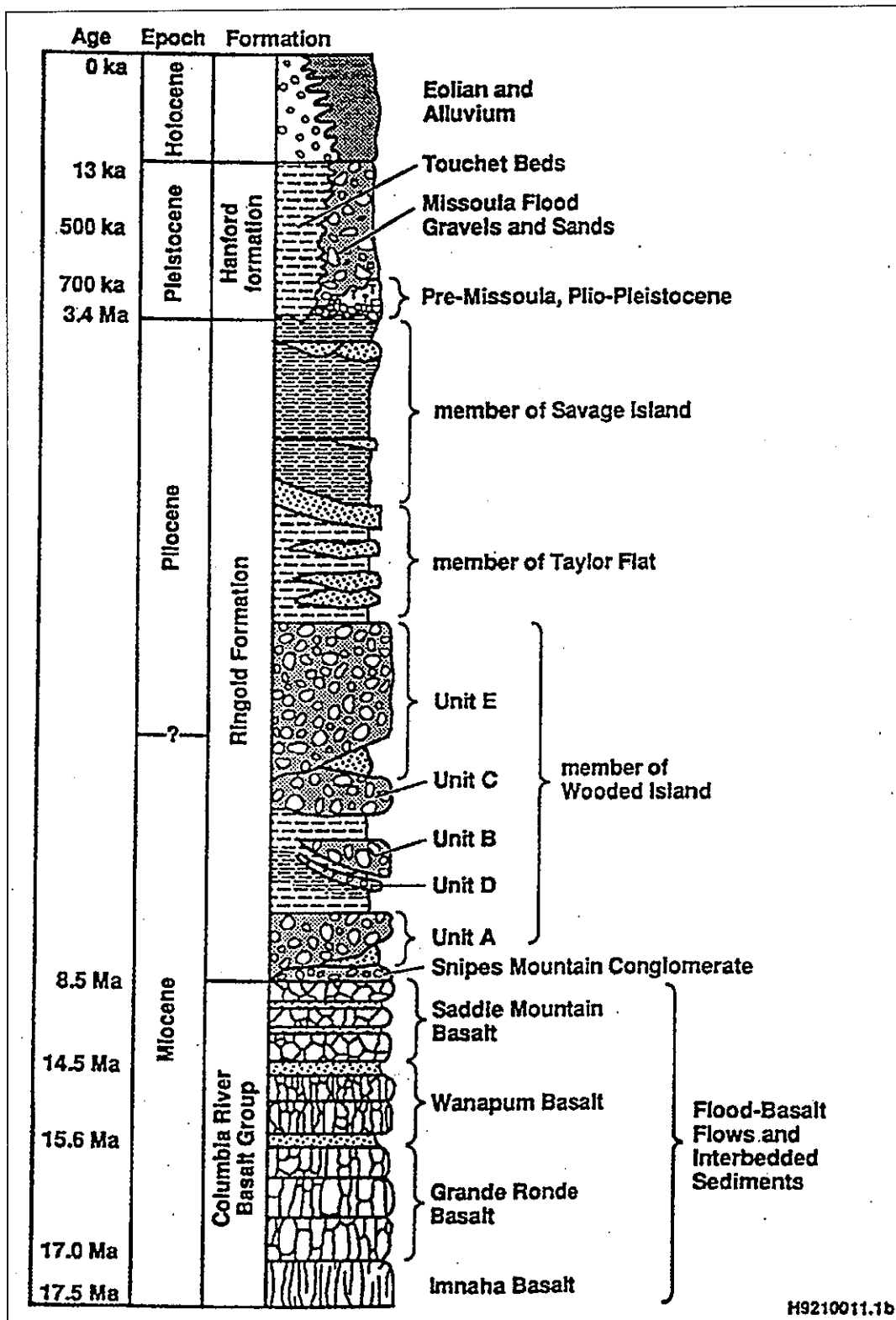
The vadose zone stratigraphy of the U tank farms is discussed in RPP-15808.

Figure 4.2. Location Map of U Tank Farm and Surrounding Facilities



2001/DCLU/007

Figure 4.3. Generalized Stratigraphic Column of the 200 West Area (BHI-00184)



4.2.2.1 Columbia River Basalt Group

The CRBG forms the bedrock base of the unconfined aquifer under WMA U. Sedimentary interbeds between CRBG flows belong to the Ellensburg Formation (Figure 4.3). A thick series of basalt flows forms the bedrock underlying WMA U. The top flow bed is the Elephant Mountain member of the Saddle Mountains Basalt formation, which is the youngest flow in the area. The Elephant Mountain member is about 25 m (80 ft) thick in the 200 West Area (“Wanapum and Saddle Mountains Basalt of the Cold Creek Syncline Area” [RHO-BWI-ST-14]) and dips gently to the southwest ($< 1^\circ$).

The Elephant Mountain Member is medium- to fine-grained tholeiitic basalt with abundant microphenocrysts of plagioclase (DOE/RW-0164). The Elephant Mountain Member has been dated by the K/Ar method at 10.5 Ma (McKee et al. 1977). The Elephant Mountain Member represents the youngest basalt flows in the study area; the top of the member lies at depths between 75 and 110 m (250 and 360 ft) bgs within the study area. The top of basalt dips south-southwest beneath WMA U (*Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area U* [PNNL-13612]).

4.2.2.2 Ringold Formation

The first sediment layer overlying the Elephant Mountain member is the Ringold Formation, a fluvial-lacustrine deposit associated with the ancestral Columbia River drainage system that developed after the last basalt flow eruption. The Ringold Formation contains several subunits that are not present everywhere on the Hanford Site. A generalized stratigraphic sequence was defined by BHI-00184 and is shown in Figure 4.3. At WMA U, Ringold Unit A, the Lower Mud unit (between Unit A and Unit D and not labeled in Figure 4.3) and Unit E are present in ascending order. No local boreholes extend all the way through the Ringold, but regional boreholes provide an indication of thickness listed below for the various subunits. Unit A, the lowest subunit, is a fluvial gravel, up to 30 m (98 ft) thick. The Lower Mud unit, a lacustrine mud deposit, is approximately 15 m (50 ft) thick and is considered sufficiently impermeable to be the bottom of the unconfined aquifer in this area. Unit E, about 90 m (295 ft) thick, is a fluvial sandy gravel with variable grain size distribution ranging from sand to silty sandy gravel and cobble gravel. The water table is currently within this unit about 67 m (220 ft) bgs.

The Ringold Formation overlies Columbia River basalt in the central Pasco Basin (DOE/RW-0164). The Ringold Formation in this area consists of multilithic, clast-supported to matrix-supported, variably cemented and/or limonitic-stained, sandy gravel sequences. Ringold Formation gravel sequences are occasionally separated by thinner sequences of horizontally laminated, ripple laminated and/or massive, locally calcareous sand, silt, and clay in various shades of blue, olive, gray, and brown (BHI-00184). Sands are generally well-sorted and predominantly quartzo-feldspathic (i.e., light colored). The gravels represent fluvial channel-fill and braidplain deposits while intervening fine-grained deposits are interpreted as lacustrine and/or fluvial overbank-paleosol deposits.

4.2.2.3 Plio-Pleistocene Unit

The Plio-Pleistocene unit overlies the Ringold Formation and consists of the two subunits. The lower subunit is a caliche-rich zone about 1 to 2 m (3 to 6 ft) thick that developed on the paleosurface of the Ringold Formation. It is a calcium carbonate-rich layer with locally derived basalt detritus, silt-rich deposits and reworked Ringold Formation material. The calcium

carbonate zones are probably discontinuous and occur as layers, nodules, and clast coatings. Cementation varies from finely disseminated carbonate particles in the silt to calcium carbonate nodules in the fine sands. Within the gravel the calcium carbonate rich zone exhibits variable matrix cementation that can form hard solid white to pale white stringers or layers. The top of the caliche zone dips approximately 3 m to the south-southwest beneath the tank farm similar to the Ringold Unit E gravels. The upper subunit is a silt-rich, sandy soil about 3 to 6 m (9 to 15 ft) thick that is relatively uniform and shows little depositional structure. Both subunits dip slightly to the southwest (RPP-15808).

4.2.2.4 Hanford Formation

The Hanford formation (informal name) overlies the Plio-Pleistocene unit and consists of glaciofluvial sediments deposited by Ice Age cataclysmic floods from glacial Lake Missoula, pluvial Lake Bonneville, and perhaps other ice-margin lakes. Cataclysmic floods were released during major glacial events that occurred during the Pleistocene starting as early as 1.5 to 2.5 Ma (Bjornstad et al. 2001). The Hanford formation consists of pebble- to boulder-size gravel, fine- to coarse-grained sand, and silt (Baker et al. 1991). These deposits are generally divided into three facies associations:

- Gravel-dominated
- Sand-dominated
- Interbedded sand and silt-dominated.

The Hanford formation is present throughout the Hanford Site below elevations of about 300 m (1,000 ft). The Hanford formation reaches its maximum thickness of 100 m (300 ft) between the 200 East and 200 West Areas beneath the Cold Creek flood bar.

At WMA U, the Hanford formation is the thickest vadose zone layer and consists of two units. The lower unit, H2, is primarily a sand and silt-dominated layer that averages about 24 m (79 ft) thick across WMA U. The H2 unit thins to the east and northeast (RPP-15808). Repetitive sequences of very thin, flat-lying lamina of silt and sand have been observed in intact core samples and apparently provide a sedimentary structure that influences moisture movement in the vadose zone. The tank waste migration pattern indicated by uranium deposition in the H2 unit illustrates the influence of these sedimentary features (RPP-15808).

The upper unit, H1, is distinguished from the H2 unit by a marked difference in grain size distribution. A significant fraction of the H1 soils are gravels and coarse sands indicating deposition in a higher energy environment. In the vicinity of WMA U, the contact between the H2 and H1 units, identified by the grain size distribution contrast, is irregular and appears to dip to the northeast in contrast to the other vadose zone contacts that dip to the southwest. At the U tank farm, the Hanford formation H1-H2 contact is near the tank farm excavation base along the eastern edge. The contact gets closer to the surface toward the west and northwest and therefore has had little influence on tank waste migration.

4.2.2.5 Recent Deposits

Two types of recent deposits are present in WMA U: (1) eolian sand and silt, and (2) backfill material. Fine to medium sand to silty sand naturally caps the sedimentary sequence in WMA U. These relatively fine-grained deposits are derived from the reworking of uppermost flood

deposits by winds since the last Ice Age flood (approximately 13,000 years before present). These poorly sorted eolian deposits contain up to 10 wt% CaCO_3 associated with recent soil development.

Eolian sand and silt, forms a relatively thin (1 to 3 m [3 to 10 ft]) blanket over the study area (RPP-15808). Most or all of the eolian material has been removed and replaced with backfill in the immediate vicinity of tank-farm operations. Backfill materials consist of unstructured, poorly sorted mixtures of gravel, sand, and silt removed during tank excavation, and then later used as fill around the tanks. Backfill materials extend to depths of 15 m (50 ft) within the tank farms (RPP-14430).

4.2.2.6 Clastic Dikes

Clastic dikes are vertical to subvertical sedimentary structures that cross-cut normal sedimentary layering. Clastic dikes are a common geologic feature of the Hanford formation in the 200 Areas, especially in the sand- and silt-dominated facies. Clastic dikes are much less common in the gravel-dominated facies of the Hanford formation. While a clastic dike could increase flow rate, it is less likely to intersect large segments of leaked wastes; when it does, the cross-sectional area of the intersection is small (DOE/RL-97-47).

Clastic dikes occur in swarms and form four types of networks (BHI-01103):

- Regular-shaped polygonal patterns
- Irregular-shaped, polygonal patterns
- Preexisting fissure fillings
- Random occurrences.

Clastic dikes probably occur randomly in the gravel-dominated facies (the Hanford formation H1 and H3 units) and as regular-shaped polygons in the sand facies (the Hanford formation H2 unit). Regular-shaped polygonal networks resemble 4- to 8-sided polygons and typically range from 3-cm to 1-m (1-in. to 3-ft) wide, from 2-m to more than 20-m (6-ft to more than 65-ft) deep, and from 1.5 to 100 m (5 to 325 ft) along their strike. Smaller dikelets, sills, and small-scale faults and shears are commonly associated with master dikes that form the polygons. These structures probably occur at WMA U although neither PNNL-13612 nor PNNL-13282 mention their presence.

In general, a clastic dike has an outer layer of clay with coarser infilling material. Clay linings are commonly 0.03- to 1.0-mm (0.001- to 0.04-in.) thick, but linings up to about 10-mm (0.4-in.) thick are known. The width of individual in-filling layers ranges from as little as 0.01 cm to more than 30 cm (0.0004 in. to more than 12 in.) and their length can vary from about 0.2 m to more than 20 m (8 in. to more than 65 ft). In-filling sediments are typically poorly sorted to well-sorted sand but may contain clay, silt, and gravel (HNF-4936).

4.2.3 Hydrogeology

General groundwater flow directions under WMA U have changed substantially because of Hanford Site operations. Before the initiation of fuel processing activities at the Hanford Site the regional flow across the site was generally west to east. The first significant perturbation to groundwater flow was probably discharge to T Pond north of WMA U in the late 1940s, which

would have had the effect of diverting flow direction to a more southerly direction under WMA U and perhaps raising the water table. A similar scenario has been postulated groundwater flow under WMA S-SX (HNF-4936). No groundwater wells were located near WMA U in this time period to measure these postulated events.

The next significant perturbation created by Hanford operations was the development of U Pond and wastewater discharge to the unconfined aquifer. A water mound developed and groundwater flow direction was altered beginning in the mid 1950s. At WMA U, elevation of the water table was measured at groundwater monitoring well 299-W19-1 (Figure 4.4). Given the location of the 216-U-10 Pond to the southwest of WMA U and the radial flow induced by the expansion of the groundwater mound underneath the pond, groundwater flow changed toward a northeasterly direction under WMA U. This directional control continued through 1985 when discharge to the pond ceased, at which point both the water table began to drop (Figure 4.5) and the general flow direction began to move toward the pre-Hanford easterly orientation.

Figure 4.4. Historical Depth Above Mean Sea Level at Well 299-W19-1 Just South of Waste Management Area U (PNNL-13282)

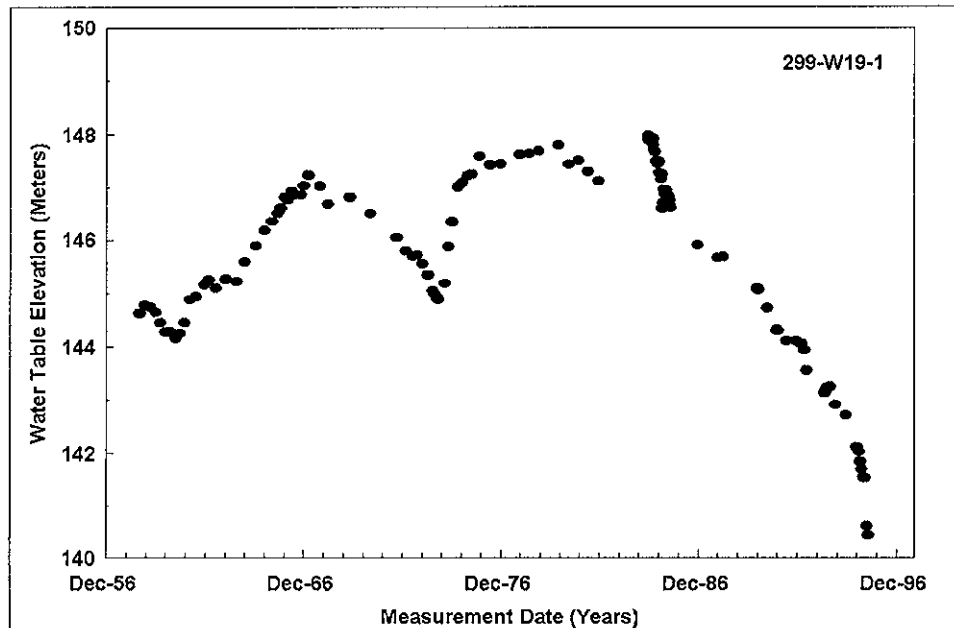
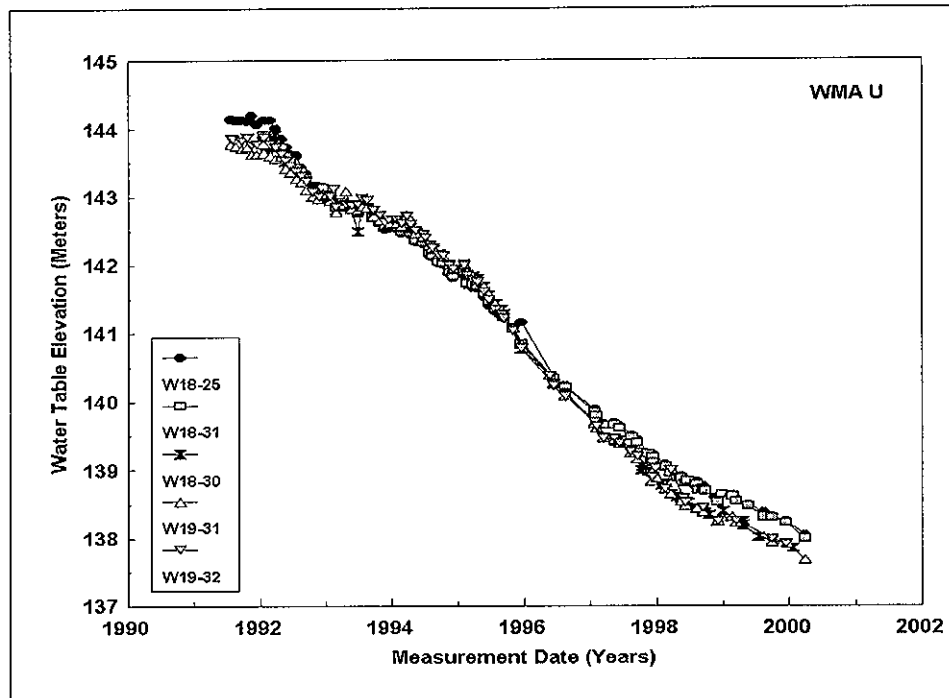


Figure 4.5. Recent Water Level Measurements from RCRA Monitoring Wells Around Waste Management Area U (PNNL-13282)



The most recent perturbation to local flow direction was caused by the short-term large volume (1.6×10^{11} L [4.2×10^{10} gal.]) discharge of wastewater from the U/VO₃ plants into the 216-U-14 ditch in 1991 just east of WMA U. In response to this high discharge, the local flow direction gradient changed from easterly to northerly and westerly in 1993. This gradient reversal lasted until early 1996, at which time a reversal to the predominantly easterly direction reoccurred. The gradient reversals are indicated in Figure 4.5 by the relative changes in the water levels of the RCRA monitoring wells around WMA U over time. Recognizing that water levels are closer to the surface at upgradient wells, the figure shows that northern and western wells (299-W18-30, 299-W18-31 and 299-W18-25) compared to the eastern wells (299-W19-31 and 299-W19-32) are upgradient between 1990 and mid 1993, downgradient between mid 1993 and late 1995, and finally upgradient again beginning in 1996 until present.

Recent measurements of aquifer properties (PNNL-13378; PNNL-13612) in WMA U RCRA monitoring wells indicate that hydraulic conductivity and effective porosity around well 299-19-42 are about 6.12 m per day (20 ft per day) and 0.17. The hydraulic gradient is about 0.002 based on water level measurements from nearby wells. Using these data, a flow velocity of about 30 m/yr (100 ft/yr) is calculated. The flow direction across WMA U is shows a generally easterly orientation with some radial component (e.g., at the northern end of WMA U flow is more northeasterly). This suggests that the impact of the U Pond groundwater mound has not completely dissipated but these effects are diminishing as indicated by the steady decrease in water levels at all local wells. Additional water table decreases of 6 to 8 m (20 to 25 ft) at a rate of about 1 m (2 ft) per year were estimated to return to pre-Hanford values at WMA S-SX just to the south (HNF-4936). If so, pre-Hanford conditions should be achieved 10 to 20 years from now.

4.2.3.1 Recharge

Recharge through the vadose zone is primarily controlled by the surface sediment type, vegetation type, topography, human-made, and spatial and temporal variations in seasonal precipitation at WMA U. As used in this addendum, the recharge rate is the amount of precipitation that enters the sediment, is not removed by evaporation or transpiration, and eventually reaches the groundwater table. The recharge to the unconfined aquifer beneath the U tank farms from infiltrating precipitation is an important parameter for calculating groundwater impacts from past tank leaks, future tank waste retrieval losses, and residual tank waste currently in the SSTs. The tank farm surface characteristics and infrastructure create an environment conducive to enhanced general recharge and transient, high-intensity events.

Most of the precipitation at the Hanford Site occurs from September through February when little to no evaporation or transpiration occurs. Recharge varies temporally and spatially. The temporal variation occurs with changes in temperature, plant activity, and precipitation. Both seasonal and long-term variations, as a result of climatic change, are important. The spatial variation occurs with changes in vegetation type, surficial sediment type, and human-made structures (e.g., paved parking lots). A lag time exists between a change in recharge rate from infiltration at the surface and a change in the flow field in the vadose zone as the water infiltrates through the ground. However, seasonal precipitation through field and simulation studies have indicated no seasonal recharge changes below 2 feet (*Retrieval Performance Evaluation Methodology for the AX Tank Farm* [DOE/RL-98-72]).

4.2.3.2 Natural Infiltration

No direct measurements of the natural infiltration rate under WMA U have been made. However, observations from similar, disturbed, gravel-covered areas at the Hanford Site indicate that as much as 10 cm (3.9 in.) can infiltrate a vegetation-free coarse gravel surface per year (Fayer et al. 1996; Gee et al. 1992; PNL-10285). That rate represents about 60% of the average annual meteoric precipitation (rainfall plus snowmelt). PNL-10285 indicates that WMA U is estimated to have about 5 to 10 cm (1.97 to 3.9 in.) of infiltration per year based on soil type, vegetation, and land use. Actual recharge is significantly different and not uniform because of the presence of the tanks, the disturbed soil surrounding the tanks, and no vegetative cover. Recharge is intercepted and “shed” by the tank domes and flows into the disturbed soil near the tanks. Thus, infiltration rates near tank edges and between rows of tanks are likely manyfold higher than average areal infiltration rates.

Lysimeter data from the Field Lysimeter Test Facility located between the 200 West and 200 East Areas show that the recharge rate ranges from 24 to 66% of the annual precipitation for years 1990 to 1994 for lysimeters with gravel over sand and bare vegetation conditions, which are typical of current tank farm ground conditions (PNL-10508). This is equivalent to approximately 4 to 11.1 cm (1.57 to 4.37 in.) of recharge per year based on the long-term annual precipitation rate of 16.8 cm (6.61 in.) per year (PNNL-11107). However, more recent lysimeter field measurements acquired August 1995 to August 1996 from the Field Lysimeter Test Facility resulted in 16.06 cm (6.32 in.) drainage per year, which is 66% of the actual precipitation over that period. These lysimeters were designed to simulate tank farm conditions in the 200 Areas.

Rapidly melting snow is one natural event that can lead to surface flooding. This type of occurrence has been documented at other tank farms (e.g., T tank farm [PNNL-11809]) but no similar record was identified for U tank farm.

4.2.3.3 Artificial Recharge

Artificial recharge in the 200 West Area is associated with trenches, cribs, ditches, and drains that were used to dispose of waste water. Leaking water lines are another source of artificial recharge in the tank farms. Higher infiltration rates are observed around the tank farms, which are covered with gravel and kept clear of vegetation.

Waterline ruptures, such as the one in September 1996 at the S tank farm, demonstrate that surface water could enter and collect in low spots (PNNL-11810). Transient saturation from runoff collected in low spots could be more significant as a driving force than average annual infiltration. There are topographic lows at U tank farm that could have collected runoff in the past, particularly south of tank U-110 and northwest of tank U-109. Recently, mitigating actions have been taken to divert runoff away from waste sites in WMA U.

Discharges within WMA U were intentional and unplanned releases. Quantities are not known for many of the identified releases. Reported releases are primarily leaks from transfer pipelines, diversion boxes, and tanks. RPP-15808 provides more information on artificial recharge related to WMA U.

4.2.4 Surface Water Hydrology

No flood plains exist in or between the 200 Areas. Floods in Cold Creek and Dry Creek have occurred historically; however, there have been no observed flood events. Based on a probable maximum flood evaluation, no impact would occur at WMA U (PNNL-6415).

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5.0 INITIAL CONDITIONS AND CORRECTIVE ACTION REQUIREMENTS AND OBJECTIVES IN WASTE MANAGEMENT AREA U

The purpose of this section is to describe what is known about confirmed or suspected contamination in the vadose zone and groundwater and identify the potential corrective action requirements and objectives. The information on known and suspected contamination is presented in Section 5.1 and RPP-15808. A summary of this information is also provided in Section 3.0 of DOE/RL-99-36. Potential corrective action requirements are provided in Section 5.2. The confirmed or suspected contamination information was used to develop the Section 5.3 discussion on the potential impacts to the public health and the environment based on potential corrective action requirements and objectives. Section 5.4 addresses preliminary corrective action objectives and alternatives with respect to Section 5.0 of DOE/RL-99-36. Additional data to support improved understanding of the nature and extent of contamination at WMA U will be collected during the field investigation described in this addendum.

5.1 KNOWN AND SUSPECTED CONTAMINATION IN WASTE MANAGEMENT AREA U

A summary of available data and conditions is needed to effectively develop a characterization plan designed to collect data to support a determination of the presence and extent of contamination at a site caused by a given event or activity. A summary of available WMA U data regarding source, sediments, and groundwater contamination is presented in the following subsections and in RPP-15808.

When interpreting the data in the following subsections, it is important to note the amount of radioactive decay that has taken place since the data were gathered. For example, the half-life of cesium-137 is 30.2 years, approximately the time between 1968 and 1998. Thus, cesium-137 levels would, in 1998, have been approximately half of their 1968 values. Where possible, the dates for radionuclide inventories have been given, but calculations of the decayed inventories through the present time have not been made.

5.1.1 Sources

Several unintentional bismuth phosphate process waste releases to the environment occurred during this time period. In 1950 during construction at diversion boxes 241-U-151 and 241-U-152, a leak occurred whose source and volume were unspecified (UPR-200-W-6). In 1953, metal waste spray was ejected from a riser in the 244-UR vault created by a violent chemical reaction in the vault (UPR-200-W-24). The geyser rose about 30 ft (9 m) into the air for thirty seconds. The volume of waste released was unspecified but should not have exceeded the 15,000 gallon (56,800 L) storage capacity of the vault. The contamination spread to the southeast covering the eastern half of the tank farm. Finally, in 1956, two events occurred. 1,900 liters (500 gal) of metal waste overflowed from the 241-UR-151 diversion box at the northeast corner of the U tank farm (UPR-200-W-132) and tank U-104 leaked an estimated 208,000 L (55,000 gallons) of metal waste (UPR-200-UW-155).

Four unintentional releases were reported that involved REDOX waste, three tank leaks and an underground pipe leak. Tanks U-101, U-110, and U-112 were reported to have leaked respectively 114,000 L (30,000 gal.) of high-level waste in 1959; 31,000 L (8,000 gal.) of coating waste in 1969, and 38,000 L (10,000 gal.) of high-level waste in 1975. Of these, the tank U-101 leak is unlikely to have occurred. The underground pipe leak (UPR-200-W-128) occurred near tank U-103 when a worker cut through the line in 1971. The waste type is presumably high-level waste, which was present in tank U-103 at the time and the leak volume is unknown.

Other than the tank U-112 leak in 1975, no other discharges to the vadose zone have occurred that are significant. A wind blown contamination event (UPR-200-W-161) in 1990 is thought to be a redistribution of contamination initially discharged to the atmosphere in 1953 from the 244-UR vault (UPR-200-W-24).

The source terms for WMA U are dependent upon nuclear and chemical aspects of the processes that generated the waste. The inventory of chemicals and radionuclides lost to the vadose zone in WMA U is a function of the waste types stored in the tanks over their decades of use. Because of their long operational history, the tank farms received waste generated by all of the major processes. The U tank farm initially received waste streams discharged from the bismuth phosphate process operating in T Plant. The U tank farm received waste generated by essentially all of the major chemical processing operations that occurred at Hanford including bismuth phosphate fuel processing, uranium recovery, PUREX fuel processing, fission product recovery, and tank farm interim stabilization and isolation activities. Best estimates of specific sources for each leak event are provided in RPP-15808.

The volume of waste lost from many of the U tanks is highly uncertain. No detailed analyses of known or suspected leaks have been done in this WMA. Available information on specific leak events is provided in RPP-15808.

Sources of releases include fluid discharges; tank waste through tank leaks; ancillary equipment leaks and failures (i.e., diversion boxes, transfer and cascade pipelines); and trenches and cribs (see Section 4.1.4). These releases impacted the sediments. These releases are discussed in detail in RPP-15808. Estimated releases or leaks from the tanks in WMA U are indicated in Table 5.1. The uncertainty associated with the leak durations is even greater than that for the estimated tank leak volumes.

Table 5.1. Estimated Past Leak Losses from U Single-Shell Tanks

Tank	Listed in Hanlon	Hanlon Leak Volume (gal.)	Treated as Leaker Here	Volume Suggested
U-101	Yes	30,000	No evidence for leak	
U-104	Yes	55,000	Yes	Inventory estimate assumes 50 Kgal leak
U-110	Yes	8,100	Yes	Inventory estimate assumes 8.1 kgal leak
U-112	Yes	8,500	Yes	Inventory estimate assumes 8.5 kgal leak

Note: Based on RCRA corrective action program, all single-shell tank leak volume estimates in HNF-EP-0182 are currently under review and significant revisions are anticipated. There will be revision to HNF-EP-0182 as a better understanding of tank leak events are developed.

To convert gallons to liters, multiply by 3.785.

NA = not applicable.

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

Throughout the operational history of the U tank farm, fluids have been discharged both deliberately and inadvertently. A summary of discharge events is provided in RPP-15808. Three types of fluid discharges associated with U tank farm operations have occurred in and around WMA U. These discharges included the following:

- Periodic failure of ancillary equipment used to transfer liquids between tanks
- Deliberate collection and routing of cooling water and tank condensate to cribs
- Mechanical failure of tanks and leakage into the underlying soil column.

Leaks from ancillary equipment were observed and recorded. The primary parts of the ancillary equipment system responsible for the surface spills appear to be the collection points for fluids being transferred around the tank farm (e.g., diversion boxes, valve pits, and catch tanks). Numerous pipes feed into these collection points. The pipes were frequently attached, detached, and reattached as part of normal operations, because the permanent pipelines would become clogged or unusable. Plugging of underground pipelines resulted in waste escaping containment, especially transfer and cascade lines.

Most of the trenches and cribs associated with the U tank farms operated from the beginning of tank farm operations in 1946 until the early 1990s. RPP-15808 supplies a history of waste and its volume released to these cribs and trenches. RPP-15808 provides more information on surface and near-surface spills.

A detailed discussion of the 4 tanks that are assumed or confirmed leakers is provided in Section 3.2 of RPP-15808. The estimated volume of the leaks is provided in Table 5.1 of this addendum. Based on HNF-EP-0182, the three highest-volume releases ranked in descending order are as follows:

- Tank U-104 with an estimated 208,175 L (55,000 gal.) leaked
- Tank U-101 with an estimated 113,550 L (30,000 gal.) leaked
- Tanks U-112 with an estimated 32,173 L (8,500 gal.) leaked.

Of these, it was concluded that the tank U-101 leak assumption was not supported by available data (RPP-15808).

5.1.2 Releases to Sediment

Releases of historical fluid discharges to trenches, and cribs to the sediment; tank waste through tank leaks; ancillary equipment leaks; and surface spills, along with evaluation of spectral and gross gamma surveys, are of direct interest to WMA U field investigation.

Detailed information about the spectral gamma surveying and historical gross gamma surveying conducted at U tank farm is provided in RPP-15808. Spectral gamma logging data are available in separate reports for the U tank farm (GJO-HAN-8; GJO-97-1-TARA).

Because SSTs U-101, U-104, U-110, and U-112 are associated with the largest release volumes, they are discussed in more detail in the following subsections. Information for other leaks that affect WMA U are presented in RPP-15808 and HNF-4872. The following sections are taken directly from RPP-15808.

5.1.2.1 Tank U-101

Tank U-101 first received metal waste from the bismuth phosphate process followed by receipt of uranium recovery waste. After tank U-101 was no longer needed to support uranium recovery operations in 1956, it received 1,858,000 L (491,000 gal.) of aged REDOX waste from tank SX-103 in 1958 to bring the total volume of waste in the tank to 2,043,900 L (540,000 gal.). This volume remained constant for almost 2 years and then waste level drops were noted. Both the waste transfer records and HNF-EP-0182 indicate a 113,550-L (30,000-gal.) loss from this tank in 1959. However, field data provide no indication of vadose zone contamination. A 113,550-L (30,000-gal.) loss of REDOX high-level waste from tank U-101 would have created a cesium-137 plume comparable to the SX-108 plume. None of the drywells around tank U-101 display high cesium-137 content to indicate a tank leak, much less a leak of this magnitude. Without physical evidence for a cesium-137 plume associated with a waste loss event from tank U-101, no substantive vadose zone contamination can be assumed.

5.1.2.2 Tank U-104

A significant leak from tank U-104 occurred in the early 1950s when physical inspection of the tank interior in 1956 ("Inspection of Waste Storage Tank 241-U-104" [Smith and Shadel 1956]) revealed a tank bottom bulge in the northeast quadrant of the tank. A 208,000 L (55,000 gal.) leak volume has been estimated (HNF-EP-0182). Operations records indicate uranium-rich metal waste as the primary waste stream in the tank at this time. This waste stream, the resulting

aqueous phase remaining after the co-precipitation of plutonium (IV) with bismuth phosphate, carried almost all of the uranium, fission products, and process chemicals. Being the first in a three-tank cascade (tanks U-104, U-105, and U-106), most of the uranium solids precipitated in this tank, along with the heat-producing fission products. This resultant heat buildup apparently was conducive to a tank bottom liner rupture.

Spectral gamma uranium activity data in ten drywells around tank U-104 and to the southwest also indicate the occurrence of a metal waste leak with tank U-104 being the source. Maximum uranium concentrations over the largest depth intervals occur in drywells 60-07-11, 60-07-10, and 60-04-08 on the south and southwest side of tank U-104. In these drywells, contamination occurs just below the tank bottom about 16 m (52 ft) bgs and extends to as much as 28 m (92 ft) bgs. Uranium-235 concentrations up to 100 pCi/g and uranium-238 concentrations approaching 1,000 pCi/g near tank bottom depth have been measured. These drywells were located closest to the leak location.

As the plume extended further to the southwest the peak concentrations and contaminated depth intervals decreased. Other drywells containing uranium contamination include 60-04-10, 60-07-01, 60-05-04, 60-05-05, 60-08-04, 60-11-12, and 60-11-07. In all the drywells uranium contamination began between 15 and 17 m (50 and 55 ft) bgs at the tank bottom. These drywell locations and the uranium distribution constrain the size of the uranium plume reasonably well to a roughly oval shape oriented toward the south-southwest with a long axis of about 69 m (225 ft) and a short axis of about 30 m (100 ft).

Historical gross gamma data in some of these drywells indicate subsequent migration of uranium at these locations, mostly in the early 1970s (*Analysis and Summary Report of Historical Dry Well Gamma logs for 241-U Tank Farm-200 West* [RPP-7729]). These include drywells 60-07-10, 60-05-04, 60-05-04, 60-04-10, and 60-04-08. At drywell 60-07-11, which contains the maximum uranium contamination in this group of drywells, vertical uranium migration is indicated throughout the monitoring period between 1975 and 1994.

5.1.2.3 Tanks U-110 and U-112

The tank U-110 leak was reported in 1975 on the basis of increased gamma activity in drywell 60-10-07 and a liquid level drop inside the tank. Both spectral gamma data and the historical gross gamma record are consistent with a tank leak. At drywell 60-10-07, a rapid increase in gamma activity was noted between May and September 1975 and continued to increase until 1984 (WHC-SD-WM-TI-356) at tank bottom depth. Subsequent spectral gamma measurements showed a high cesium-137 zone is present near the tank bottom between 16 and 17 m (52 and 56 ft) bgs. In this zone a sharp peak concentration approaching 10^7 pCi/g occurs at 17 m (55 ft) bgs. Given the high cesium-137 concentration, this drywell is assumed to be close to the leak location. The estimated leak volume of 19,000 to 31,000 L (5,000 to 8,100 gal.) is not well constrained but appears to be consistent with the spectral gamma data because this is the only drywell indicating a leak.

Determination of the chemistry of the waste leaked from tank U-110 is uncertain because of complex waste receipt and transfer history at tank U-110 before the leak event in the early 1970s. Tank U-110 first received first cycle waste from the bismuth phosphate process in the late 1940s,

a relatively dilute waste stream. This waste was transferred from tank U-110 in 1952. In 1954, tank U-110 was filled with REDOX high-level waste. In 1955 through 1957, tank U-110 began receiving REDOX cladding waste, another dilute waste type. Finally, from 1972 through 1975, tank U-110 received laboratory wastes from 222-S Laboratory and PNNL. Given this operational history and the apparent leak event occurring in the 1970s, it is difficult to project a waste composition for the leaked supernate but it was likely a mixture of REDOX high-level supernate mixed with various low-activity waste streams. Given the high cesium-137 concentration, REDOX waste seems to be the largest contaminant contributor in the leaked tank fluid.

Tank U-112 appears to have leaked in a similar fashion to tank U-110. One drywell, 60-02-01, shows two distinct high cesium-137 concentration zones. Near the tank bottom between 15 and 21 m (50 and 68 ft) bgs concentrations exceeding 10^7 pCi/g are common and a maximum value near 10^9 pCi/g occurs near 18 m (60 ft) bgs. A second less concentrated zone occurs between 25 and 30 m (83 and 97 ft) bgs where cesium-137 concentrations largely fall between 10^4 and 10^5 pCi/g. The bifurcated zones could indicate more than one leak. The leak may have occurred in the late 1960s when some indication of a liquid level drop inside the tank was observed beginning in 1967 and continuing until 1969 (GJO-HAN-8). Historical gamma data do not indicate contaminant movement beginning in the early 1970s suggesting that cesium-137 migration had already finished. The estimated leak volume of 32,000 L (8,500 gal.) is not well constrained and may be larger. The longer period of apparent liquid level drops in the tank and the greater amount of contamination in drywell 60-12-01 versus drywell 60-10-07 may indicate a somewhat larger leak. Tank U-112 stored similar waste to tank U-110 suggesting that REDOX waste was a significant component in the leaked tank fluid.

Additional information is presented in RPP-15808.

5.1.3 Intentional Liquid Waste Disposals to Surrounding Cribs and Trenches

Numerous cribs, trenches, tile fields, and retention basins surround WMA U (see Figure 4.2). Throughout the operational history of the U tank farm, fluids were discharged to the ground, both deliberately and inadvertently. A list of intentional discharge sites and UPRs with descriptive information is provided in Appendix A of RPP-15808 and RPP-7580.

The total liquid amounts released to the ground within WMA U from UPRs are not well quantified. However, the descriptions indicate that these releases were uniformly small (no more than a few gallons) within WMA U. Clean soil was placed over the contaminated areas. More information is provided in RPP-7580 and Appendix A of RPP-15808 on unplanned releases.

5.1.4 Groundwater

This section covers the historical and current state of groundwater contamination surrounding WMA U. The history of local groundwater contamination is limited by the scarcity of nearby groundwater monitoring wells and systematic sampling and analyses of these wells before 1991. In 1991, a series of upgradient and downgradient monitoring wells were installed as part of a site-wide RCRA assessment program of Hanford facilities. The most comprehensive evaluation

of groundwater monitoring data from these wells and other preexisting wells was documented by PNNL-13282 and is the primary source of information summarized below.

5.1.4.1 Data Summary

Eight groundwater monitoring wells have provided the most useful groundwater contaminant data near WMA U. Before the installation of RCRA groundwater monitoring wells, the nearest sampled well was 299-W19-12, which was installed in 1983 and is located just east of tanks U-104 and U-107. To satisfy RCRA monitoring requirements for WMA U, two upgradient wells (299-W18-25 and 299-W18-31) on the west side of the U tank farm and three downgradient wells (299-W19-30, 299-W19-31 and 299-W19-32) located on the northeast and east side of U tank farm (Figure 4.2) were installed in 1991 and 1992. Since then, water table subsidence eliminated sampling capability at some wells, necessitating the installment of some replacement wells including 299-W-42 to replace 299-W19-31, 299-W19-41 to replace 299-W19-32 in 1999 and 299-W18-40 to replace 299-W18-25 in 2001. When functional, these wells have been sampled and analyzed regularly since installation.

Generally speaking, groundwater flows in an easterly to northeasterly direction. However, during this sampling period, the upgradient-downgradient relationship was temporarily reversed between mid 1993 and early 1996 (see Figure 4.4) because of large liquid discharge events in the 216-U-14 ditch just east of the U tank farm in 1991 and 1993 (*Groundwater Impact Assessment report for the 216-U-14 Ditch* [WHC-EP-0698]). The discharge volume over a short period (about 2×10^9 L (5×10^8 gal.) in 1991) was sufficient to affect local groundwater flow. This event was apparently sufficient to affect the contaminant concentration histories in the RCRA monitoring wells (Figures 5.1 through 5.7).

Figure 5.1. Nitrate Measurements at Monitoring Well 299-W19-12 (PNNL-13282)

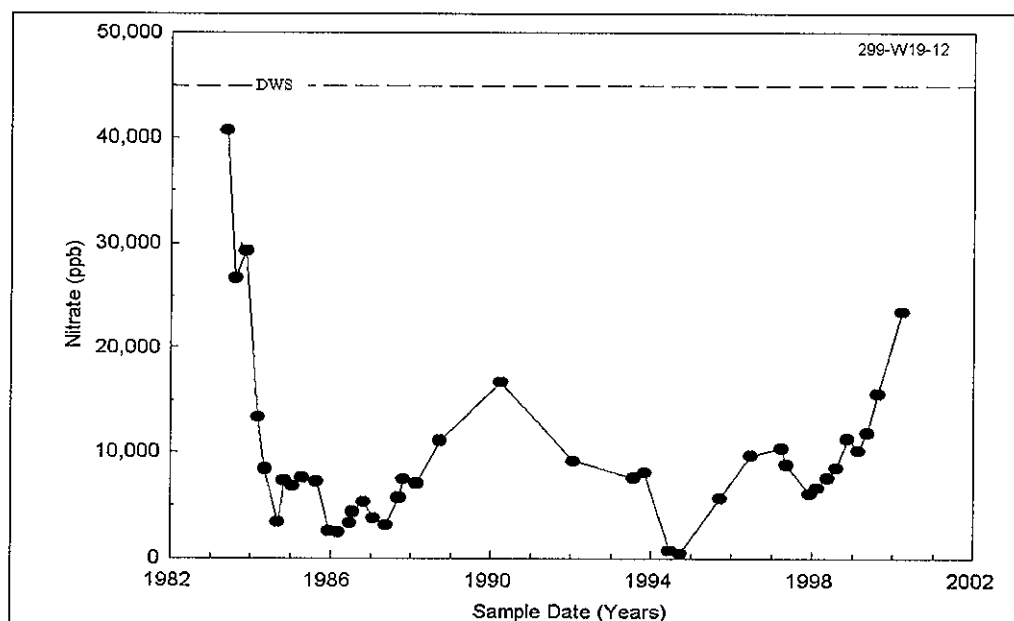


Figure 5.2. Technetium-99 and Gross Beta Measurements at Monitoring Well 299-W19-12 (PNNL-13282)

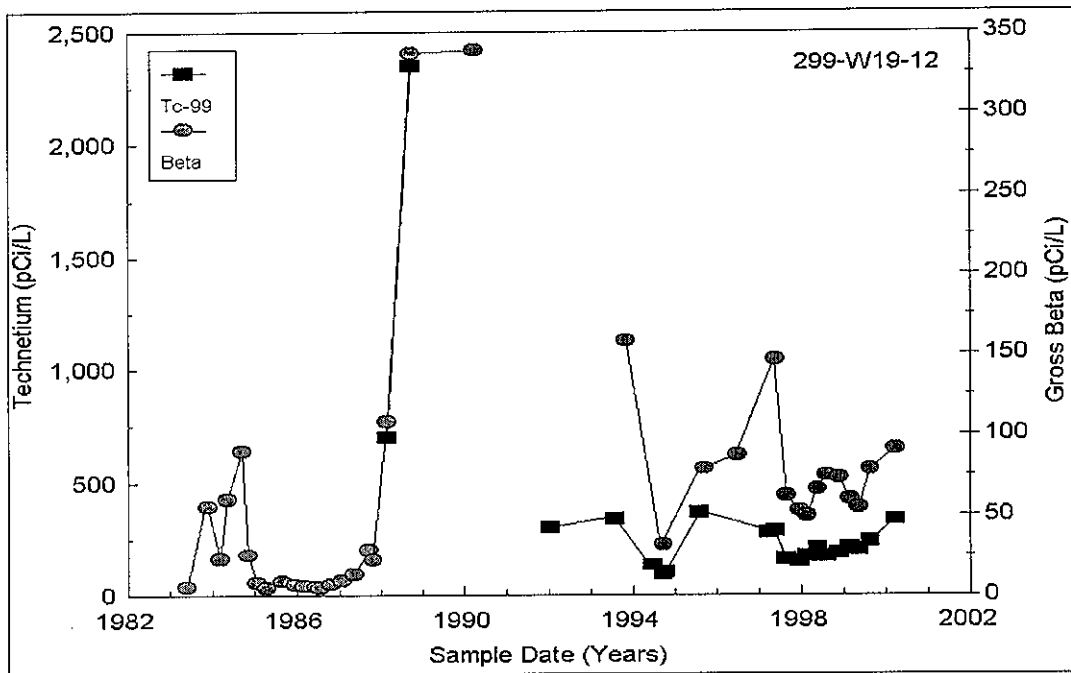


Figure 5.3. Nitrate Measurements at Monitoring Wells 299-W18-25, 299-W18-30, and 299-W18-31 (PNNL-13282)

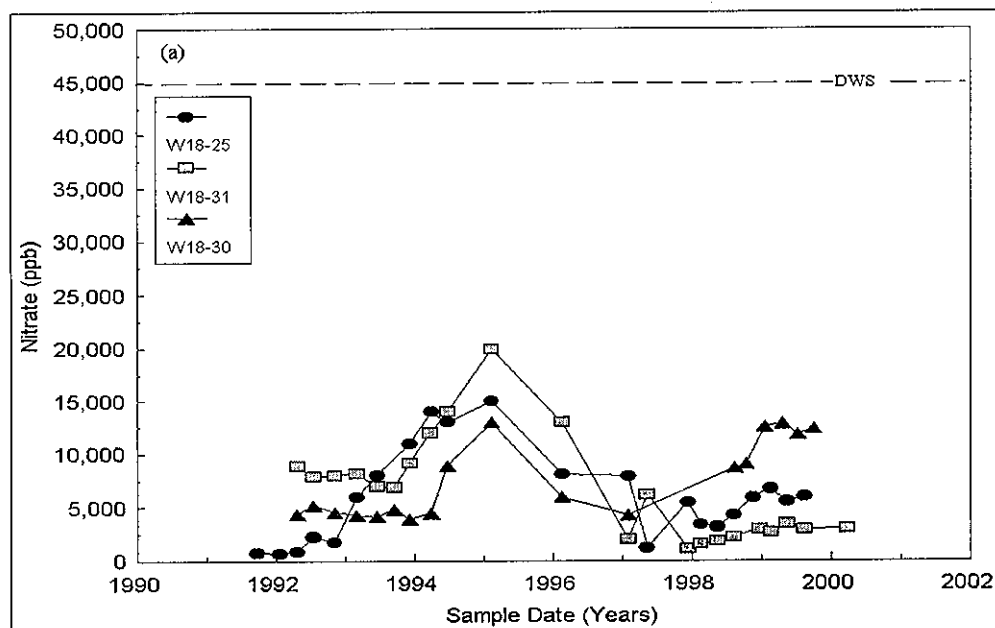


Figure 5.4. Nitrate Measurements at Monitoring Wells 299-W19-12, 299-W19-31, 299-W19-32, 299-W19-41 and 299-W19-42 (PNNL-13282)

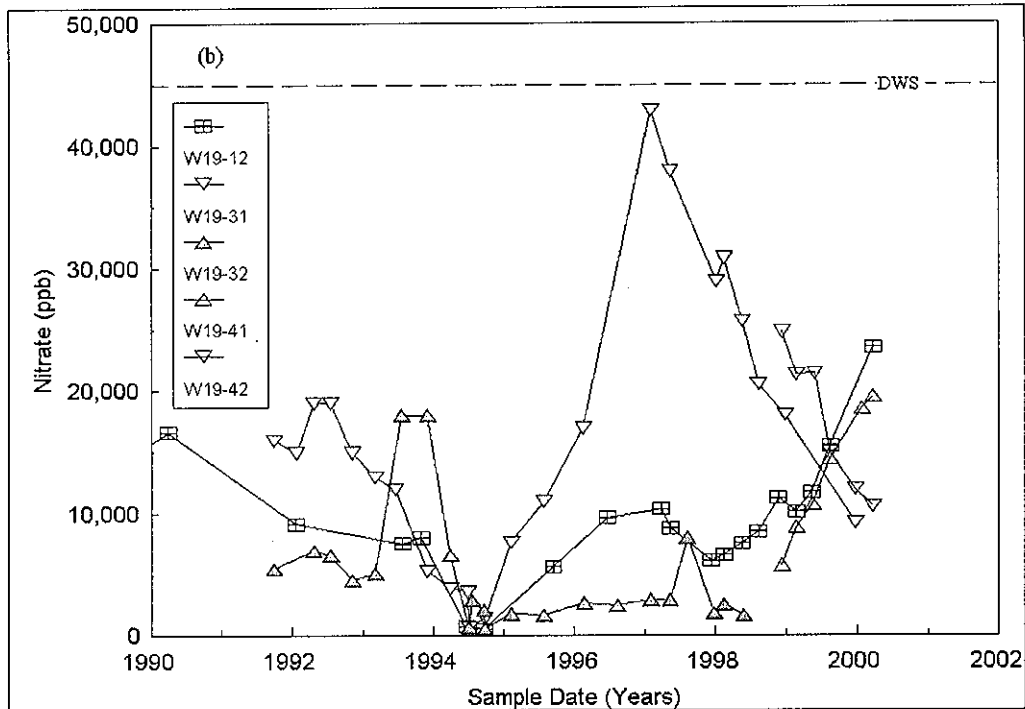


Figure 5.5. Technetium-99 Measurements at Monitoring Wells 299-W19-12, 299-W19-31, 299-W19-32, 299-W19-41 and 299-W19-42 (PNNL-13282)

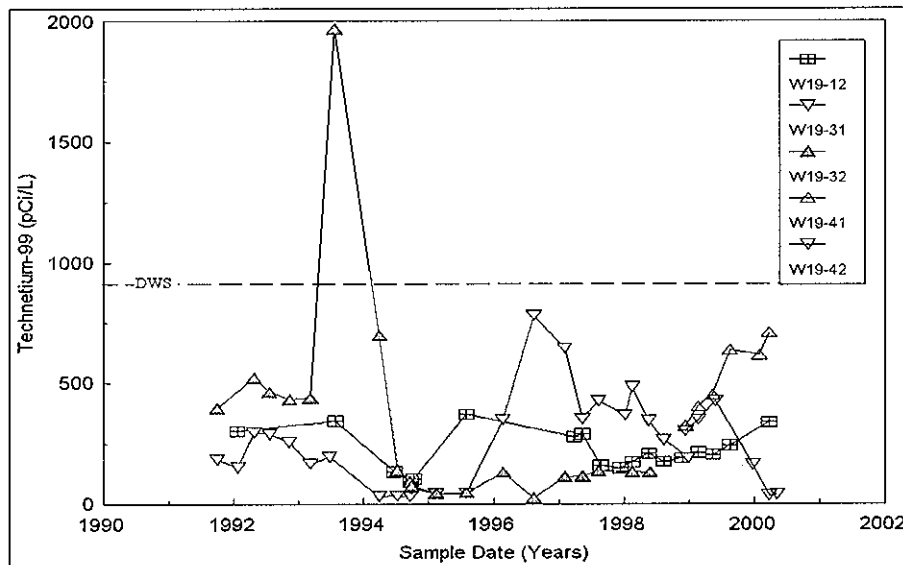


Figure 5.6. Nitrate Measurements at Wells 299-W18-31, 299-W19-12, 299-W19-41, and 299-W19-42 (PNNL-13404)

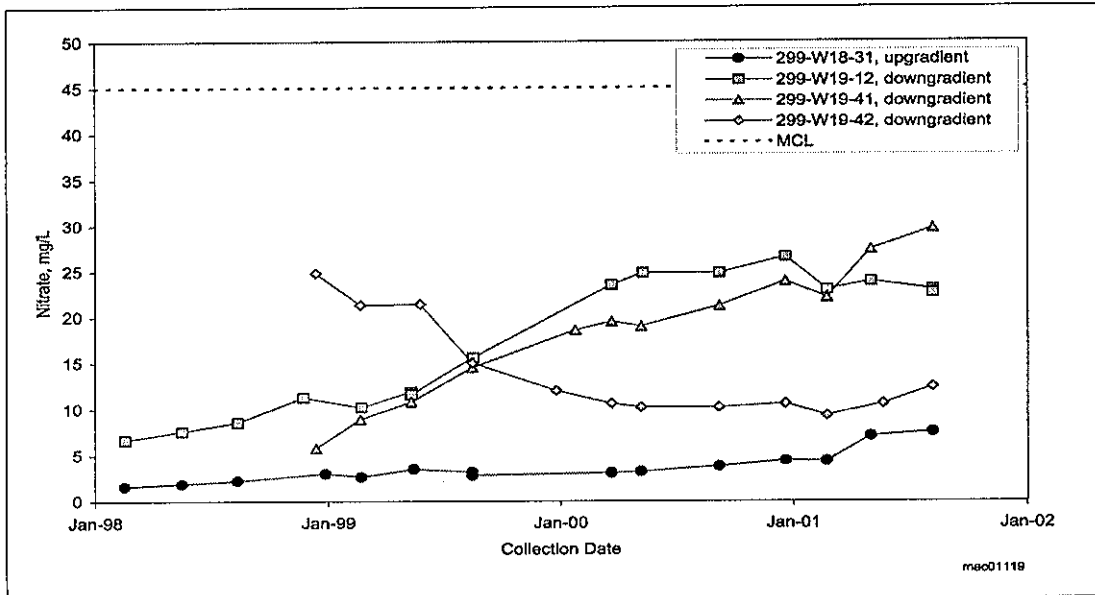
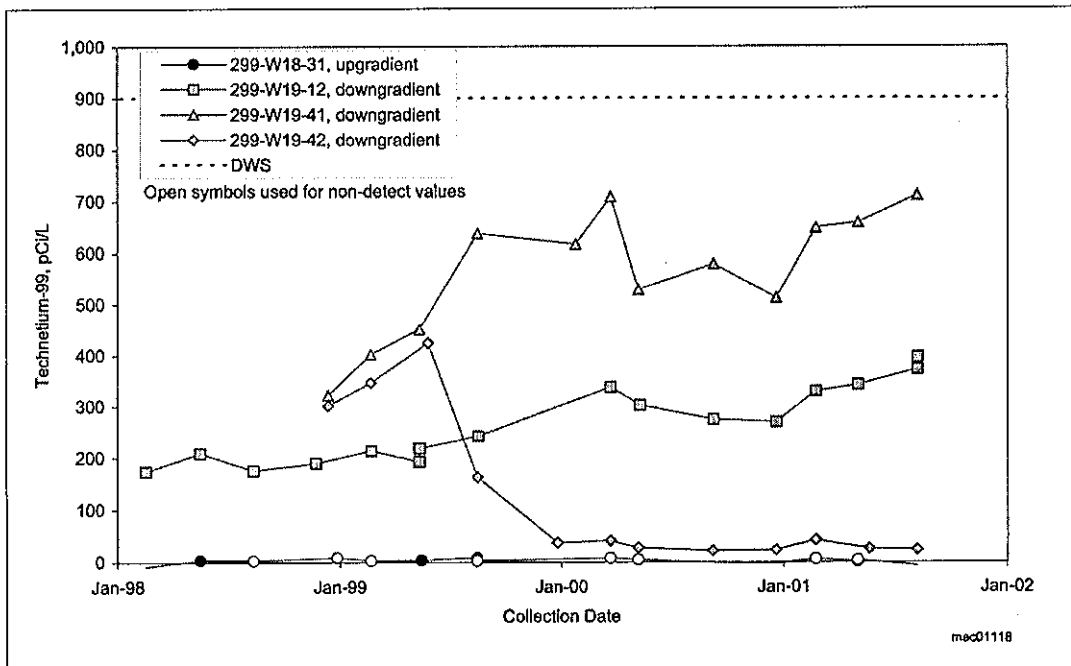


Figure 5.7. Technetium-99 Measurements at Wells 299-W18-31, 299-W19-12, 299-W19-41 and 299-W19-42 (PNNL-13404)



In these monitoring wells the groundwater contaminants that are present and apparently derived from waste processing sources are technetium-99 and nitrate. The first indication of tank waste contaminants in groundwater occurred at borehole 299-W19-12 where a nitrate concentration of about 40,000 parts per billion (ppb) was measured in 1983 (Figure 5.1). At the same time, a gross beta peak was also observed (Figure 5.2). Presumably, technetium-99 was the primary contributor but no direct measurements are available. Subsequently, around 1990, secondary peak concentrations of nitrate and technetium-99 were measured at this well (Figures 5.1 and 5.2). The technetium-99 peak concentration period is less well defined than the nitrate peak because technetium-99 was not measured as frequently (i.e., a measurement gap occurs between 1989 and 1992). Maximum technetium-99 and nitrate values of 2,350 pCi/L and about 18,000 ppb, respectively, were measured. Finally, after falling to minimum values between 1994 and 1995, concentrations have been rising in this well (see Figures 5.3 and 5.6 for nitrate and Figures 5.4 and 5.7 for technetium-99). Last reported nitrate and technetium-99 values in 2001 (Figures 5.6 and 5.7, respectively) were about 23,000 ppb and 400 pCi/L.

Sampling data from the RCRA monitoring wells show that relative changes in constituent concentrations with time have been similar in normally upgradient monitoring wells 299-W18-25, 299-W18-31, and 299-W18-30 and different from the downgradient wells. In these wells, technetium-99 has been either not present or in low concentrations. The dominant characteristic is the occurrence of a nitrate concentration peak in early 1995 (see Figure 5.3).

Sampling data from the normally downgradient wells (299-W19-12, 299-W19-31/299-W19-42, and 299-W19-32/299-W19-41) show more complex patterns. In the northern wells (299-W19-31/299-W19-42) nitrate and technetium-99 peak values (Figures 5.4 and 5.5) occur fairly close together, first in 1992 (about 20,000 ppb and 250 pCi/L) and then in late 1996 to early 1997 (about 43,000 ppb and about 750 pCi/L). Minimum values (< 1,000 ppb and < 50 pCi/L) occurred in 1994. In the most recently published data, nitrate, and technetium-99 values at these wells (Figures 5.6 and 5.7) remain low or are decreasing (Hartman et al. 2001). In the southern wells (299-W19-12 and 299-W19-32/299-W19-41) nitrate and technetium-99 peaked in late 1993 (about 18,000 ppb and 2,000 pCi/L at 299-W19-32). Values then remained low for the most part until 1997 to 1998 and began to rise (Figures 5.6 and 5.7). This trend diverges from that shown in the remaining functional northern well (299-W19-42) where technetium-99 concentrations have decreased to very low values.

5.1.4.2 Data Interpretation

Three primary observations from the groundwater monitoring well data indicate that tank waste has been a source of groundwater contamination at WMA U. First, the occurrence of several short-term pulses of linked nitrate and technetium-99 concentrations in several downgradient groundwater monitoring wells on the east side of WMA U indicates a nearby tank waste source. This inference is supported by the observation that technetium-99 has been detected at elevated concentrations only in the downgradient monitoring wells. A high chromium concentration (about 100 ppb) was also noted in monitoring well 299-W19-32 in July 1993 that coincided with the high technetium-99 peak (about 2,000 pCi/L) in the same sample suggesting a potential tank waste source for chromium as well. However, two later chromium peaks were measured at this same well that were associated with increases in metal corrosion elements nickel and iron.

Therefore, it seems more likely that well casing corrosion products are the source of occasional elevated chromium concentrations.

Second, sequential nitrate/technetium-99 pulse occurs at several downstream monitoring wells indicating more than one contamination event. Also, nitrate to technetium-99 concentration ratios change between pulses. These observations suggest multiple contamination sources that may be different vadose zone tank waste sources or a combination of a primary tank waste source and sources outside the WMA. While the source of technetium-99 is probably tank waste, nitrate sources in addition to tank waste are abundant. Sources that could have contributed nitrate contamination to local groundwater includes U Pond discharges, the 216-U-14 ditch discharges, the suite of ditches and cribs just to the west of WMA U (e.g., 216-Z-1D and 216-Z-20), and contaminated vadose zone soil in WMA U. Discharges from the 216-Z-20 crib are the most recent (*Groundwater Impact Assessment Report for the 216-Z-20 Crib, 200 West Area* [WHC-EP-0674]).

Third, migration of tank waste away from WMA U has been retarded by local groundwater flow perturbations caused by liquid waste discharge into the 216-U-14 ditch just east of WMA U in the early 1990s. Recharge from this event caused a temporary reversal of the upgradient downgradient conditions in the nearby groundwater monitoring wells. Normally, the wells on the west side of WMA U are upgradient relative to the wells on the eastern side of WMA U. However, from mid 1993 to early 1996 water level measurements were lower in the western versus eastern wells indicating a reversal in the hydraulic gradient orientation. Since 1996, the normal condition of a dominant easterly flow direction has been reestablished. The impact of this event on tank waste migration is discussed below.

The combination of apparent multiple contamination events and short-term changes in local groundwater flow conditions complicates data interpretation. An approach for explaining the chronology of various contamination and migration events is to consider pulse events that are characterized by similar nitrate to technetium-99 ratios in the context of well location and the temporal changes in hydraulic gradient orientation.

The most concentrated technetium-99 contamination event (maximum concentration of 2,350 pCi/L) was first observed at well 299-W19-12 in 1990. A nitrate peak of about 18,000 ppb occurred about the same time in this well. This occurrence is the clearest indication of tank waste migration to the unconfined aquifer and presumably that with the highest observed impact on groundwater contamination. At the time the predominant flow direction was probably easterly suggesting that the plume originated underneath WMA U and was migrating eastward. A second occurrence of a similar peak (maximum technetium-99 and nitrate values of about 2,000 pCi/L and 18,000 ppb, respectively) occurs at well 299-W19-32 in late 1993 just south of well 299-W19-12. By late 1993, the impact of the 216-U-14 ditch discharges on groundwater flow was indicated by the reversal of upgradient-downgradient relationships between eastern and western wells such that the potential for groundwater flow was no longer easterly. It is suggested that these two peak concentration observations are measurements of the same volume of contaminated groundwater that had migrated east of 299-W10-12 and was then diverted southward by recharge created by the 216-U-14 discharge event in 1991.

A different and earlier contamination event is suggested by the more nitrate-rich peak concentrations (about 40,000 ppb) that were measured in late 1983 at well 299-W19-12. A gross beta peak of about 750 pCi/L was also closely associated with the nitrate and may be largely technetium-99. A second indication of this peak may have occurred at well 299-W19-31 in mid 1996 when a nitrate peak of about 43,000 ppb was measured. A technetium-99 peak (about 750 pCi/L) occurred in mid 1996, preceding the nitrate peak slightly. It is noteworthy that this nitrate to technetium-99 ratio is distinctly different than that described above. If the pulses at these two monitoring wells indicate migration of the same groundwater volume, the relationship between the migration path and the groundwater flow perturbations is not simple. By mid to late 1996, water level measurements once again showed an easterly flow direction. If the contamination seen in 1983 at 299-W19-12 had passed to the east of that location before 1993, perhaps recharge from the 216-U-14 discharge event forced northwesterly migration of this contamination and subsequent reversal to the east past 299-W19-32 after 1996.

A third distinct contamination and migration event may be indicated by the nitrate pulse occurring between 1993 and 1996 in the upgradient wells 299-W18-25, 299-W18-30 and 299-W18-31. Maximum nitrate concentrations from 12,500 to 20,000 ppb were measured in early 1995. Essentially no technetium-99 is associated with this pulse. The timing of the nitrate pulse coincides with reversal of the local hydraulic gradient from easterly to westerly suggesting that the observed nitrate could have been under WMA U. However, the lack of technetium-99 suggests sources other than tank waste. It is conceivable that by the time the 216-U-14 recharge effects took place, the technetium-99 from tank waste had migrated too far east to reverse migrate as far as the western and northern sides of WMA U. Subsequent migration of this contamination, presumably to the east, is not clearly identifiable in downstream wells.

Since the mid 1990s, the southeastern wells (299-W19-12 and 299-W19-41) show gradually increasing nitrate and technetium-99 concentrations although the ratios are not constant. On the other hand, the northeastern well (299-W19-42) shows lower, quasi steady state concentrations of nitrate and greatly diminished technetium-99 concentrations. These data may indicate the commingling of various contaminants from other events that are now at the southeastern corner of WMA U and are migrating away from WMA U as easterly flow continues. The reduction of contamination in the northern well may indicate some southerly component to the migration pattern.

The preceding discussion of groundwater contamination indicates the complexity of contamination and migration events that have occurred in WMA U. Given the measured technetium-99 concentrations and the sharp changes in concentration observed in the 299-W19-12 well in 1988, a nearby relatively concentrated source is indicated. It is reasonable to hypothesize that a contaminated vadose zone source is the dominant source for the observed technetium-99 contamination. The particular vadose zone source is not known. At the same time, if vadose zone contamination is the source of technetium-99 in the unconfined aquifer, minimal contamination has been contributed. Only two measurements have exceeded the 900 pCi/L maximum concentration level and these have only occurred once in each of two monitoring wells.

5.1.5 Surface Water and River Sediment

Based on contaminant plume maps in *Hanford Site Groundwater Monitoring for Fiscal Year 2001* (PNNL-13788), surface water and river sediment contamination has not occurred related to contamination releases associated with WMA U.

5.2 POTENTIAL CORRECTIVE ACTION REQUIREMENTS

The purpose of this addendum is to propose field investigations in the vicinity of WMA U to characterize these sites sufficient to reach a decision as to whether corrective action is needed. The RCRA corrective action process as specified in Section 7 of the HFFACO is used to establish the framework within which vadose zone investigations at WMA U are planned and conducted. Based on Section 7.5 of the HFFACO, any required corrective action at WMA U will be conducted to comply with federal and state environmental laws and promulgated standards, requirements, criteria, and limitations that are legally applicable or relevant and appropriate requirements under the circumstances presented by the release or threatened release of dangerous substances, pollutants, or contaminants. Site-specific and plateau-wide potential applicable or relevant and appropriate requirements are identified and discussed in Section 2.0 and Appendix F of DOE/RL-99-36 that was prepared pursuant to HFFACO Milestone M-45-51. DOE/RL-99-36 includes identification of potential corrective action standards for protection of human health and the environment.

Only two potentially applicable or relevant and appropriate requirements from the list in Appendix F of DOE/RL-99-36 are not applicable or relevant and appropriate requirements for this addendum. These requirements are related to emissions of asbestos-related material during disposal or demolition and renovation activities (“National Emissions Standards for Asbestos” [40 CFR 61, Subpart M]).

5.3 POTENTIAL IMPACTS TO PUBLIC HEALTH AND THE ENVIRONMENT

This section presents a preliminary conceptual model of the vadose zone portion of the groundwater exposure pathway because the vadose zone is the focus of this addendum. The vadose zone conceptual model is a set of working hypotheses made up of elements of tank waste characteristics, past leak characteristics, geology, hydrogeology, and driving forces that include infiltration from precipitation and human sources of water. The data, both existing and to be collected, will be used to test these hypotheses. If the hypotheses are consistent with the data, then that consistency would initially be deemed an endorsement. If the hypotheses are not consistent, then the hypotheses will be revised in an effort to refine and improve the conceptual model.

DOE/RL-99-36 focuses on all potential exposure pathways, including groundwater. The conclusions in the following subsections are based on preliminary data and are tentative; they will be subject to refinement as data are gathered during the RFI/CMS process.

This section presents a preliminary vadose zone conceptual model for WMA U. The conceptual model is based on information presented in Sections 4.0 and 5.1 of this addendum and is, therefore, intended to be preliminary. The exposure pathway in this conceptual model is limited

to near-surface releases associated with the waste tanks and transport in the vadose zone. A generic set of release and migration processes are shown conceptually in Figure 5.8. Through the corrective action process, the concepts illustrated in Figure 5.8 must ultimately be confirmed, disproved, or shown to be inconsequential in the context of retrieval and closure, including the WMA U endstate. A generalized conceptual model is provided in Section 4.0 of DOE/RL-99-36 and identifies the preliminary conceptual model of this addendum.

The data and evaluations previously discussed are integrated and summarized in this section in the form of a preliminary vadose zone conceptual model. The conceptual model is a preliminary working effort because the data are not complete, not all the data have been evaluated, and in many cases, the data are not validated. The purpose of the vadose zone conceptual model is to help focus the preliminary field data collection. The vadose zone conceptual model will be refined in the site-specific Phase 1 RFI/CMS field investigation report for WMAs U based on evaluation of the data collected under the guidelines in this addendum and the continued evaluation of existing data.

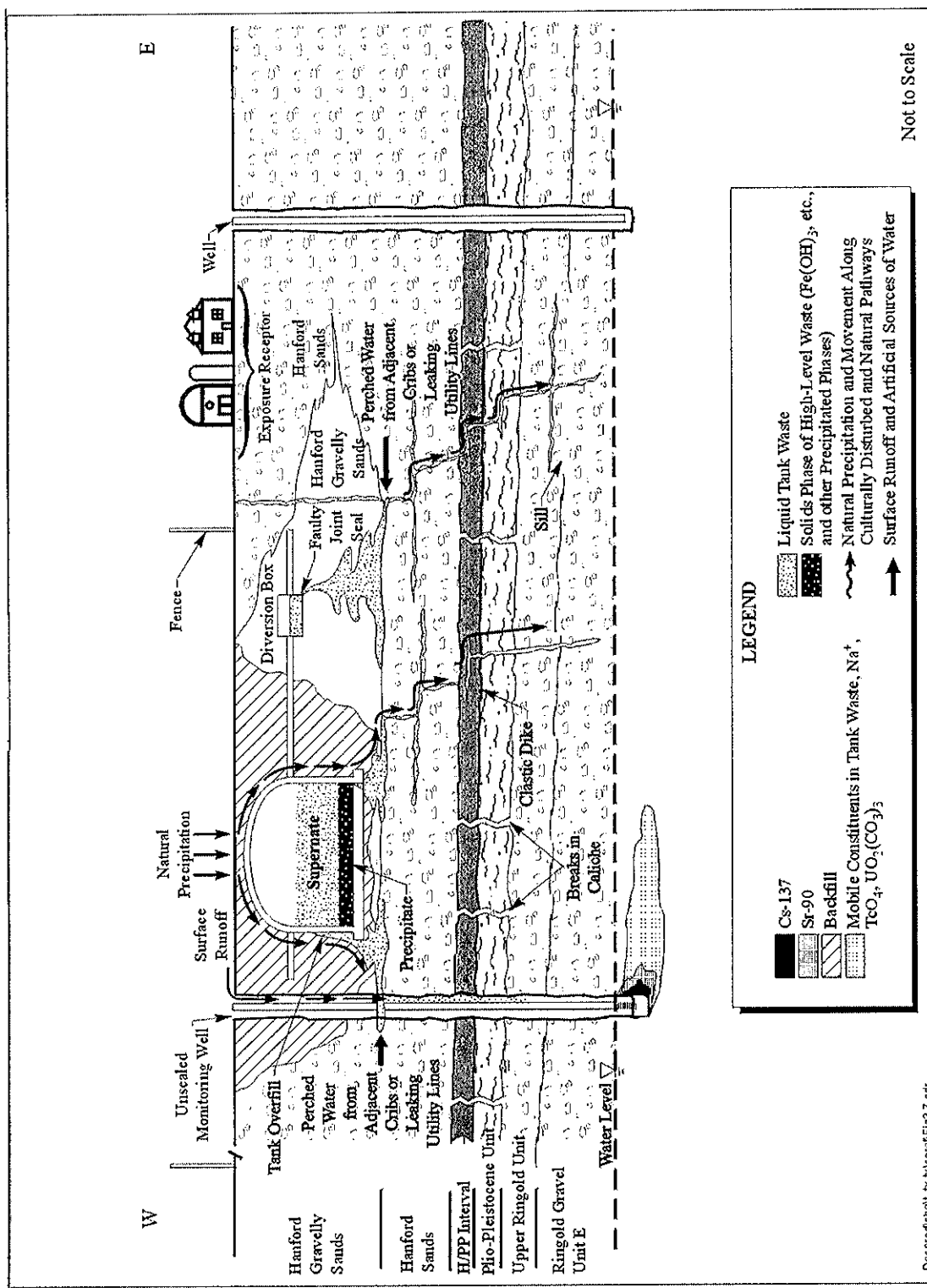
The contaminant sources, mechanisms for these contaminants to be released into other environmental media, potential types of movement through the vadose zone, and one type of potential receptor are shown conceptually in Figure 5.8. The schematic illustrated on Figure 5.8 — together with estimates of values for key parameters (e.g., contaminant concentrations) — are a part of the basis for assessing initial human health risks associated with the various contaminants and receptors.

The results of the human health risk assessment will be provided in the site-specific Phase 1 RFI/CMS field investigation report for WMAs U. The vadose zone conceptual model is used in this addendum to qualitatively express the current understanding of the following:

- Pathways that contaminants may follow to the groundwater based on the integration of contaminants, hydrochemical, hydrogeologic, and geologic data (inferences are made on relatively sparse and unevenly distributed data)
- Contaminant sources with most of the available data for source locations for the upper 40 m (130 ft) of the vadose zone (inference is made to the presence of contaminants in the lower vadose zone based on groundwater contamination and historic records of water levels).

Key aspects of the WMA U vadose zone conceptual model required to support this addendum are summarized in the following subsections.

**Figure 5.8. Preliminary Generalized Waste Management
Area U Vadose Zone Conceptual Model**



5.3.1.1 Sources

5.3.1.1.1 Chemical Processing

Irradiated nuclear fuel from the Hanford Site plutonium production reactors contained fission products and lesser amounts of neutron activation products as well as the unreclaimed uranium and transuranic radionuclides. Plutonium was chemically extracted from the fuel matrix at T Plant and S Plant in the 200 West Area and B Plant and A Plant in the 200 East Area.

The U tank farm received waste generated by a variety of major chemical processing operations. The U tank farm contains aqueous waste generated from four different operations: post-war bismuth phosphate operation (1946-1956), uranium recovery and scavenging (1952-1958), ITS (1960-1974), and interim stabilization and isolation (1975-present) (RPP-7580).

5.3.1.1.2 Tank-Related Considerations

The SSTs are constructed of a single layer of carbon steel surrounded by a layer of reinforced concrete, which forms the roof and sidewall support. The tanks declared leakers in the U tank farm (Section 5.1.1) apparently failed because of waste transfer leaks and/or accelerated corrosion of the steel liner and leaked through the reinforced concrete.

The vadose zone conceptual model for this addendum focuses on those contamination sources in the vicinity of the SSTs in WMA U. As discussed in Section 5.1 and RPP-15808, one hypothesis for the observed contaminants in the RCRA groundwater monitoring wells is that contaminants from tank leaks have migrated downward through the vadose zone and then traveled in a direction consistent with the local groundwater flow. Releases from the SSTs in WMA U could represent a significant present contamination source in the vadose zone. It is certain that the leaks from those tanks contained several radioisotopes and chemicals commonly found in tank waste (e.g., cesium-137, technetium-99, sodium, chromium, and nitrate). Thus, contaminants (i.e., technetium-99, chromium, and nitrate) that are remnants of these past leaks are likely present in the vadose zone, especially within the finer-grained sediments of the Hanford formation. RPP-15808 provides a discussion of the contaminated areas in WMA U.

5.3.1.2 Geologic Conceptual Model

The geology of the U tank farm was documented after the drywell boreholes were completed in the early 1970s (*Geology of the 241-U Tank Farm* [ARH-LD-138]). The major stratigraphic units of the suprabasalt sediments present beneath WMA U are the Ringold Formation, Plio-Pleistocene unit, and the Hanford formation (in ascending order) (see Section 4.2). Several sources of data were included in evaluating valid conceptual model(s) for the U tank farm geology (ARH-LD-138; BHI-00184; HNF-2603; PNNL-13282; PNNL-13612; RPP-15808). Potential geologic control or influence on contaminant migration in the vadose zone is of particular interest. Elevation maps for stratigraphic units are presented in RPP-15808 and will be used as a source for this information.

Clastic dikes, illustrated conceptually in Figure 5.8, are lenses or tabular bodies, relatively narrow at 18 to 38 cm (7 to 15 in.) (*Geologic Field Inspection of the Sedimentary Sequence at the Environmental Restoration Disposal Facility* [BHI-00230]; BHI-01103), with textural characteristics typically comprised of clay and sand. The presence of clastic dikes has been observed in this WMA. The localized effect of the dikes on contaminant movement may occur over the scale of a few meters, but no direct indication of this movement has been measured. While a clastic dike could increase flow rate, it is less likely to intersect large segments of leaked wastes; when it does, the cross-sectional area of the intersection is small (DOE/RL-97-47). The geologic cross-sections provided in RPP-15808 represent the preliminary working geologic conceptual model for this work plan.

5.3.1.3 Hydrologic Properties

Preliminary hydrologic property values will be provided in the site-specific Phase 1 RFI/CMS field investigation report for WMA U that will be prepared.

5.3.1.4 Receptors

Receptors are organisms with the potential for exposure to the released contaminants and include both biota and humans. A likely point of exposure for terrestrial biota is in the plant root zone where flora could absorb buried contaminants. Terrestrial animals (especially burrowing animals) may be exposed by direct contact, inhalation, and ingestion of contaminated sediment, water, plants, and animals.

For the receptors, the site-specific Phase 1 RFI/CMS field investigation report for WMA U will use WAC 173-340 Methods B and C exposure scenarios at these WMA boundaries to evaluate human health risks for the chemicals, the Hanford Site risk assessment methodology (DOE/RL-91-45) and the 15 mrem/yr dose above background standard (EPA OSWER Directive No. 9200.4-18) to evaluate human health risks from radionuclides.

The Model Toxics Control Act Method B (defined in WAC 173-340-705) residential scenario is a combination of the risk equations specified in WAC 173-340-720 through 173-340-750 inclusive of sections 173-340-7490 through 173-340-7494. The Model Toxics Control Act Method C (defined in WAC 173-303-706) industrial scenario is a combination of the risk equations specified in WAC 173-340-720 through 173-340-750 inclusive of sections 173-340-7490 through 173-340-7494. WAC 173-340-730 is not applicable to either scenario as it is not expected that WMA U or any remedial activity under consideration will impact surface water.

6.0 WORK PLAN RATIONALE AND APPROACH

The RFI/CMS process is the RCRA-specified method by which risks from releases to the environment are characterized and corrective action alternatives are evaluated and implemented if required to minimize potential risks to human health and the environment. Objectives and data needs must be identified before designing a data collection program to support the RFI/CMS process. The data collected are used as a basis for making an informed risk management decision regarding the most appropriate corrective action(s) to implement. Although the RFI/CMS process is not required currently for WMAs C and A-AX, because they are not classified as RCRA corrective action WMAs, they will be included in the RFI report (HFFACO Milestone M-45-55) to aid in closure decisions for these WMAs. The data needs for field characterization efforts at WMAs C, A-AX, and U were identified through a process that was executed based on the requirements established in the HFFACO commitments identified in Change Control Form Number M-45-98-03 and in Section 6.0 of DOE/RL-99-36. The data needs identified in the planning process will be collected in accordance with DOE/RL-99-36 (Milestone M-45-51) and this addendum.

6.1 RATIONALE

An understanding of subsurface conditions and contaminant migration processes is required to support decision making on interim measures and ICMs, SST waste retrieval, and tank farm closure. A comprehensive list of data needs to support these decisions has been developed based on the current level of understanding. However, it is generally recognized on both a technical and regulatory basis that uncertainties regarding existing contaminant inventory, distribution of contaminants in the vadose zone from past leaks, and uncertainties associated with contaminant migration processes are of primary importance to future decision making for waste retrieval and tank closures. The need to reduce these uncertainties through field and laboratory investigations serves as the basis for initiating characterization activities through this addendum.

Characterization objectives and data needs for WMAs C, A-AX, and U were developed during the planning process that was carried out for the Phase 1 RFI/CMS work plan (DOE/RL-99-36) and this addendum. A separate planning process (RPP-14430; RPP-15808) was conducted to support the development of this document.

The planning process is a planning tool to aid in the determination of the type, quantity, and quality of data needed to take the next step in the iterative process of characterizing a contaminated site or area. There are a number of possible approaches to implementing the planning process. The planning process used to identify data collection activities in this addendum is described in Section 6.0 of DOE/RL-99-36 and summarized in this section.

Before initiating meetings to discuss characterization activities to be conducted in the FY 2004 timeframe, the Tank Farm Vadose Zone Project technical team conducted a review of existing information that included published and unpublished reports, interpretations of historical and recent geophysical survey data, and information from previous DQO meetings. To prioritize data needs for inclusion in the FYs 2004 and 2005 effort, a review of the available information on the current state of knowledge of WMAs C, A-AX, and U subsurface contamination was

conducted by the Tank Farm Vadose Zone Project technical team. The review results were incorporated into RPP-14430 and RPP-15808 and summarized in Sections 3.0 and 5.0 of this addendum.

A meeting was held on June 3, 2003 that focused specifically on the data needs for the field characterization efforts to be conducted at WMAs C, A-AX, and U. These meetings served to identify the following:

- Existing data and what is currently known about WMAs C, A-AX, and U
- Data needs that will likely be satisfied by FYs 2004 and 2005 characterization activities
- Options for data collection from the additional characterization activities.

The meeting included representatives from Ecology, DOE, and Hanford Site contractors.

Meetings held as a part of the planning process involved varying levels of involvement by all participants. The planning meeting provided a foundation of existing information and identification of characterization options for consideration by the decision makers.

Through the planning process, it was determined that the primary goal of the WMAs C, A-AX, and U field investigation is to implement vadose zone characterization activities that will support the iterative process of improving the understanding of inventory (i.e., nature and extent of past releases) and contaminant migration processes (fate and transport) necessary to support risk assessments. Additional characterization data are needed to support near-term corrective measures decisions and SST waste retrieval and tank farm closure decisions.

The characterization effort will provide data that, when combined with historical data, will improve the ability to make informed corrective measures, waste retrieval, and WMA or tank farm closure decisions.

6.2 DATA NEEDS

Current understanding of the nature and extent of contamination at WMAs C, A-AX, and U is based largely on order-of-magnitude estimates of past leak volumes and inventories and on historical information on the distribution of gamma-emitting radionuclides measured to a depth of 30.5 to 45.7 m (100 to 150 ft) in drywells located around the tanks. Historical drywell gross gamma data was collected from the early 1960s through 1994; however, detailed analysis of the gross gamma data has only recently been conducted. Four reports have been issued on this subject, one for the A tank farm (*Analysis and Summary Report of Historical Dry Well Gamma Logs for 241-A Tank Farm-200 East* [RPP-8820]) one for the AX tank farm (*Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-AX Tank Farm – 200 East* [RPP-8821]) and one for the C tank farm (RPP-8321) and one for the U tank farm (RPP-7729).

Comprehensive spectral gamma logging of all drywells in WMAs C, A-AX, and U was completed in the 1996 through 1999 period. Spectral gamma logging reports have been issued for the C, A, AX, and U tank farms (GJO-HAN-8; GJO-HAN-12; GJO-HAN-18; GJO-HAN-23). Spectral gamma logging data provide greater insight into the distribution and movement of specific gamma-emitting contaminants (e.g., cesium-137). However, limited data exist on the distribution of non-gamma-emitting mobile tank waste contaminants (e.g., technetium-99, hexavalent chromium, and nitrate). While there is emerging data on the

distribution and movement of tank waste contamination in the groundwater, the data are not sufficient to support more than qualitative hypotheses on the specific sources of contaminant releases responsible for the observed groundwater contamination.

During the planning process, the participants determined that the primary focus of the FY 2004 data collection effort at WMAs C, A-AX, and U should be directed toward characterizing the contamination source in the vicinity of the probable largest releases. This effort should improve the understanding of tank leak inventory and distribution to support testing and refining a site-specific conceptual model for past operational leaks and contaminant migration processes. A number of characterization technologies, including screening techniques, were considered. Because the current understanding of the distribution of radionuclides in the leak-contaminated vadose zone is still limited and is based primarily on indirect evidence, the focus of the FYs 2004 and 2005 data collection program at WMAs C, A-AX, and U will be on sampling the vadose zone soils in areas of known tank leaks, spills, and overfill events within the tank farms and analyzing the samples for a range of contaminants of interest.

6.3 CHARACTERIZATION OPTIONS

The Tank Farm Vadose Zone Project technical team plans to use existing information and the characterization data collected during the Phase 1 characterization to develop a best basis or best estimate of the concentration and distribution of CoCs in WMAs C, A-AX, and U. This will involve the integration and synthesis of historical data, process knowledge, in-tank inventory models, and the characterization data collected during Phase 1. The integration and synthesis of these data will require interpolation and extrapolation due to the limitations of collecting samples within the tank farms. This effort will result in a conceptualization of CoC concentrations and distributions that would be used to evaluate human health and environmental risks.

Based on data needs identified in Section 5.0 of RPP-14430 and RPP-15808 and in the planning meetings, a number of characterization options were considered for the FY 2004 effort at WMAs C, A-AX, and U. These characterization options included installing new boreholes; decommissioning and/or extending existing boreholes; using direct-push technology; using auger drilling; and using nonintrusive geophysical techniques. These options are based on characterization techniques and innovative technologies identified in Section 6.3 of DOE/RL-99-36 for methods that have been successfully used on the Hanford Site. These options and potential deployment locations were evaluated in terms of the type of information that could be provided, as well as the technical risk associated with deployment during FY 2004. Although all of the options considered could provide valuable data that would serve to improve the understanding of subsurface contamination, a number of the options were considered to be of lesser value or not feasible due to technical risk for the characterization effort to be implemented in FY 2004. The list of characterization options considered during the planning process, along with the rationale for including or omitting each option from FYs 2004 and 2005 effort, is provided in RPP-14430 and RPP-15808.

The characterization options selected for implementation at WMAs C, A-AX, and U during FY 2004 and 2005 are provided in Table 6.1 and consist of vertical borehole installation near selected waste releases, direct push, and gamma monitoring of laterals. Table 6.1 includes the sampling method, implementation design, and rationale. The planning process identified four

sites for installation of vertical boreholes (tanks C-105, U-104, U-112 and UPR-200-E -82). This initial (Phase 1) site-specific investigation to be conducted in FY 2004 is anticipated to entail the installation of two vertical boreholes near tank C-105 and UPR-200-E -82 along with direct-push technology at UPR-200-E-82 plus lateral geophysical surveys under tanks in the A tank farm. Two additional vertical boreholes at U tank farm will be installed in FY 2005, provided funding is available and its installation is consistent with other schedule priorities.

6.3.1 Installation of Vertical Boreholes

Several options were considered for collection of deeper vadose zone data. The preferred option was installation of vertical borehole(s). Four locations, in the vicinity of tanks C-105, U-104, U-112, and UPR-200-E -82, will receive boreholes as part of the initial site-specific investigation in FYs 2004 and 2005. Vadose zone samples will be collected as the borehole(s) are advanced down to the maximum extent of contamination, or groundwater in WMA C and to the maximum extent of contamination unless refusal is encountered in WMA U. Determination of maximum extent of contamination will be through laboratory analyses of technetium-99 water leach samples and nitrate water leach samples with a threshold detection limit of less than 10 pCi/g. Refusal is determined by 100 blows per 15.2 cm (6 in). This option was selected because a vertical borehole at these locations (i.e., in the vicinity of tanks C-105, U-104, U-112, and UPR-200-E-82) would provide source characterization along with distribution of contaminants at the locations of interest from within WMAs C, A-AX, and U. Source characterization would do the following:

- Provide a basis for estimating contaminant inventories and processes that would control the migration of contaminants
- Support evaluation of the correlations between concentrations of CoCs and existing gamma data, and potentially support evaluation of the relationship between the CoCs in the soil and the concentrations of CoCs present in the tanks at the time the leaks were believed to occur
- Support assessment of contaminant mobility; potential drivers (e.g., moisture content); and the effects of tank leaks on soil properties to support predictive numerical modeling efforts necessary to evaluate potential future groundwater impacts, the associated risks, ICMs, and further characterization as warranted.

Source characterization efforts also would involve identifying what contaminants are present and, subsequently, identifying the potential CoCs for corrective action, waste retrieval, and closure decisions. If correlations between the CoCs and available gamma data can be established, there is a potential that the wealth of existing gross gamma and spectral gamma data can be used to better understand the location and distribution of CoCs in the vadose zone.

Table 6.1. Proposed Waste Management Areas C, A-AX, and U Phase 1 Characterization Design (2 Sheets)

Area of Interest	Screening Technology	Sampling Method	Implementation Design*	Rationale
Tank C-105	Gross alpha/beta; gamma spectrometry, soil moisture	Vertical borehole. Borehole advanced using cable tool drilling rig or pile driver with split-spoon or core barrel sampler for subsurface sample recovery.	Vertical borehole planned to maximum extent of contamination. Collect soil samples by split-spoon techniques and grab samples at a minimum of 3-m (10-ft) intervals beginning 9 m (30 ft) bgs and continue to maximum extent of contamination. All samples would be conditionally analyzed for the CoCs.	The vertical borehole needed to determine CoC distribution, support risk assessment.
UPR-200-E-82	Gross alpha/beta; gamma spectrometry, soil moisture Gross gamma; moisture	Vertical borehole. Borehole advanced using cable tool drilling rig or pile driver with split-spoon or core barrel sampler for subsurface sample recovery. Direct push technology.	Attempt to drill to maximum extent of contamination. Collect soil samples by split-spoon and grab sample techniques at 3-m (10-ft) intervals beginning 3 m (10 ft) bgs and continue to maximum extent of contamination. All samples would be conditionally analyzed for the CoCs. Pushes until refusal to ascertain lateral extent of technetium migration over area larger than surface expression.	The vertical boreholes needed to determine CoC distribution, support risk assessment. Field sample analysis of this release indicates a substantial potential for downward and horizontal migration of contaminants. This investigation activity will support assessment of this release.
Tank U-104	Gross alpha/beta; gamma spectrometry, soil moisture	Vertical boreholes. Boreholes advanced using cable tool drilling rig or pile driver with split-spoon or core barrel sampler for subsurface sample recovery.	Attempt to drill to maximum extent of contamination. Collect soil samples by split-spoon techniques and grab samples at 3-m (10-ft) intervals beginning 9 m (30 ft) bgs and continue to maximum extent of contamination. All samples would be conditionally analyzed for the CoCs.	The vertical borehole needed to determine CoC distribution, support risk assessment, and correlate to local groundwater observations.

Table 6.1. Proposed Waste Management Areas C, A-AX, and U Phase 1 Characterization Design (2 Sheets)

Area of Interest	Screening Technology	Sampling Method	Implementation Design*	Rationale
Tank U-112	Gross alpha/beta; gamma spectrometry, soil moisture	Vertical boreholes. Boreholes advanced using cable tool drilling rig or pile driver with split spoon or core barrel sampler for subsurface sample recovery.	Attempt to drill to maximum extent of contamination. Collect soil samples by grab sample techniques at 3-m (10-ft) intervals beginning 9 m (30 ft) bgs and continue maximum extent of contamination. All samples would be conditionally analyzed for the CoCs.	The vertical borehole needed to determine CoC distribution, support risk assessment, and correlate to local groundwater observations.
Tanks A-105 and A-104	Gamma	Laterals under tanks using gamma probe.	Attempt to collect gamma data to maximum extent of the laterals.	Correlate gamma data to validate size of the leak. If minimal concentrations of Cs-137 are found in laterals measurements about 3 m (10 ft) from the leak location, then the released tank waste volume will be constrained to a minimal value.

*Figure 6.1 indicates the proposed locations as discussed in the implementation design.

bgs = below ground surface.

CoC = contaminant of concern.

6.3.1.1 Borehole Locations

Candidate locations for vertical borehole installation considered in the planning process are presented in RPP-14430 and RPP-15808. Each option evaluated was identified because samples from the identified locations could provide data to address source characterization (i.e., nature of contamination); location and distribution (i.e., extent of contamination); and transport pathways and processes (i.e., contaminant fate and transport). An additional consideration was potential programmatic risk (i.e., risk to the program if the characterization effort were unsuccessful) associated with FYs 2004 and 2005 deployment. Each option could provide data to address a number of different questions and data gaps. A location (i.e., vicinity of tanks C-105 and UPR-200-E -82) has been identified from these evaluations (Figure 6.1). The locations were selected based on historical knowledge of WMAs C, A-AX, and U (e.g., waste transfer records, leak history, previous vadose zone characterization efforts, historical gross gamma logging data, recent spectral gamma logging data, and RCRA groundwater assessment findings). Based on the information provided in RPP-14430 and RPP-15808 and as summarized in Sections 3.0 and 5.0, the planning participants decided that one of the areas of interest in the WMAs C, A-AX, and U was in the vicinity of tank C-105. A vertical borehole is recommended to be placed southwest of tank C-105, between tanks C-105 and C-104 (Figure 6.1) as close to drywell 30-05-07 as feasible (Figure 6.2). The spectral gamma database shows a contamination zone indicated by high cesium-137 concentrations at this drywell between tanks C -105 and C-104. Currently, neither the waste leak volume nor the real distribution of contaminants in the vadose zone is very well understood. Consequently, it is recommended that sampling and analysis of contaminated soils be completed if possible. Gaining access to the contaminated zone does present difficulties. The high contamination zone is only expressed at drywell 30-05-07 which is very close to the tank sidewall and it is likely that some contamination exists underneath the tank.

Contaminant information is not available for this zone except for the cesium-137 isotope but it is expected that technetium-99 will be present in this zone. The concentration and distribution of technetium-99 can be partially determined by completing a deep borehole near the middle of the plume.

For UPR-200-E -82, a vertical borehole is recommended to be placed immediately north of the diversion box 241-C-152 (Figures 6.1 and 6.3). Review of the historical database indicates an extensive and fairly well-defined contaminant zone from a past leak event. Historical records and previous field characterization efforts indicate that the largest contamination events in WMA C were two UPRs of high-activity derivatives of PUREX waste in waste transfer lines at the western edge of WMA C, UPR-200-E-82 in 1969 and UPR-200-E-86 in 1971. Both transfer line leaks are estimated to have released collectively about 11 Ci of technetium-99, the primary constituent of concern for future groundwater contamination. The contamination zone created by UPR-200-E-82 is the preferred alternative site even though a smaller volume, but more concentrated leak occurred here. The historical documentation of the leak is more complete at this site and locating the contamination zone should be more straightforward. The combination of these data with the tank C-105 borehole data should also provide a useful indication of the effects of tank structures on infiltration rates.

Figure 6.1. C Tank Farm Borehole Locations

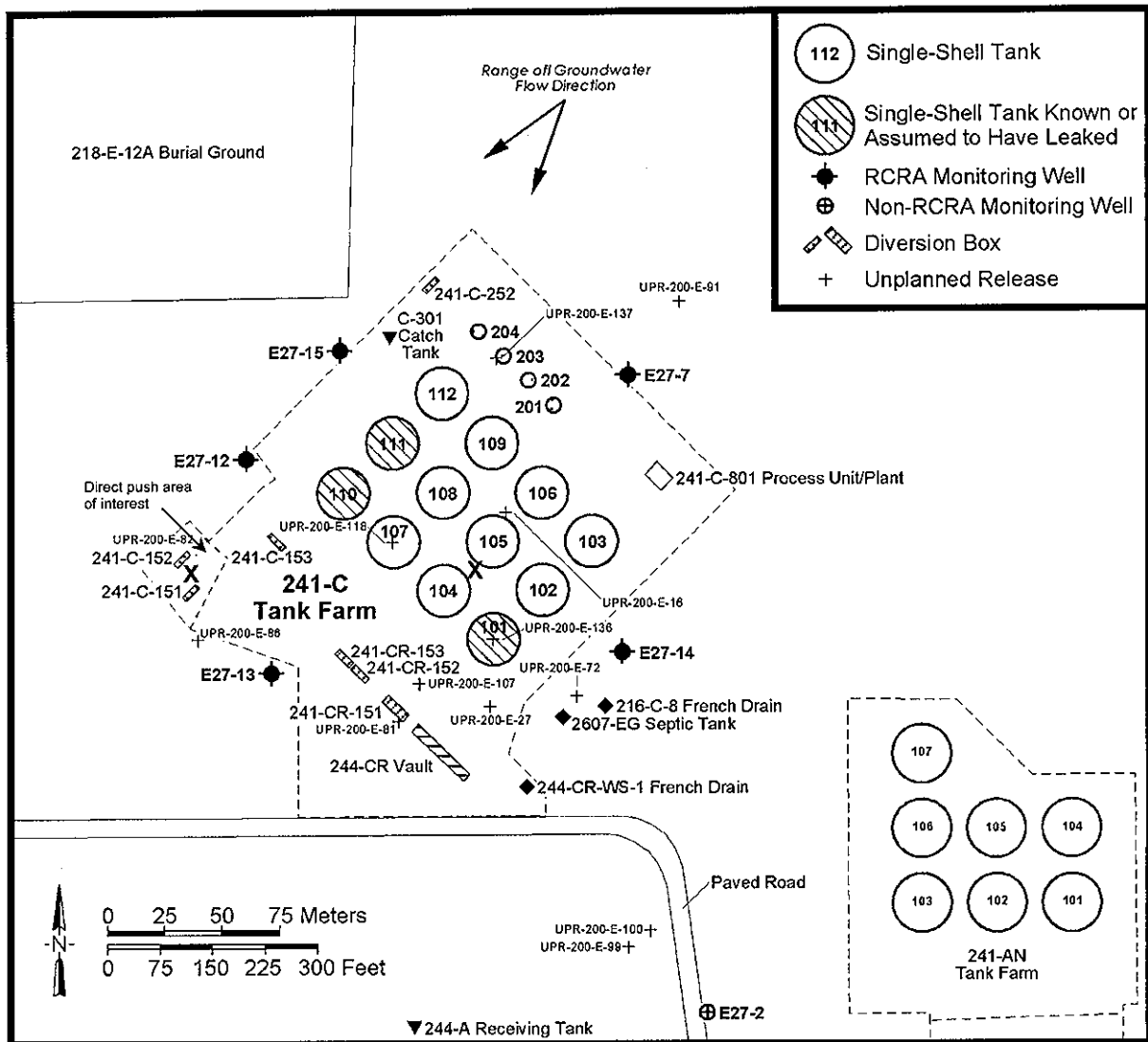


Figure 6.2. Plan View of the C Tank Farm Showing Drywells

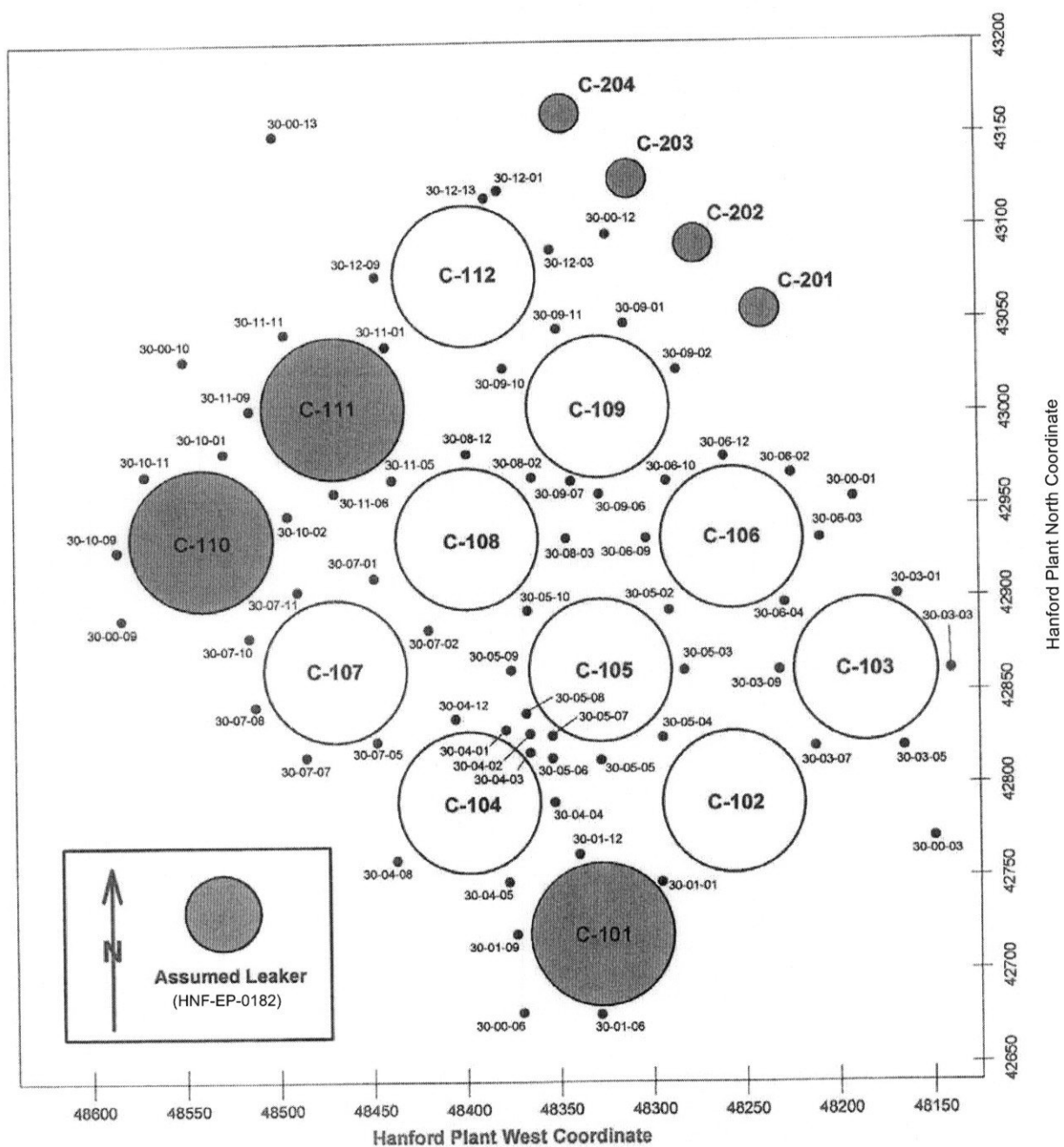
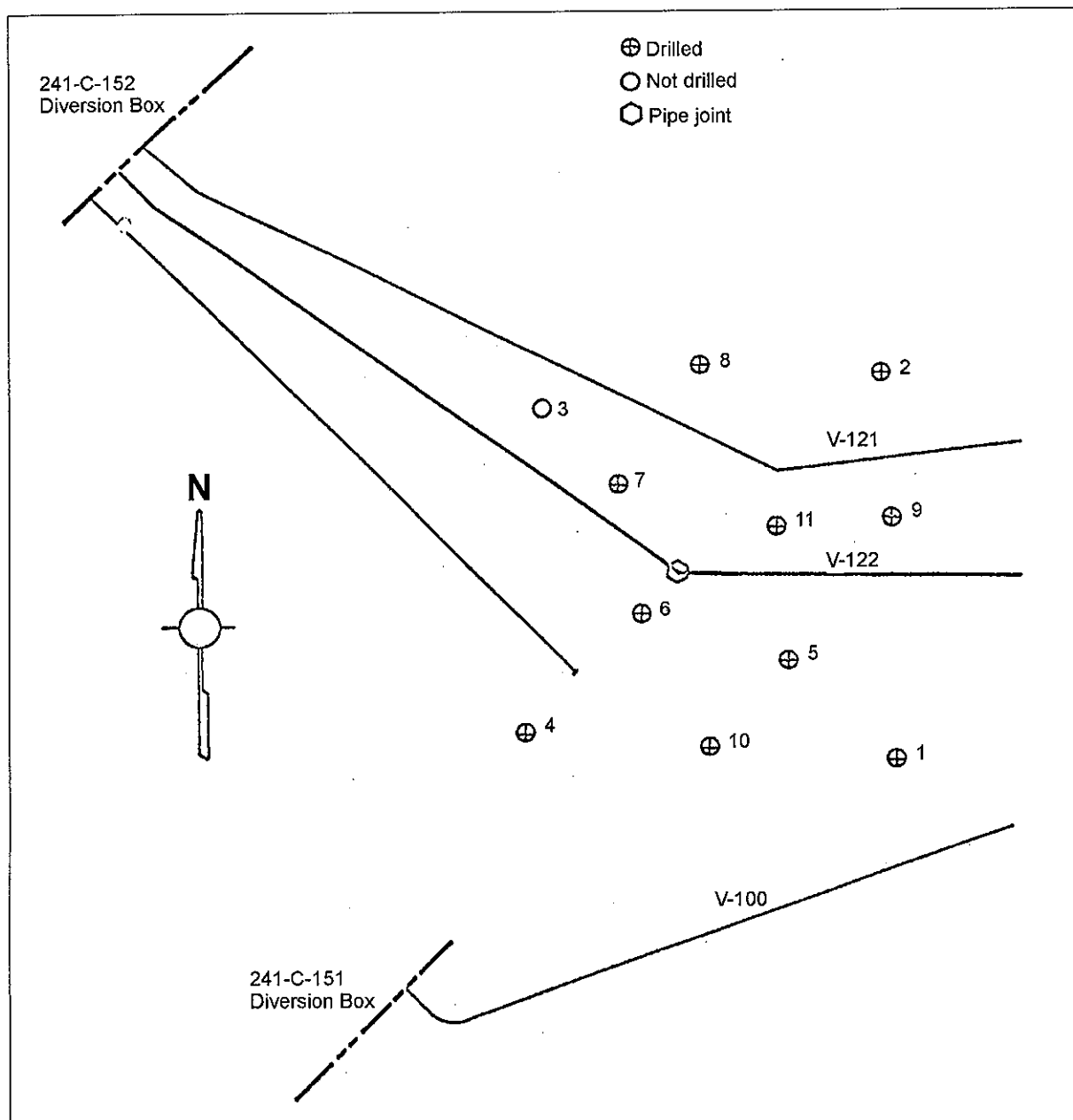


Figure 6.3. Sketch of Well Locations



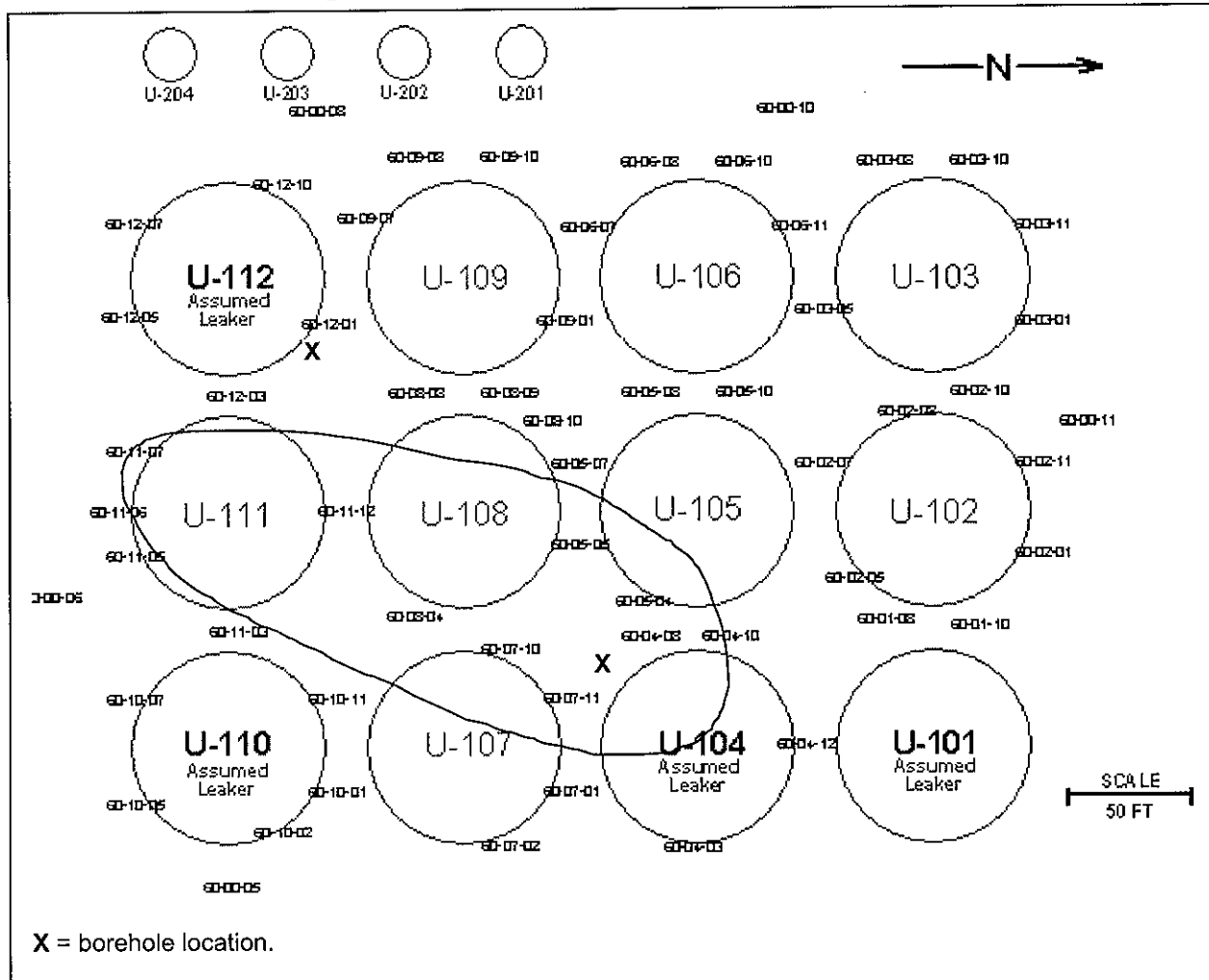
A third vertical borehole is recommended to be placed southeast of tank U-104 (Figure 6.4). Historical records and spectral gamma data clearly indicate that tank U-104 leaked and caused the most extensive contamination of the vadose zone in WMA U. Review of spectral gamma data indicates that the leading edge of the contaminant zone attributed to tank U-104 extends to the southwest far away as drywells around tank U-111. It is proposed to drill a sampling borehole through the vadose zone in the area closest to the source of the leak. As the leak occurred under tank U-104, the closest available characterization location lies between drywells 60-07-11, 60-07-10, and 60-04-08. At this location the uranium is found between 50 and 90 ft (15 and 27 m) bgs.

A fourth vertical borehole is recommended to be placed northeast of tank U-112 (Figure 6.4). Two high concentration zones of cesium-137 (up to 10^9 pCi/g) are present in drywell 60-12-01 adjacent to the north side of the tank, concentration values that exceed gamma concentrations in all other contaminated areas in WMA U. This distribution strongly indicates the occurrence of a leak near the bottom of tank U-112. Historical data indicate a relatively small leak of REDOX waste in the late 1960s. REDOX waste was highly contaminated and while the size of the leak may limit the inventory of mobile constituents, it is important to quantify the current nature and extent in the vadose zone for purposes of risk assessment. Therefore, it is recommended that a borehole be drilled as near to drywell 60-12-01 as possible.

6.3.1.2 Borehole Construction and Sampling Methodology

The final borehole construction and sampling methodology for the vertical boreholes in WMAs C, A-AX, and U has not been completed. Installation of these boreholes is targeted to intercept tank waste plumes and could encounter highly contaminated sediments. The proposed sampling methodology to be used during construction of the WMAs C, A-AX, and U boreholes is to collect sediment samples ahead of the casing. There are a number of uncertainties associated with application of this sampling methodology. The primary uncertainty is associated with the potential worker doses resulting from handling highly radioactive samples. Additional uncertainties include sample handling in the laboratory and interfaces between the field and the laboratory. Limitations associated with collecting sediment samples include having to sample without the benefit of gamma ray logging to identify radiation levels. Because of this limitation, the details of the sampling plan will be developed assuming that each sample has the potential to be highly contaminated. The final borehole construction and sampling methodology for the vertical boreholes in WMAs C, A-AX, and U will be designed to maintain compliance with the requirements of the Notice of Construction (*Notice of Construction for Tank Waste Remediation System Vadose Zone Characterization* [DOE/ORP-2000-05]) for drilling operations inside the tank farms and WAC 173-160. The following subsections provide the history and rationale for installation of a borehole at the four locations.

Figure 6.4. U Tank Farm Borehole Locations



6.3.1.2.1 Tank C-105 Borehole

Three approaches to sampling this zone are considered. The first is to drill a slant borehole underneath tank C-105. However, the area is congested with other drywells and piping systems. Also, it is difficult to drill a slant hole at an angle that comes close to the bottom of the tank (e.g., within 10 ft [3 m]). Thus, there is a real possibility that the contamination zone would be missed. The second is to examine the feasibility of deepening the drywell in which high cesium-137 concentrations have been observed (30-05-07) and collecting soil samples down to the Plio-Pleistocene about 76 m (250 ft) bgs. The data to be collected are a complete set of chemical and radiological soil sample analyses with depth. The distribution and concentration of technetium-99 with depth are of particular interest. This database will increase substantially our understanding of the nature and extent of non-gamma-emitting constituents in this zone because no information exists presently.

The third and recommended approach is a vertical borehole located southwest of tank C-105 that would provide confirmation and better understanding of the nature and extent of non-gamma-emitting contaminants in this zone where no information exists (Figure 6.2). A new borehole provides a better opportunity to protect the workers through the highly contaminated zone and still collect quality samples by starting with a larger diameter borehole than the drywell 30-05-07.

6.3.1.2.2 UPR-200-E-82 Borehole

Historical records and previous field characterization efforts indicate that the largest contamination events in WMA C were two UPRs of high activity derivatives of PUREX waste in waste transfer lines at the western edge of WMA C, UPR-200-E-82 in 1969 and UPR-200-E-86 in 1971. Both transfer line leaks are estimated to have released collectively about 11 Ci of technetium-99, the primary constituent of concern for future groundwater contamination. The contamination zone created by UPR-200-E-82 is the preferred alternative site even though a smaller volume, but more concentrated leak occurred here. The historical documentation of the leak is more complete at this site and locating the contamination zone should be more straightforward.

The primary characterization goal is to determine the extent and magnitude of vertical migration of technetium-99 inventory in the vadose zone over a thirty-year period from a pipeline leak (similar to an ancillary equipment pipeline leak) as well as other mobile constituents (e.g., nitrate) at the site. Additionally, information on the migration of technetium-99 in natural conditions within a tank farm to support ancillary equipment study for risk assessments supporting WMA closure is another primary goal for this borehole. A secondary purpose is to characterize technetium-99 and other contaminant migration and perform modeling to confirm conceptual models of contaminant transport.

Therefore, the information obtained by drilling this borehole are:

- Develop an understanding of waste constituent transport mechanisms through a pipeline leak (i.e., ancillary equipment leak analysis).
- Provide pipeline status

- Sample the pipe or external tests of pipe
- Estimate of technetium-99 vadose zone inventory at site.
- Provides superb opportunity to test numerical models before investigation.
- Extrapolation of analysis to other sites.

The recommended characterization approach is to complete a borehole down to the maximum extent of contamination and collect a complete set of chemical and radiological soil sample analyses with depth. The combination of these data with the tank C-105 borehole data should also provide a useful indication of the effects of tank structures on infiltration rates.

A vertical borehole located just northeast of 241-C-152 diversion box near the source of the plume would provide better understanding of the nature and extent of non-gamma-emitting contaminants in this zone where no information exists. Because of the high gamma zone near the surface, the exact location of this borehole must be located in a low gamma zone since cable-tool drilling method will be used.

6.3.1.2.3 Tank U-104 Borehole

An elongated uranium contamination region underlies tank U-104. Historical records show that metal waste from the bismuth phosphate was present in the tank and was being sluiced around the time of the tank leak. The discharge of metal waste into the vadose zone was confirmed by the uranium spectral gamma measurements in nearby drywells completed in the 1990s.

The metal waste leak from tank U-104 event was similar in several respects to the tank BX-102 leak (*Field Investigation Report for Waste Management Area B-BX-BY* [RPP-10098]). The tank BX-102 leak also released metal waste and distributed uranium in the vadose zone in a pattern that is analogous to that shown in WMA U. It was concluded from extensive evaluation of the tank BX-102 leak (RPP-10098) that three factors dominated the observed contaminant migration behavior during the initial phase of the leak event:

- A short term, high volume discharge of waste
- Metal waste chemistry that temporarily solubilized uranium such that it migrated with tank fluid
- The occurrence of horizontal soil layers in the vadose zone with differing hydrologic properties due different grain size distributions.

These factors also are proposed to be those that controlled the tank U-104 leak.

The tank U-104 leak began with a substantial rupture of the steel liner at the bottom of the tank, which was probably accelerated by high temperatures inside the tank. Given the occurrence of the tank liner rupture and the presence of a large fluid volume in the tank at the

time of the leak, it is likely that the initial loss of tank waste fluid was a high-rate, high-volume discharge. Also, waste release may have been enhanced by a leak test that was completed after discovery of the tank bottom bulge in 1956. The leak volume estimate of 190,000 L (50,000 gal.) in HNF-EP-0182 is not well supported and may be low. If the size of the contaminant footprint in the vadose zone is roughly proportional to the leak volume, then the tank U-104 leak may be larger than the current estimate. The tank BX-102 leak volume was well constrained by tank farm operations records to be about 327,000 L (92,000 gal.) (RPP-10098). However, the U-104 uranium distribution is larger than the BX-102 footprint (e.g., each plume is roughly oval in map view with the long axis of the U-104 plume being about 61 m [200 ft] versus the BX-102 plume being about 31 m [100 ft] long).

Once tank waste was discharged underneath the tank, fluid flow behavior was greatly influenced by sedimentary structures that favored lateral versus vertical migration, although both occurred during the release event. The migration path is marked by the uranium distribution pattern in a sequence of drywells to the southwest of tank U-104. The uranium was clearly mobile during this time because trace amounts are found more than 61 m (200 ft) from tank U-104. On the other hand, uranium is measured not much more than 12 m (40 ft) below the tank bottom. A similar lateral to vertical ratio is seen at the tank BX-102 site. At the tank BX-102 site, this distribution is partly attributed to the presence of horizontal layers of sediments with different grain size distributions and correspondingly different hydrologic properties. At the tank U-104 contamination site, uranium is present in the H2 unit of the Hanford formation, which is characterized by a laminate structure of alternating thin layers of sandy versus silty soils. These characteristics apparently promoted lateral migration during the initial phase of the leak migration.

The observation that uranium is still present in relatively large concentrations confined to relatively cohesive depth intervals also indicates that uranium mobility decreased rapidly some time after the initial leak event and stabilized in the vadose zone. Extensive soils characterization at the tank BX-102 contamination site shows that uranium largely precipitated in the vadose zone and is currently rather immobile. It is proposed that the same process has occurred at the tank U-104 contamination site.

Once the metal waste fluid stopped leaking from the tank and spreading rapidly through the vadose zone, drainage began. Drainage was driven by natural infiltration rates and perhaps by occasional manmade discharges that accelerated vertical migration. By this time, the uranium had largely precipitated. More mobile radionuclides and chemicals, particularly technetium-99 and nitrate, migrated more deeply into the vadose zone and some fraction of the inventory may have reached the unconfined aquifer. The elevated technetium-99 and nitrate concentrations that have peaked sporadically and more or less coincidentally in the groundwater monitoring wells on the eastern side of WMA U may have drained from this contaminated zone. Because of the changes in flow direction that have occurred under WMA U in the 1990s, it appears that this contamination has not migrated far from WMA U, first migrating easterly until 1993, then back towards WMA U (perhaps radially) from 1993 to about 1996, and finally back to easterly, the current general flow direction.

It is not certain that the source of this contamination is the tank U-104 leak. At the tank BX-102 site, uranium was observed in groundwater coincident with technetium-99 and nitrate. At these wells, no uranium has been measured in groundwater. The reason for this difference is unclear. Technetium-99 and nitrate may have originated from another source or uranium may be less mobile. Given the relative location of vadose zone contamination to groundwater monitoring wells containing these elevated contaminants and the upgradient/downgradient relationships indicated by general groundwater flow directions, the tank U-104 leak appears to be the most logical contamination source. If the tank U-104 vadose zone contamination has reached the unconfined aquifer, elevated liquid discharges through the contamination zone, either natural (e.g., snowmelt) or manmade (e.g., pipe leaks), must have played a role in accelerating travel time through the vadose zone.

The primary characterization goal is to determine the extent and magnitude of vertical migration of technetium-99 and uranium inventory in the vadose zone over a forty-seven-year period from a tank leak (similar to tank BX-102 leak) as well as other mobile constituents (e.g., nitrate) at the site.

The recommended characterization approach is to complete a borehole down to the maximum extent of contamination and collect a complete set of chemical and radiological soil sample analyses with depth. The combination of these data with the other characterization data related to metal waste leaks should provide a useful indication of the effects of tank structures on uranium mobility.

A vertical borehole located just southwest of drywells 60-07-10, 60-07-11 and 60-07-01 near the source of the plume would provide better understanding of the nature and extent of uranium and non-gamma-emitting contaminants in this zone where no information exists at depth.

6.3.1.2.4 Tank U-112 Borehole

Small leaks from tanks U-110 and U-112 are indicated by spectral gamma measurements of high cesium-137 concentration zones near the tank bottom from single drywells near each tank. The drywells (60-10-07 on the southwest side of tank U-110 and 60-12-01 on the north side of tank U-112) suggest leaks occurred near the tank bottoms at these locations. Both tanks contained high temperature wastes with the significant waste type being REDOX supernate. At tank U-110, the leak probably occurred in 1975 when increased gamma activity was noted in drywell 60-10-07. At tank U-112, apparent liquid level drops in the tank in the late 1960s may have indicated a leak. In both tanks there is no indication of a prolonged leak and this hypothesis is supported by the spectral gamma drywell data.

Subsequent distribution of tank waste contaminants following the leak events are not known. The only available marker is cesium-137 which apparently sorbed very rapidly to the soil upon contact. In neither case does the high cesium-137 concentration zone extend more than 10 ft (3 m) below the tank bottom. More mobile constituents have undoubtedly migrated deeper, both laterally and vertically in the vadose zone. However, because there appears to be no substantive liquid discharge at the time of the leaks, extensive lateral migration is not anticipated. The extent of vertical migration is unknown. A connection between these

contamination zones and the technetium-99 and nitrate contamination in the eastern groundwater monitoring wells cannot be ruled out. An attempt should be made to drive the borehole to the maximum extent of contamination and sample soils regularly to the borehole bottom. Soil sample analyses will provide an indication of relative depth of tank fluid constituents in the vadose zone, particularly the mobile constituents, technetium-99 and nitrate. Also, by comparing the ratios of various measured constituents (e.g., technetium-99 versus cesium-137), the hypothesized source fluid chemistry may be corroborated.

The primary characterization goal is to determine the extent and magnitude of vertical migration of technetium-99 inventory in the vadose zone since the leak occurred (i.e., 1975) to improve the technetium-99 inventory estimate. High cesium content from 16.1 to 29.6 m (53 to 97 ft) bgs ranging in concentration from 10^8 pCi/g to 10^3 pCi/g is present in borehole 60-12-01.

The recommended characterization approach is to complete a borehole down to the maximum extent of contamination and collect a complete set of chemical and radiological soil sample analyses with depth near borehole 60-12-01. A vertical borehole located just northeast of tank U-112 in close proximity to drywell 60-12-01, which is near the source of the plume, would provide better understanding of the nature and extent of non-gamma-emitting contaminants in this zone where no information exists at depth.

6.3.2 Near-Surface Characterization

One of the characterization options considered and selected during the planning process was the collection of sediment samples from the upper portion of the vadose zone using direct-push technology. Direct-push technology is the preferred method for defining the lateral extent of contamination in the upper part of the vadose zone. The near-surface characterization will be implemented in the area indicated by gamma contamination at the C tank farm at the UPR-200-E-82 location (Figure 6.1).

A phased approach will be used for near-surface characterization. Shallow soil characterization will be carried out using a truck-mounted, direct-push based system. At specific sites cleared for access (underground piping and electrical services identified) and for which an excavation permit has been approved, the first phase will be to interrogate with a gross-gamma/spectral gamma probe. The depth of investigation will be determined by the depth to which the direct-push boring can be advanced using a standard deployment truck. The probe will be deployed using the gross gamma mode with the tool lowered or raised at approximately 2 cm/sec (0.8 in./sec). Based on regulatory requirements for direct contact of contaminated soils, the upper 5 m (15 ft) of the vadose zone will use a lower action level than the vadose zone below 5 m (15 ft). If, in the upper 5 m (15 ft) the downhole instrument indicates a potential cesium-137 concentration of 3.7 pCi/g or greater, logging will be shifted to the spectral mode to determine the presence and level of concentration of cesium-137. If the downhole instrument is below 5 m (15 ft) the threshold limit for spectral gamma determinations will be 20 pCi/g. In zones where cesium-137 is present at concentrations greater than 20 pCi/g, spectral gamma readings will be taken at 0.5-m (1.5-ft) intervals. In addition, moisture measurements will be taken.

The second phase will use the graphical log developed using the gross and spectral gamma measurements and moisture measurements to select intervals to be sampled. The sampling push is to be made in a location that is no more than 0.7 m (2 ft) from the site of the gamma push. A single point sampler will be used to collect the required samples. Sampling intervals will be selected from those horizons with a cesium-137 concentration of 20 pCi/g or greater and a soil moisture of 15%. In the event that horizons are penetrated that would yield samples having a greater than 50 mrem/hr dose rate at 30 cm (12 in.) (based on calculations using sampler size and cesium-137 concentration), a sample will be collected from the first interval below the high-rate zone that has a dose rate of less than 50 mrem/hr. No sample will be collected from zones where the gamma instrument exhibits excessive deadtime. The sediment samples collected using direct-push technology may require multiple pushes if sufficient material for analysis of CoCs was not collected from the initial push. Direct-push technology was successfully deployed at nine locations in WMA S-SX in the 200 West area during near-surface characterization activities carried out in early 2000 (*Field Investigation Report for Waste Management Area S-SX* [RPP-7884]).

Deployment of direct-push technology at the proposed locations in WMA C would be expected to begin to address a number of questions related to the concentration and distribution of contaminants, including those listed below.

- What contaminants are present that are routinely identified as CoCs from a groundwater impact standpoint (e.g., technetium-99, nitrates)?
- What are the concentration/inventory correlations between the CoCs and cesium-137 in soil samples and with the tank contents?
- What is the vertical extent of the CoCs in the backfill material?
- What is the horizontal extent of the CoCs across the areas of interest?
- What are the potential drivers (e.g., sediment moisture profile) in the upper portion of the vadose zone that could control the migration of contaminants?

The benefits and uncertainties associated with direct-push technology were identified in *Data Quality Objectives Report for Waste Management Area B-BX-BY* (HNF-6020), a previous DQO document. Direct-push technology has been previously deployed in the tank farms and is limited to approximately the base of the tank or refusal in geology that is similar to the tank farms. The authorization basis for using one type of direct-push technology, the direct-push technology, has been completed (*Hazard Identification and Evaluation for Deploying the Cone Penetrometer in the Tank Farm for Vadose Zone Characterization* [HNF-SD-WM-HIE-012]).

Direct-push technology sediment sample pushes would only be performed if moisture measurements exceeded 15% above 18.3 m (60 ft) bgs. Two transects through the plume area would be performed, with 10 pushes on each transect, for a total of 20 pushes. One transect would be oriented along the axis of the pipeline and the other perpendicular to the pipeline. Direct-push sampling techniques may be impeded by the quantity of piping in the area and the high gravel content of the soils. Spacing of the sediment sample pushes will be dependent on accessibility within the tank farm due to infrastructure.

6.3.3 RCRA Monitoring Well Characterization

A planning process addressed collection of vadose zone data during installation of the planned RCRA groundwater monitoring wells (PNNL-13024). The planned installation of new RCRA groundwater monitoring wells near WMA C provides the opportunity to collect vadose zone sediment samples from a location near the tank farms in a clean or uncontaminated area. The potential benefit of using sediment samples from the RCRA wells is to develop a site-specific representative set of physical property data for the WMA to aid in closure decisions. This representative set of physical property data would then be used in developing and refining conceptual models and in future contaminant rate and transport modeling activities associated with closure decisions. This is a cost-effective approach to collecting physical property data and eliminates the difficulty of trying to obtain physical property data from contaminated sediment samples obtained from within the tank farms.

6.4 INVESTIGATIVE SAMPLING AND ANALYSIS AND DATA VALIDATION

Samples and data will be collected during the vertical borehole installation while driving the casing and by conducting geophysical surveying as described in the Sampling and Analysis Plan presented in the Appendix to this document. Periodic sediment samples will be collected. Sample lengths will be reduced if necessary when penetrating known hot zones to reduce worker exposure. All samples will be field screened for radiation, sealed, refrigerated, and shipped for analysis. Laboratory analyses will be performed on the sediment samples for radiological and geochemical constituents, as described in the Appendix. Limited analysis for physical parameters (e.g., moisture retention and hydraulic conductivity) may also be performed on sediments that show visible evidence of being altered by the tank leak chemistry (e.g., cementation, discoloration).

Data from the vertical boreholes determined by project management to be relevant for the purpose of validation will be made available by the primary laboratory on request. Validation will be performed in accordance with the quality assurance project plan in DOE/RL-99-36.

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7.0 RCRA FACILITY INVESTIGATION/CORRECTIVE MEASURES STUDY TASKS AND PROCESS

The primary purpose of this section is to provide a summary of the tasks that will be performed for the WMAs C, A-AX, and U field investigation. A detailed description of these tasks is provided in the Sampling and Analysis Plan (Appendix). Tasks are designed to provide information needed to meet the planning process identified in Section 6.0. Environmental monitoring requirements for protecting the health and safety of onsite investigators are described in DOE/RL-99-36.

Following approval, this addendum will not be modified without notification to Ecology and DOE. Any changes to the scope of work that may be needed will be documented through change requests in accordance with the procedures identified in Appendix A of DOE/RL-99-36.

To satisfy the data needs and planning process specified in Section 6.0, the following tasks will be performed during the RFI:

- Task 1 – Project Management
- Task 2 – Geological and Vadose Zone Investigation
- Task 3 – Data Evaluation.

The tasks and their component subtasks and activities are outlined in the following subsections. Information about each task is provided to allow estimation of the project schedule (see Section 8.0) and costs.

A separate plan will be developed by the Hanford Groundwater Monitoring Program to cover groundwater investigations at WMAs C, A-AX, and U (PNNL-13023; PNNL-13024; PNNL-13612).

7.1 TASK 1 – PROJECT MANAGEMENT

The project management objectives throughout the course of the WMAs C, A-AX, and U RFI/CMS are to direct and document project activities so the data and evaluations generated meet the goals and objectives of the work plan and to ensure that the project is kept within budget and on schedule. General project management objectives are addressed in Section 7.0 of DOE/RL-99-36. The project management activity will be to assign individuals to the roles established in Section 9.0 of this addendum. Specific subtasks that will occur throughout the RFI and RFI/CMS are addressed in Section 7.0 of DOE/RL-99-36.

7.2 TASK 2 – GEOLOGIC AND VADOSE ZONE INVESTIGATION

The geologic and vadose zone investigation will further characterize the geology of WMAs C, A-AX, and U and provide additional information on the source, nature, and extent of contamination and the potential migration paths of the contamination.

The geologic and vadose zone information will be evaluated to determine the following:

- WMA conceptual vadose zone model
- Release and movement of contaminants
- Development of ICM alternatives
- Initiation of data collection for support of retrieval and closure activities.

The geologic and vadose zone investigation for WMAs C, A-AX, and U will comprise compiling pertinent existing data and collecting data from drilling activities in the vadose zone. The types of data needed from the surface and vadose zone include the following:

- Thickness and areal extent of geologic units
- Lithology, bedding types, facies geometry, particle size, and sorting
- Presence, concentration, and nature of contaminants in sediments.

Subtasks 2a and 2b have been established to gather geologic and vadose zone data.

7.2.1 Subtask 2a – Field Activities

Field activities will include geologic and geophysical logging associated with deep vadose zone characterization in vertical boreholes south of tanks C-105 and U-104 and north of tank U-112 and diversion box 241-C-152 at UPR-200-E-82, direct push technology at UPR-200-E-82 in C tank farm, laterals under tanks in A tank farm, and vadose zone samples from RCRA groundwater monitoring well. The tentative locations of the planned vertical boreholes are provided in Figures 6.1 and 6.4.

The requirements for geologic and geophysical surveying and sediment sampling for physical and laboratory analytical parameters in the vadose zone borings are provided in the Appendix to this document. Information and data will be collected from the surface downward to the maximum extent of contamination in WMA C and WMA U. Geologic logging will be performed with the drilling operations unless highly radioactive sediments require removal of samples at a separate sample extraction facility.

The following activities are planned for the vadose zone characterization in vertical boreholes:

- Conduct borehole geophysical surveying and analysis (i.e., neutron, gross gamma, and spectral gamma).
- Obtain sediment samples to analyze for the presence and concentration of contaminants and to evaluate alterations of the sediments from waste chemistry effects.
- Obtain sediment samples to support preparation of the borehole geologic logs and stratigraphic and lithologic contact correlation with other boreholes and wells in the WMAs C and U vicinity.

The final design for the vertical boreholes has not been completed. One of the primary constraints on sample collection is the potential radiation level, which will limit the sample

volumes that can be brought to the surface for the boreholes at tanks C-105, U-104, and U-112 and at UPR-200-E-82. In addition, logistics will need to be coordinated because tank farm operations may exist in the vicinity of tanks C-105 and U-104 (waste retrieval of tanks C-106 and C-104 and waste retrieval of tank U-107).

The current planning basis for the vertical boreholes south of tanks C-105, U-104, and U-112 and at UPR-200-E-82 includes soil samples that will be collected and transported to the laboratory and analyzed for nitrate and technetium-99 in a 2-day turnaround for continuing drilling operations. These samples will be further analyzed for the CoCs identified in the Appendix at a later date. Nominally, 21 horizons will be sampled based on the geophysical surveys or the need to provide depth coverage as identified in the Appendix.

Subsurface conditions are variable and the process of installing the vertical boreholes must be flexible. Some or all of the work described in the Appendix may require modification. This addendum is intended to serve as a guideline and is designed to allow for changes depending on conditions encountered in the field. Any change will be recorded on the appropriated field documentation, memoranda, or letters. A complete documented record of activities will be maintained for preparation of a final summary report.

Appropriate permits and compliance with the Notice of Construction permit (DOE/ORP-2000-05) will be maintained during the drilling operations for inside the tank farm. The selected drilling method will comply with the requirements of the Washington State Department of Health for the Notice of Construction permit and other pertinent requirements and appropriate engineering systems to prevent the possible contaminated air from being released to the environment.

One area has been identified as a region of interest for the Phase 1 characterization of the shallow vadose zone soil. The area is within the southwest end of the C tank farm, north of diversion box 241-C-152. A north-south and east-west transect north of diversion box 241-C-152 will be conducted if increased soil moisture measurements are observed in the upper 18.3 m (60 ft) of the borehole.

For the purpose of the planning process, the shallow investigation of this area will comprise collecting sediment samples between the tank farm surface and refusal using direct-push technology at 20 locations within the transects. The samples will be transported to the laboratory and analyzed for the CoCs identified in the Appendix of this document. The physical and operational constraints will require evaluation prior to identifying the specific target locations.

Shallow soil characterization will be carried out using a truck-mounted direct-push technology-based system similar to what was conducted in S tank farm. Specific sites cleared for access (i.e., underground piping and electrical services identified) and with an approved excavation permit will be interrogated with a gross-gamma/spectral-gamma probe. The depth of investigation will be determined by the depth to which the direct-push boring can be advanced using a standard deployment truck. The probe will be deployed using the gross gamma mode with the tool lowered or raised at approximately 2 cm/sec (0.8 in./sec). Based on regulatory requirements, if in the upper 5 m (15 ft) the downhole instrument indicates a potential

cesium-137 concentration of 3.7 pCi/g or greater, logging will be shifted to the spectral mode to determine the presence and level of concentration of cesium-137. If the downhole instrument is below 5 m (15 ft) the threshold limit for spectral gamma determinations will be 20 pCi/g. In zones where cesium-137 is present at concentrations greater than 20 pCi/g, spectral gamma readings will be taken at 0.5-m (1.5-ft) intervals. No sample will be collected from zones where the gamma instrument exhibits excessive downtime.

The graphical log developed using the gross and spectral gamma measurements and moisture measurements will be used to select intervals to be sampled. The sampling push is to be made in a location that is no more than 0.7 m (2 ft) from the site of the gamma push. A single point sampler will be used to collect the required samples. Sampling intervals will be selected from those horizons with a cesium-137 concentration of 20 pCi/g or greater and a moisture measurement of 15% or greater. In the event that horizons are penetrated that yield samples having a greater than 50 mrem/hr dose rate at 30 cm (12 in.) (based on calculations using sampler size and cesium-137 concentration), a sample will be collected from the first interval below the high-rate zone that has a dose rate of less than 50 mrem/hr. No sample will be collected from zones where the gamma instrument exhibits excessive downtime.

The following activities are planned for sampling vadose zone sediment in the proposed RCRA groundwater monitoring well.

- Obtain sediment samples to determine physical properties, including moisture content, that will be used to support development of background and/or baseline conditions
- Obtain sediment samples to support preparation of the borehole geologic logs and stratigraphic and lithologic contact correlation with other boreholes and wells in the WMA C vicinity.

Data expected from sampling at the proposed RCRA groundwater wells will include the following:

- Continuous collection of samples from the cuttings between the surface and groundwater
- Experienced geologist (see the Appendix of this document) logs that detail all cuttings to the finest resolution possible.

Groundwater sampling activities at these RCRA wells will be conducted under the Hanford Site Groundwater Monitoring Project (PNNL-13024).

7.2.2 Subtask 2b – Laboratory Analysis

Laboratory analyses to be conducted for the WMAs C, A-AX, and U geologic and vadose zone investigation are described in the Appendix. These analyses will include radiological and chemical analysis of selected sediment samples. Physical and hydrologic analysis of selected sediment samples will also be performed. Rapid (2-day) turnaround analyses of technetium-99 and nitrate water leach samples will be performed to support continued drilling operations. The threshold limit for continued drilling will be set at 10 pCi/g for technetium-99.

7.3 TASK 3 – DATA EVALUATION

Data generated during the field investigation will be integrated and evaluated, coordinated with RFI activities, and presented in an ongoing manner to allow decisions regarding any necessary rescoping to be made during the course of the project. The assessment of data against the planning process, use of the data by others, and potential use to support future activities will be conducted and documented in a field investigation report for WMAs C, A-AX, and U.

The results of these evaluations will be made available to project management personnel to keep project staff informed of progress being made. The interpretations developed under this task will be used to refine the conceptual model and to determine whether interim measures or ICMs are warranted for WMAs C, A-AX, and U through a field investigation report for WMAs C, A-AX, and U to support closure requirements and future risk assessments.

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8.0 SCHEDULE

The work described in Section 7.0 is detailed in the schedule for developing plans and conducting field activities. The schedule, shown in Figure 8.1, is the baseline that will be used to measure progress. The characterization activities described in this addendum were identified during a planning process to support tank farm waste retrieval and tank closures. Activities were planned using the work breakdown structure and project milestones defined in Section 7.0 of DOE/RL-99-36. No planned waste retrievals or closure activities will conflict with the schedule.

Based on DOE guidance for establishing a baseline scope, schedule, and budget document, the use of a multi-year work plan was adopted. The activities identified in Figure 8.1 were taken from the multi-year work plan, which is updated annually and describes the specific details associated with each proposed project. The multi-year work plan incorporates milestones defined in the HFFACO and reflects the schedule and commitments made therein. The multi-year work plan defines the scope, schedule, and budget to a level of detail that will be adequate for the planning and management of that project. The work breakdown schedule numbers and activity identification numbers are included in Figure 8.1 to correspond with the schedule maintained by the Integrated Mission Execution Schedule. The planned field investigation report for WMAs C, A-AX, and U that will address interim measures and ICMs is scheduled for submittal to Ecology on January 31, 2007 (Figure 8.1).

Figure 8.1. Preliminary Characterization Schedule (2 Sheets)

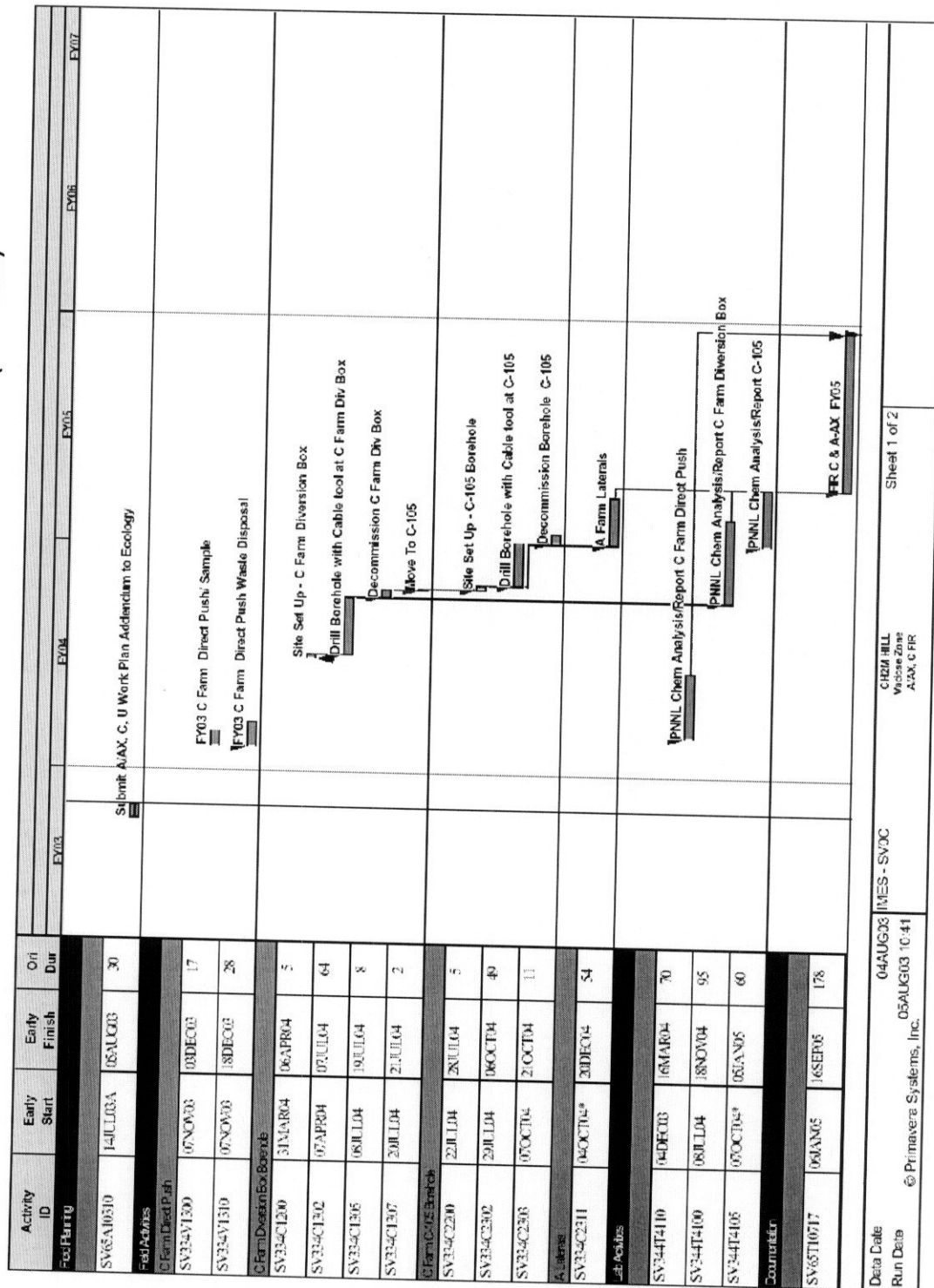
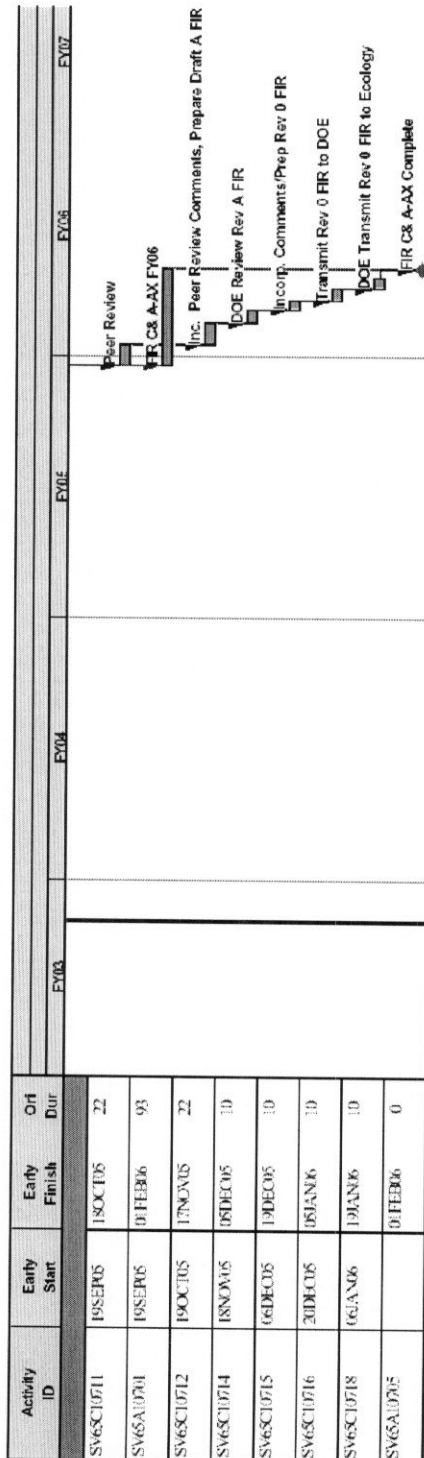


Figure 8.1. Preliminary Characterization Schedule (2 Sheets)



Sheet 2 of 2

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9.0 PROJECT MANAGEMENT

This section defines the administrative and institutional tasks necessary to support the RFI/CMS process for WMAs C, A-AX, and U and manage activities described in Section 7.0 of this addendum. This section also defines the responsibilities of the various participants, organizational structure, and project tracking and reporting procedures. This section is in accordance with the provisions of the HFFACO action plan. Any revisions to the HFFACO action plan that would result in changes to the project management requirements would supersede the provisions of this section.

9.1 PROJECT ORGANIZATION AND RESPONSIBILITIES

The project organization and responsibilities are described in Section 7.2 of DOE/RL-99-36. Discussion of the roles of SST Program Manager (now Tank Farm Closure Project Manager) and Tank Farm Vadose Zone Project Manager (now Groundwater/Vadose Zone Project Task Lead) and of work control, cost control, schedule control, meetings, records management, progress and final reports, quality assurance, health and safety, and community relations are also addressed in Section 7.2 of DOE/RL-99-36. This addendum follows the structure outlined in that work plan except where more detail is required. Interfaces with tank farm operations is part of the work control, schedule control, and roles and responsibilities as defined in DOE/RL-99-36. Integration with other organizations, including the Groundwater and Vadose Zone Integration Project (now Groundwater Protection Program), are addressed in Section 7.3 of DOE/RL-99-36.

Detailed information in the form of a work package defining the site-specific activities and instructions needed to carry out the investigative tasks discussed in this section will be developed before initiating field work. Where appropriate, the work package will reference the appropriate procedure or standards rather than listing the entire procedure for a task and will be in accordance with *Hanford Analytical Services Quality Assurance Requirements Document* (DOE/RL-96-68). Any reference to the quality assurance project plan provided in Appendix A of DOE/RL-99-36 as a source of additional information will be referenced.

The work package shall be prepared in accordance with CH2M HILL Hanford Group, Inc. work control procedures and the procedures listed in Appendix A of DOE/RL-99-36. The work package must satisfy the following requirements:

- Include a scope of work introductory section.
- Identify any field screening activities not described in the work plan or in the relevant procedures. Identify any field screening equipment to be used that is not described in the relevant procedures.
- Include the frequency of measurement.
- Identify the applicable procedures needed to conduct the work. If a procedure includes several different ways to accomplish the work, the work package should specify the method of choice or reference the specific procedure.

9.2 DOCUMENTATION AND RECORDS

All RFI/CMS plans and reports will be categorized as primary or secondary documents, as described by Section 9.1 of the HFFACO action plan. The process for document review and comment will be as described in Section 9.2 of the action plan. If necessary after finalization of any document, revisions will be in accordance with Section 9.3 of the HFFACO action plan. Changes in the work schedule, as well as minor field changes, can be made without having to process a formal revision. The process for making these changes will be as stated in Section 12.0 of the HFFACO action plan.

Administrative records, which must be maintained to support Hanford Site RCRA activities, will be in accordance with Section 9.4 of the HFFACO action plan.

10.0 REFERENCES

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11.0 GLOSSARY

Accuracy: The measure of the bias in a system. Analytical accuracy is normally assessed through the evaluation of matrix-spiked samples, reference samples, and split samples.

Audit: Systematic checks to verify the quality of operation of one or more elements of the total measurement system. In this sense, audits may be of two types: (1) performance audits, in which quantitative data are independently obtained for comparison with data routinely obtained in a measurement system or (2) system audits, which involve a qualitative onsite evaluation of laboratories or other organizational elements of the measurement system for compliance with established quality assurance program and procedure requirements. For environmental investigations at the Hanford Site, performance audit requirements are fulfilled by periodic submittal of blind samples to the primary laboratory or by the analysis of split samples by an independent laboratory. System audit requirements are implemented through the use of standard surveillance procedures.

B Plant High-Level Waste: B Plant reprocessed large quantities of the high-level waste streams produced by the PUREX and REDOX processes to recover cesium-137 and strontium-90. The waste streams from B Plant operations were very high in total activity and contained substantial concentrations of organic complexants.

Bias: A systematic error that contributes to the difference between a population mean of a set of measurements and an accepted reference or true value.

Blind Sample: Any type of sample routed to the primary laboratory for performance audit purposes, relative to a particular sample matrix and analytical method. Blind samples are not specifically identified as such to the laboratory. They may be made from traceable standards or may consist of sample material spiked with a known concentration of a known compound. (See Audit).

Borehole: A circular hole made by boring; esp. a deep vertical hole of small diameter, such as a shaft, a well (an exploratory oil well or a water well), or a hole made to ascertain the nature of the underlying formations, to obtain samples of the rocks penetrated, or to gather other kinds of geologic information.

Comparability: An expression of the relative confidence with which one data set may be compared with another.

Completeness: A measure of the amount of valid data obtained compared to the total data expected under correct normal conditions.

Conceptual Model: A tool designed to represent a simplified version of reality based on a set of working hypotheses. For instance, the vadose zone conceptual model includes the simplified elements of tank waste characteristics, past leak characteristics, geology, hydrogeology, and driving forces that include infiltration from precipitation and human sources of water.

Deviation: An approved departure from established criteria that may be required as a result of unforeseen field situations or that may be required to correct ambiguities in procedures that may arise in practical applications.

Dip: The angle that a structural surface makes with the horizontal, measured perpendicular to the strike of the structure.

Down Dip: A direction that is downwards and parallel to the dip of a structure or surface.

Drywell: A hollow cylinder of reinforced concrete, steel, timber, or masonry constructed in a pit or hole in the ground that does not reach the water table and is used principally for monitoring in the unsaturated zone.

Equipment Blanks: Pure deionized, distilled water washed through decontaminated sampling equipment and placed in containers identical to those used for actual field samples. Equipment blanks are used to verify the adequacy of sampling equipment decontamination procedures.

Field Duplicate Sample: A sample retrieved from the same sampling location using the same equipment and sampling technique; placed in separate, identically prepared and preserved containers; and analyzed independently. Field duplicate samples are generally used to verify the repeatability or reproducibility of a dataset.

First- and Second-Cycle Waste: The first- and second-cycle waste streams were generated by the successive purification steps in the bismuth phosphate process. The first-cycle waste stream was frequently mixed with the metal waste stream. Second-cycle waste contained significantly less total activity and mixed fission product content than the first-cycle and metal waste streams.

Interim Isolation: Administrative designation reflecting the completion of the physical effort required for interim isolation (except for isolation of risers and piping) that is required for jet pumping or for other methods of stabilization.

Interim Stabilized: Status term for when a tank contains less than 189,250 L (50,000 gal.) of drainable interstitial liquid and less than 18,925 L (5,000 gal.) of supernate liquid. If the tank was jet pumped to achieve interim stabilization, then the jet pump flow or saltwell screen inflow must also have been at or below 0.19 L (0.05 gal.) per minute.

Intrusion Prevention: Administrative designation reflecting completion of the physical effort required to minimize the addition of liquids into an inactive storage tank, process vault, sump, catch tank, or diversion box. Under no circumstances are electrical or instrumental devices disconnected or disabled during the intrusion prevention process (with the exception of the electrical pump).

Laboratory Duplicate Samples: Two aliquots removed from the same sample container in the laboratory and analyzed independently.

Matrix-Spiked Sample: A type of laboratory quality control sample. The sample is prepared by splitting a sample received from the field into two homogenous aliquots (i.e., replicate

samples) and adding a known quantity of a representative analyte of interest to one aliquot to calculate the percentage of recovery of that analyte.

Maximum Contaminant Level: The maximum permissible level of a contaminant in water that is delivered to any user of a public water system.

Metal Waste: Metal waste was the first waste stream generated by the bismuth phosphate process after fuel rod dissolution. The metal waste stream contained approximately 0.5 pounds of uranium/gallon. A high level of carbonate was added to the stream to maintain uranium solubility, resulting in carbonate concentration of approximately 2.5 molar. Metal waste is unique at the Hanford Site for being the only large volume waste stream containing high concentrations of uranium as well as high concentrations of mixed fission products.

Nonconformance: A deficiency in the characteristic, documentation, or procedure that renders the quality of material, equipment, services, or activities unacceptable or indeterminate. A deficiency is not categorized as a nonconformance when it is of a minor nature, does not effect a permanent or significant change in quality if it is not corrected, and can be brought into conformance with immediate corrective action. If the nature of the condition is such that it cannot be immediately and satisfactorily corrected, however, it shall be documented in compliance with approved procedures and brought to the attention of management for disposition and appropriate corrective action.

Operable Unit: A group of land disposal sites placed together for the purposes of doing a remedial investigation and feasibility study and subsequent cleanup actions. The primary criteria for placement of a site into an operable unit includes geographic proximity, similarity of waste characteristics and site type, and the possibility for economics of scale.

Out of Service: Designation of a tank that is no longer authorized to receive waste; a tank that does not meet the definition of an in-service tank. Before September 1998, such tanks were designated inactive.

Partially Interim Isolated: Administrative designation reflecting the completion of the physical effort required to minimize the addition of liquids into an inactive storage tank, process vault, sump, catch tank, or diversion box. In June 1993, the designation interim isolation was replaced by intrusion prevention.

Past-Practice Units: A waste management unit where waste or substances (intentionally or unintentionally) have been disposed of and that is not subject to regulation as a treatment, storage, and/or disposal unit.

Precision: A measure of the repeatability or reproducibility of specific measurements under a given set of conditions. The relative percent difference is used to assess the precision of the sampling and analytical method. Relative percent difference is a quantitative measure of the variability. Specifically, precision is a quantitative measure of the variability of a group of measurements compared to their average value. Precision is normally expressed in terms of standard deviation, but may also be expressed as the coefficient of variation (i.e., relative standard deviation) and range (i.e., maximum value minus minimum value). Precision is assessed by means of duplicate and replicate sample analysis.

Quality Assurance: The total integrated quality planning, quality control, quality assessment, and corrective action activities that collectively ensure that the data from monitoring and analysis meets all end user requirements and/or the intended end use of the data.

Quality Assurance Project Plan: An orderly assembly of management policies, project objectives, methods, and procedures that defines how data of known quality will be produced for a particular project or investigation.

Quality Control: The routine application of procedures and defined methods to the performance of sampling, measurement, and analytical processes.

Range: The difference between the largest and smallest reported values in a sample and is a statistic for describing the spread in a set of data.

REDOX High-Level Waste: REDOX waste was the primary high-activity waste stream produced by the REDOX process. This waste stream contained substantial mixed fission products and displayed high total activity.

Reference Samples: A type of laboratory quality control sample (e.g., laboratory control standard, independent calibration verification standard) prepared from an independent, traceable standard at a concentration other than that used for analytical equipment calibration but within the calibration range.

Refusal: When 100 blows per foot nominally have been reached in attempting to collect a soil sample.

Removed from Service: Designation of a tank that is no longer authorized to receive waste or intended for reuse.

Representativeness: May be interpreted as the degree to which data accurately and precisely represent a characteristic of a population parameter, variations at a sampling point, or an environmental condition. Representativeness is a qualitative parameter that is most concerned with the proper design of a sampling program.

Split Sample: A sample produced through homogenizing a field sample and separating the sample material into two equal aliquots. Field split samples are usually routed to separate laboratories for independent analysis, generally for purposes of auditing the performance of the primary laboratory relative to a particular sample matrix and analytical method (See Audit). In the laboratory, samples are generally split to create matrix-spiked samples (see Matrix-Spiked Samples).

Strike: The direction or trend that a structural surface takes as it intersects the horizontal.

Treatment, Storage, and/or Disposal Unit: A unit used for treatment, storage and/or disposal of hazardous waste and is required to be permitted (for operation and/or post-closure care) and/or closed pursuant to *Resource Conservation and Recovery Act of 1976* requirements under the Washington State “Dangerous Waste Regulations” (WAC 173-303) and the applicable provisions of *Hazardous and Solid Waste Amendment of 1984*.

Up-Dip: A direction that is upwards and parallel to the dip of a structure or surface.

Uranium Recovery Waste (or Tributyl Phosphate Waste): The tributyl phosphate waste stream was generated during processing of metal waste at U Plant for uranium recovery. The tributyl phosphate waste stream is basically metal waste with the uranium largely removed, ferric oxide added, and diluted by approximately a factor of two. The waste stream also contains variable amounts of tributyl phosphate.

Volatile Organics Analysis Trip Blanks: Volatile organics analysis trip blanks are a type of field quality control sample, consisting of pure deionized distilled water in a clean, sealed, sample container, accompanying each batch of containers shipped to the sampling site and returned unopened to the laboratory. Trip blanks are used to identify any possible contamination originating from container preparation methods, shipment, handling, storage, or site conditions.

Validation: A systematic process of reviewing data against a set of criteria to provide assurance that the data are acceptable for their intended use. Validation methods may include review of verification activities, editing, screening, cross-checking, or technical review.

Verification: The process of determining whether procedures, processes, data, or documentation conform to specified requirements. Verification activities may include inspections, audits, surveillance, or technical review.

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APPENDIX A SAMPLING AND ANALYSIS PLAN

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CONTENTS

A1.0	INTRODUCTION	A-1
A2.0	PROJECT MANAGEMENT (TASK 1 OF SECTION 5.0).....	A-3
A3.0	GEOLOGIC AND VADOSE ZONE INVESTIGATION (TASK 2 OF SECTION 5.0)	A-3
A3.1	FIELD ACTIVITIES (SUBTASK 2A OF SECTION 5.0)	A-3
A3.1.1	Drilling Activities	A-3
A3.1.2	Geophysical Surveying Activities.....	A-9
A3.1.3	Sediment Sampling Activities.....	A-10
A3.1.4	Groundwater Sampling Activities.....	A-14
A3.1.5	Field Reporting Activities.....	A-14
A3.2	LABORATORY ANALYSIS (SUBTASK 2B OF SECTION 5.0).....	A-14
A4.0	PROJECT MANAGEMENT (TASK 1 OF CHAPTER 5.0)	A-30
A5.0	GEOLOGIC AND VADOSE ZONE INVESTIGATION (TASK 2 OF CHAPTER 5.0).....	A-30
A5.1	FIELD ACTIVITIES (SUBTASK 2A OF CHAPTER 5.0)	A-30
A5.1.1	Exploratory Activity	A-30
A5.1.2	Field Quality Control	A-31
A5.1.3	Geophysical Surveying Activities.....	A-32
A5.1.4	Field Reporting Activities.....	A-32
A5.2	LABORATORY ANALYSIS (SUBTASK 2B OF CHAPTER 5.0).....	A-32
A5.2.1	Near-Surface Characterization Sediment Sample Analysis Requirements	A-32
A6.0	PROJECT MANAGEMENT (TASK 1 OF CHAPTER 5.0)	A-34
A7.0	GEOLOGIC AND VADOSE ZONE INVESTIGATION (TASK 2 OF CHAPTER 5.0).....	A-34
A7.1	FIELD ACTIVITIES (SUBTASK 2A OF CHAPTER 5.0)	A-34
A7.1.1	Exploratory Activity	A-34
A7.1.2	Geophysical Surveying Activities.....	A-35
A7.1.3	Laboratory Analysis (Subtask 2B of Section 5.0)	A-35
A8.0	PROPOSED RCRA GROUNDWATER MONITORING WELL SEDIMENT SAMPLE ANALYSIS (SUBTASK 2B OF CHAPTER 5.0).....	A-36
A9.0	REFERENCES	A-36

FIGURES

A.1.	Waste Management Area C Proposed Sampling Locations for Vertical Boreholes	6
A.2.	Waste Management Area U Proposed Sampling Locations for Vertical Boreholes	7
A.3.	Tank C-105 Borehole Sampling Strategy	11
A.4.	UPR-200-E-82 Borehole Sampling Strategy	12
A.5.	Tanks U-104 and U-112 Borehole Sampling Strategy	13
A.6.	Schematic Showing the Construction of a Typical Single-Shell Tank at A Tank Farm with a 1 Mgal Capacity (after DOE/RL-88-21)	35

TABLES

A.1.	Constituents and Methods for Sediment Sample Analyses for Waste Management Areas C, A-AX, and U	17
A.2.	Constituents and Methods for Organic Analysis of Borehole Sediment Samples.....	28

LIST OF TERMS

bgs	below ground surface
CH2M HILL	CH2M HILL Hanford Group, Inc.
Ecology	Washington State Department of Ecology
FY	fiscal year
RCRA	<i>Resource Conservation and Recovery Act of 1976</i>
SAP	Sampling and Analysis Plan
WMA	waste management area

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A1.0 INTRODUCTION

The focus of this Sampling and Analysis Plan (SAP) is vadose zone investigation of waste management areas (WMAs) C, A-AX, and U, which contain the A, AX, C, and U tank farms. Sampling and analysis of vadose zone sediments will occur in the vicinity of the C, A, and U tank farms to meet the objectives of this investigation.

This plan details the field and laboratory activities to be performed in support of the investigation of vadose zone contamination in WMAs C, A-AX, and U and is designed to be used in conjunction with the work plan and referenced procedures. The field investigations at WMAs C, A-AX, and U addressed in this SAP are to be conducted in fiscal year (FY) 2004 is anticipated to entail:

- Near-surface characterization investigation of UPR-200-E-82 leak area using direct push technology
- Installation of two new vertical exploratory boreholes south of tank C-105 and north of diversion box 241-C152
- Lateral gamma surveys under tanks in A tank farm
- Sediment drill cutting samples collected in conjunction with the installation of proposed *Resource Conservation and Recovery Act of 1976 (RCRA)* groundwater monitoring well.

The proposed site-specific investigation to be conducted in FY 2005 is anticipated to entail the installation of two boreholes (one southwest of tank U-104 and one northeast of tank U-112) at WMA U.

Technical procedures or specifications that apply to this work include Duratek Federal Services sampling and geophysical surveying procedures (DFSNW-SSPM-001) and vadose zone characterization at the Hanford Site tank farms, high-resolution passive spectral gamma-ray logging procedures (*Vadose Zone Characterization at the Hanford Tank Farms, High-Resolution Passive Spectral Gamma-Ray Logging Procedures* [P-GJPO-1783]). All field and laboratory work prescribed by this SAP shall also be in conformance with *Hanford Analytical Services Quality Assurance Requirements Document* (DOE/RL-96-68). Field and laboratory personnel should be familiar with these documents, as appropriate, and maintain a copy for guidance during work activities.

The field activities related to this investigation comprise vadose zone sampling and geophysical logging. This SAP addresses the requirements of the vadose zone sampling and analysis.

The quality assurance project plan, Appendix A of DOE/RL-99-36, is an integral part of this SAP and must be used jointly. Knowledge of the health and safety plan (Appendix B of DOE/RL-99-36) is required by those involved in the field sampling because it specifies procedures for the occupational health and safety protection of project field personnel. The data management plan (Appendix C of DOE/RL-99-36) denotes the requirements for field and laboratory data storage. The waste management plan (Appendix D of DOE/RL-99-36) denotes

the requirements for the management of waste and the appropriate collection, characterization, and designation of waste produced by the characterization activities.

PART I INSTALLATION OF VERTICAL BOREHOLES (WELL NUMBER TBD)

The following sections provide a discussion of the field tasks and associated subtasks required for the drilling, sampling, and sample analysis associated with the vertical boreholes.

A2.0 PROJECT MANAGEMENT (TASK 1 OF SECTION 5.0)

Project management will be followed as described in DOE/RL-99-36.

A3.0 GEOLOGIC AND VADOSE ZONE INVESTIGATION (TASK 2 OF SECTION 5.0)

The geologic and vadose zone investigation task has two subtasks relevant to the installation of the new boreholes: Subtask 2a, field activities, and Subtask 2b, laboratory analysis. The following subsections describe these subtasks.

A3.1 FIELD ACTIVITIES (SUBTASK 2A OF SECTION 5.0)

The field activities addressed in this subtask required to support the geologic and vadose zone investigation are drilling, geophysical logging, sediment sampling, and reporting activities.

A3.1.1 Drilling Activities

Drilling will be conducted using specifications and guidance in accordance with WAC 173-160. Drilling operations will also conform to SP 4-1, "Soil and Sediment Sampling"; WP 2-2, "Field Cleaning and/or Decontamination of Equipment"; and the task-specific work package that will be generated for these field activities (*Sampling Services Procedures Manual* [DFSNW-SSPM-001]). The work package will contain such information as borehole construction, sampling technique, and radiation protection. All waste will be handled in accordance with the requirements of "Dangerous Waste Regulations" (WAC 173-303) and/or the site-specific waste control plan. These techniques are based on minimizing the exposure of field personnel to both radiation and chemical pollutants to as low as reasonably achievable and in compliance with regulatory requirements.

Current plans for the initial site-specific investigations of WMAs C, A-AX, and U are to install two vertical boreholes in FY 2004 and two vertical boreholes in FY 2005. This initial (Phase 1) site-specific investigation to be conducted in FY 2004 is anticipated to entail the installation of two vertical boreholes near tank C-105 and UPR-200-E-82 and an additional two other boreholes near tanks U-104 and U-112 in FY 2005 for a total of four boreholes.

Vadose zone samples would be collected as the borehole(s) are advanced down to maximum extent of contamination, unless refusal is encountered at WMA C and WMA U. Each borehole has a unique sampling strategy. The sampling strategy is as follows:

- For UPR-200E-82 borehole, near-continuous grab sampling (i.e., every 2 ft) beginning 3 m (10 ft) bgs to the end of technetium-99 and nitrate contamination, with split-spoon samples at 3 m (10 ft) intervals and/or at depths thought to be more moist or at lithology contacts. Grab samples will be collected for chemical analysis at nominal 0.6-m (2-ft) intervals over the length of the borehole. Collect samples for technetium-99 and nitrate water leach analysis at 46 m (150 ft) bgs and 61 m (200 ft) bgs for quick turnaround analysis (approximately 2 days). If technetium-99 and nitrate are not detected, drilling operations will be stopped. If technetium-99 and nitrate are detected at 46 m (150 ft) bgs, collect a sample at 61 m (200 ft) bgs for quick turnaround analysis (2 days). If technetium-99 and nitrate are detected, take a sample at 69 m (225 ft) bgs for quick turnaround analysis. Drilling waits at 69 m (225 ft) for analysis to see if the borehole goes to groundwater. The threshold criteria is detection of 10 pCi/g for technetium-99 or greater in soil for continued drilling deeper for any of these quick turnaround analysis.
- For tank C-105 borehole, near continuous grab samples (i.e., every 2 ft) beginning at 9 m (30 ft) bgs. Grab samples will be collected for chemical analysis at nominal 0.6-m (2-ft) intervals over the length of the borehole. Collect samples for technetium-99 and nitrate water leach analysis at 46 m (150 ft) bgs and 61 m (200 ft) bgs for quick turnaround analysis (approximately 2 days). If technetium-99 and nitrate are not detected, drilling operations will be stopped. If technetium-99 and nitrate are detected at 46 m (150 ft) bgs, collect a sample at 61 m (200 ft) bgs for quick turnaround analysis (2 days). If technetium-99 and nitrate are detected, take a sample at 69 m (225 ft) bgs for quick turnaround analysis. Drilling waits at 69 m (225 ft) for analysis to see if the borehole goes to groundwater. The threshold criteria is detection of 10 pCi/g for technetium-99 or greater in soil for continued drilling deeper for any of these quick turnaround analysis.
- For tank U-104 borehole, split-spoon samples will be collected every 10 ft beginning at 9 m (30 ft) bgs to the end of technetium-99 and nitrate contamination and/or at depths thought to be more moist or at lithology contacts. Grab samples will be collected for chemical analysis at nominal 0.6 m (2 ft) intervals over entire depth of borehole. Collect samples for technetium-99 and nitrate water leach analysis at 46 m (150 ft) bgs and 61 m (200 ft) bgs for quick turnaround analysis (approximately 2 days). If technetium-99 and nitrate are not detected, drilling operations will be stopped. If technetium-99 and nitrate are detected at 46 m (150 ft) bgs, collect a sample at 61 m (200 ft) bgs for quick turnaround analysis (2 days). Drilling waits at 61 m (200 ft) for analysis to see if the borehole goes to groundwater. The threshold criteria is detection of 10 pCi/g for technetium-99 or greater in soil for continued drilling deeper for any of these quick turnaround analysis.
- For tank U-112 borehole, near continuous grab samples (i.e., every 2 ft) beginning at 9 m (30 ft) bgs to the end of technetium-99 and nitrate contamination (i.e., maximum extent of contamination). Grab samples will be collected for chemical analysis at nominal 0.6-m (2-ft) intervals over the length of the borehole. One split-spoon sample will be collected at the base of tank depth (approximately 12.8 m [42 ft] bgs). Collect samples for technetium-99 and nitrate water leach analysis at 46 m (150 ft) bgs and 61 m (200 ft) bgs for quick turnaround analysis (approximately 2 days). If technetium-99 and nitrate are not detected, drilling operations will be stopped. If technetium-99 and nitrate are

detected at 46 m (150 ft) bgs, collect a sample at 61 m (200 ft) bgs for quick turnaround analysis (2 days). Drilling waits at 61 m (200 ft) for analysis to see if the borehole goes to groundwater. The threshold criteria is detection of 10 pCi/g for technetium-99 or greater in soil for continued drilling deeper for any of these quick turnaround analysis.

This option was selected because vertical boreholes at these locations (i.e., in the vicinity of tanks C-105, U-104, and U-112 and of UPR-200-E-82) would provide source characterization along with distribution of contaminants at the locations of interest from within WMAs C, A-AX, and U. The approximate location of the boreholes in the vicinity of tanks C-105, U-104, and U-112 and of UPR-200-E-82 are shown in Figures A.1 and A.2. At tank C-105, the goal is to drill as near to drywell 30-05-07 as possible. At tank U-104, the goal is to drill as near to drywells 60-07-11, 60-07-10, and 60-07-01. At tank U-112, the goal is to drill as near to drywell 60-12-01 as possible. At UPR-200-E-82, the goal is to drill as near to the pipe joint at line V-122 as possible. These locations are the maximum points of contamination.

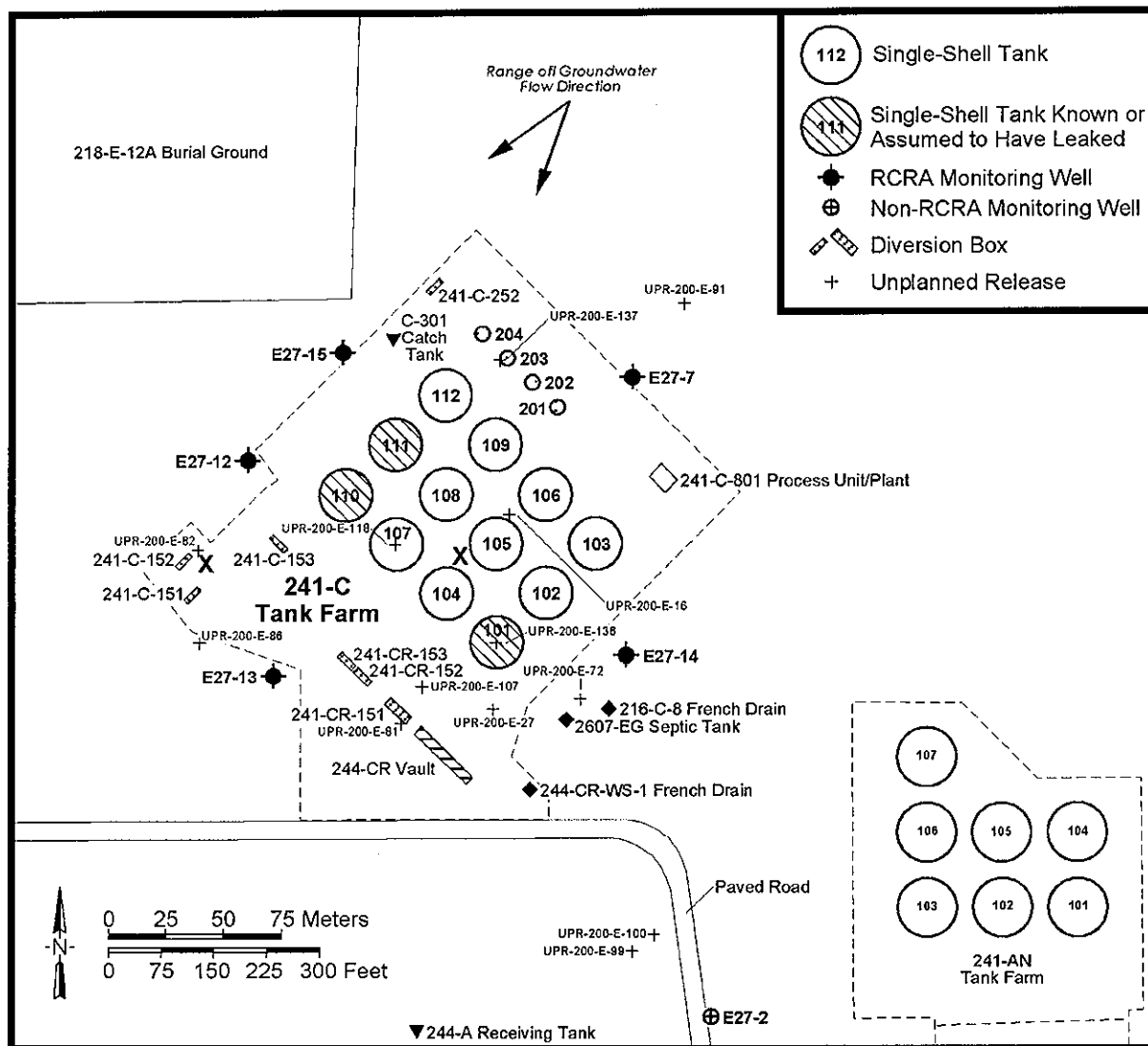
The boreholes would be advanced using a variation of the cable tool method. The final design for the vertical boreholes has not been completed. One of the primary constraints on sample collection could be the potential of a high radiation level, which would limit the sample volumes from that borehole that can be brought to the surface. In addition, logistics will need to be coordinated because tank farm operations may exist in the vicinity of tanks C-105 and U-104 (waste retrieval of tank C-106 and C-104 and waste retrieval of tank U-107).

Subsurface conditions are variable, and the process of installing the vertical boreholes must be flexible. Some or all of the work may require modification. This addendum is intended to serve as a guideline and is designed to allow for changes depending on conditions encountered in the field. Any change will be recorded on the appropriated field documentation, memoranda, or letters. A complete documented record of activities will be maintained for preparation of a final summary report.

Appropriate permits and compliance with the Notice of Construction permit (DOE/ORP-2000-05) will be maintained during the drilling operations inside the tank farm. The selected drilling method will comply with the requirements of the Washington State Department of Health for the Notice of Construction permit and other pertinent requirements and appropriate engineering systems to prevent contaminated air from being released to the environment.

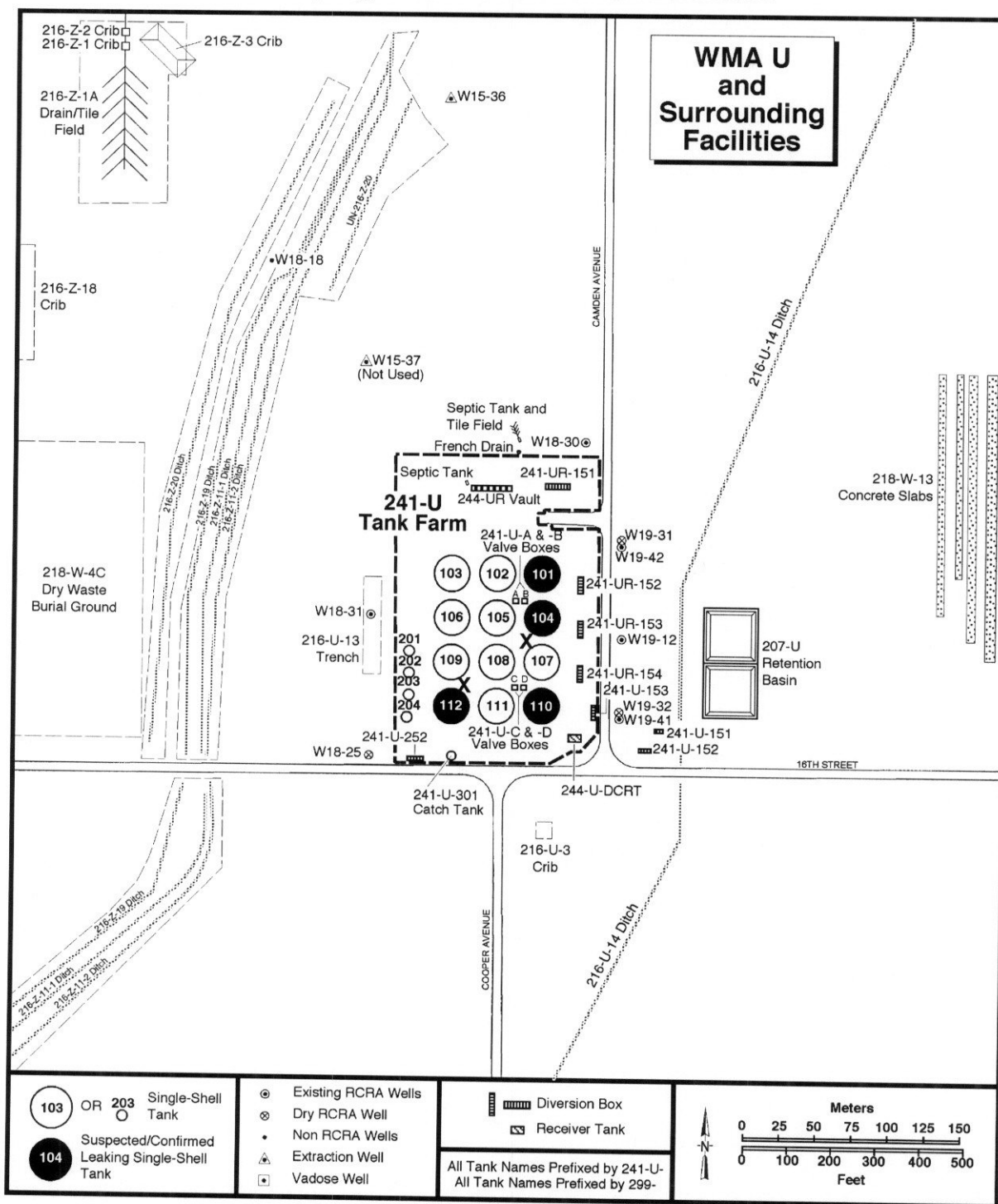
All split-spoon samples will be collected in advance of the casing being driven. Driven split-spoon samples will be attempted at a maximum of every 3-m (10-ft) intervals beginning at 9 m (30 ft) bgs in WMA U and at the borehole at tank C-105 in WMA C. Driven split-spoon samples will be attempted at a maximum of every 3-m (10-ft) intervals beginning at 3 m (10 ft) bgs in WMA C for the borehole located at UPR-200-E-82. The casing is to be driven to total sample depth at the end of each day's drilling effort to prevent potential hole collapse. Split-spoon samplers will be new or decontaminated before reuse. Procedures for decontamination of sampling equipment are contained in WP 2-2, "Field Cleaning and/or Decontamination of Equipment" (*Well Services Procedures Manual* [DFS NW-WSPM-001]).

Figure A.1. Waste Management Area C Proposed Sampling Locations for Vertical Boreholes



X = proposed borehole location.

Figure A.2. Waste Management Area U Proposed Sampling Locations for Vertical Boreholes



X = proposed borehole location.

2001/DCLU/007

The depth of the vadose zone borings will be to the maximum extent of contamination unless refusal or perched water is encountered in WMA C and WMA U. If the U.S. Department of Energy desires to continue the borehole through a perched water zone, then the Washington State Department of Ecology (Ecology) would be notified. The use of 2-day turnaround laboratory analyses of water leach samples for technetium-99 and nitrate concentrations is expected to be effective in determining the maximum extent of contamination. A detection of less than 10 pCi/g for technetium-99 will constitute the maximum extent of contamination.

In addition to the borehole geologic logging, radiation measurements will be made using hand-held instruments on each segment of sample recovered during sampling and on the drill cuttings brought to the surface. Blow count measurements will be collected during all drive samples while advancing the split-spoon sampler. General observation will be noted as to drilling progress and problems. All of this information will be included in each borehole geologic log. Borehole geologic logs and well summary sheets will be prepared in accordance with approved Duratek procedures using American Society for Testing and Materials procedures (*Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)* [ASTM D2488]).

A geologist will prepare a geological log for the vertical boreholes, based on the sediment samples. Borehole geologic logs will be prepared in accordance with approved procedures. The geologic log will include lithologic descriptions, sampling intervals, health physics technician hand-held instrument readings, screening results, evidence of any alteration of sediments, and general information and observations deemed relevant by the geologist to the characterization of subsurface conditions. Sediment samples will be screened with hand-held instruments for radiation, as appropriate, using techniques and procedures defined in the work package. Screening results and general observations as to drilling progress and problems will be included in each borehole log.

Waste containing unknown, low-level mixed radioactive waste and/or hazardous waste will be contained, stored, and disposed of in accordance with Appendix D of DOE/RL-99-36, or the most current procedures approved by Ecology, including waste utilizing the area of contaminant approach, and as specified in the quality assurance project plan (Appendix A of DOE/RL-99-36). These activities will be documented in the field activity reports. Waste will be disposed of at the mixed waste burial grounds in accordance with Appendix D of DOE/RL-99-36. All important information will be recorded on field activity report forms per approved procedures. The field activity report form includes the following:

- Borehole number
- Site location drawings
- Downhole tool strings drawing
- List of site personnel
- Sampling types and intervals
- Zones noted as elevated in radiological contaminants by the health physics technician
- Instrument readings and the depth represented by those readings
- Specific information concerning borehole completion.

The new boreholes will be decommissioned in accordance with WAC 173-160 following completion of geophysical surveys. All temporary steel casing removed from a boring will be surveyed and either decontaminated and released or transferred to an appropriate disposal facility. Specific procedures for borehole abandonment will be documented in the field work package. These procedures will comply with U.S. Environmental Protection Agency requirements and WAC 173-160.

Should the contamination extend to groundwater and drilling to groundwater is feasible (i.e., refusal does not occur), the new boreholes may be completed as a RCRA-compliant groundwater monitoring wells. A groundwater sample will be collected and analyzed based on current groundwater analysis for WMAs C and U. Should technetium-99 concentrations exceed 10 times the drinking water standard of 900 pCi/L, or 9,000 pCi/L, a RCRA-compliant groundwater monitoring well will be installed. If so, the new wells may be included in the RCRA groundwater monitoring network for routine groundwater sampling and analysis. If not completed as RCRA-compliant groundwater wells, then the boreholes will be decommissioned in accordance with WAC 173-160 or completed as a vadose zone monitoring well in accordance with WAC 173-160.

If completed as a groundwater monitoring well, a 4-in. stainless steel casing and screen will be permanently installed and a flush mount surface protection/well seal will be constructed. The well will be completed in accordance with WAC 173-160 requirements to meet groundwater protection goals. Specific work steps for well completion will be documented in the tank farm work package.

Contaminant dragdown during drilling and sampling activities is unavoidable and has been observed in recent sampling activities. Different drilling and sampling techniques will impact dragdown to varying degrees. Because the objective of the characterization activities identified in the planning process is to safely sample in and below regions of known leakage, the dragdown issue is a secondary concern. However, appropriate drilling procedures will be used to minimize the effect of contaminant dragdown.

A3.1.2 Geophysical Surveying Activities

Based on sampling and construction methods, downhole spectral-gamma or gross gamma geophysical logging will be conducted to ascertain the gamma-emitting radionuclide concentrations. The spectral-gamma or gross gamma logging frequency will be directed by CH2M HILL Hanford Group, Inc. (CH2M HILL).

A suite of geophysical logs, as determined by the CH2M HILL Field Team Leader, will be run any time the casing size is changed and at the completion of the borehole. This will provide some flexibility with the planning of geophysical logging during the drilling process.

The following logging techniques could be used for the vertical boreholes:

- Gross-gamma logging to support correlation of confining layers and stratigraphy
- Spectral-gamma logging for measuring the distribution of selected radionuclides
- Neutron logging for measuring the relative moisture content.

The existing equipment and procedures for gross-gamma and spectral-gamma logging in use at the Hanford Site provide acceptable data (P-GJPO-1783).

All steel casing will be removed and transferred to an appropriate disposal facility or controlled decontamination facility and released for future use, and each boring will be in accordance to U.S. Environmental Protection Agency requirements and WAC 173-160.

A3.1.3 Sediment Sampling Activities

Borehole sampling will be performed to define the depth of contamination. The borehole will serve to establish the general lithology of the sediments lying below the site and to give indications of how radionuclides and other contaminants have migrated. It also will provide sediment samples for determination of sediment chemistry and vadose zone properties. This SAP is specific to the borehole and is not applicable to future borehole or shallow soil sampling events.

For the new boreholes soil sampling will begin at 9 m (30 ft) bgs to allow for a limited open borehole and placement of a sealed surface casing, except UPR-200 E-82 borehole, which will begin at 3 m (10 ft) bgs. Drilling and sampling will continue until maximum extent of contamination or refusal. Refusal is defined as 100 blows per foot. Maximum extent of contamination will be based on laboratory measurements for technetium-99 and nitrate water leach analysis. Grab samples will be attempted at a maximum of every 3 m (10 ft) beginning at 9 m (30 ft) bgs for all boreholes except UPR-200-E-82 borehole, which will begin at 3 m (10 ft) bgs because of the occurrence of contamination at this depth. Approximate sample locations will be adjusted to capture locations with elevated or altered gamma or moisture content, any paleosols, and to provide coverage by taking one sample every 3 m (10 ft). Figures A.3 through A.5 show the proposed sampling strategy for the new boreholes at the identified locations.

After the sediment samples are screened, these samples will be transported to the Pacific Northwest National Laboratory Applied Geology and Geochemistry group for analysis. All material removed from the borehole will be sent to the laboratory for possible future analysis. Samples will be contained in airtight sample containers after their initial screening by the health physics technician and are to be kept under refrigeration. This process is used to retain sediment moisture in as close to field condition as possible. All samples will be transported to the laboratory under refrigeration to further limit alteration of sediment moisture.

Field quality control samples also will be submitted for the full spectrum of chemical and radionuclide analyses. These quality control samples will consist of the following:

- **Equipment rinseate blanks** – One equipment rinseate blank per borehole drilling activity or, if multiple types of samplers are used, once per type of sampler.

Figure A.3. Tank C-105 Borehole Sampling Strategy

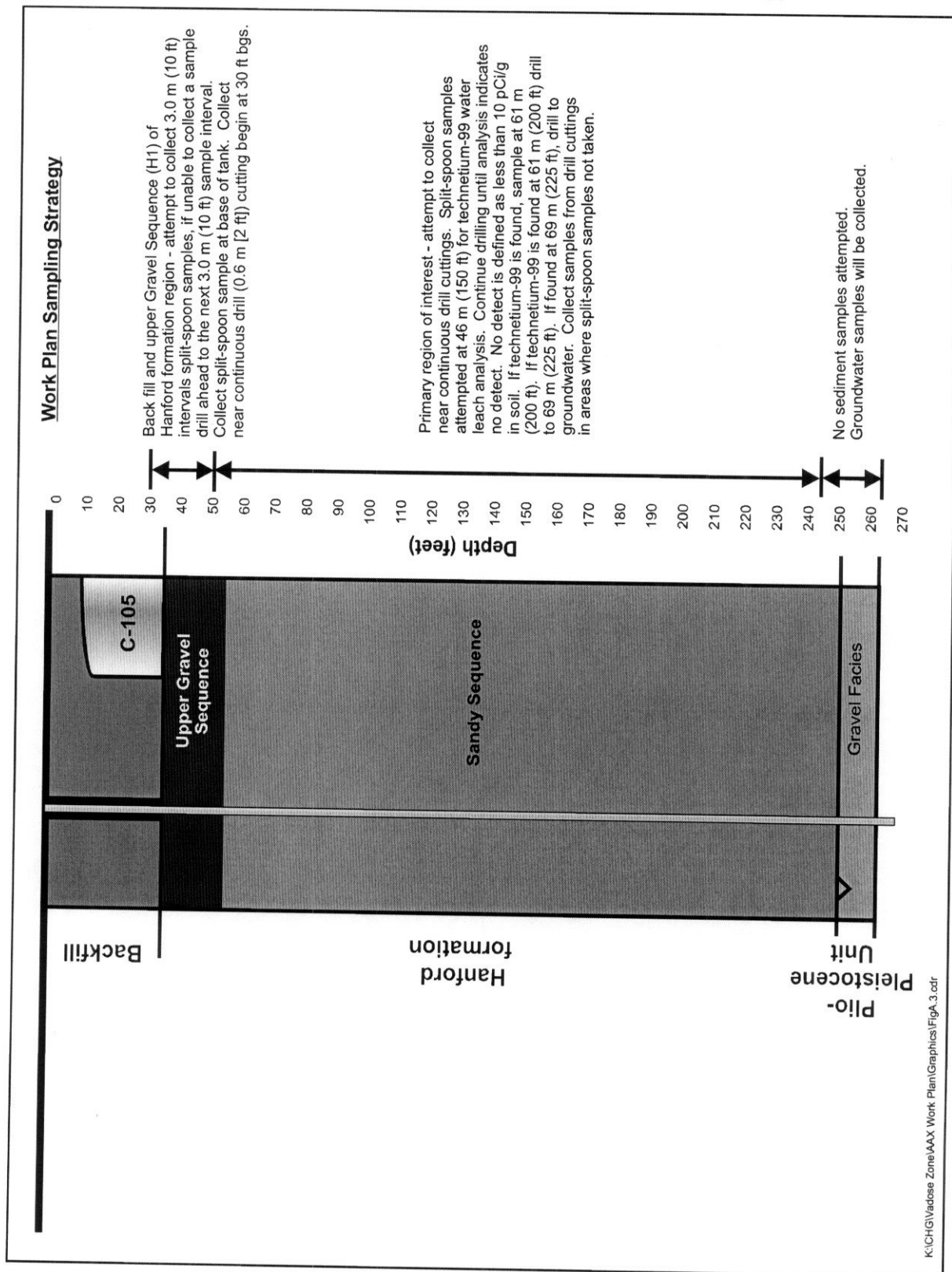


Figure A.4. UPR-200-E-82 Borehole Sampling Strategy

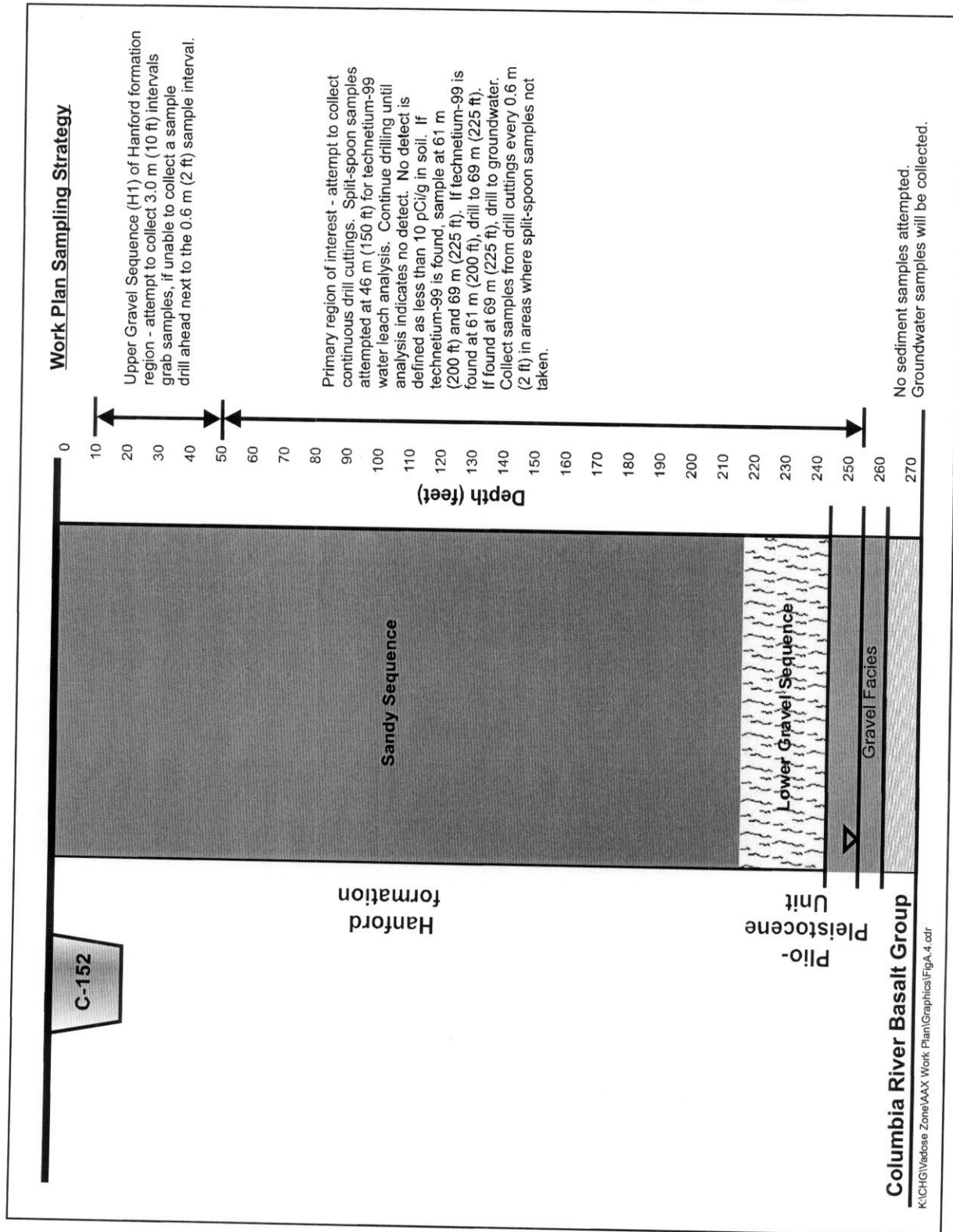
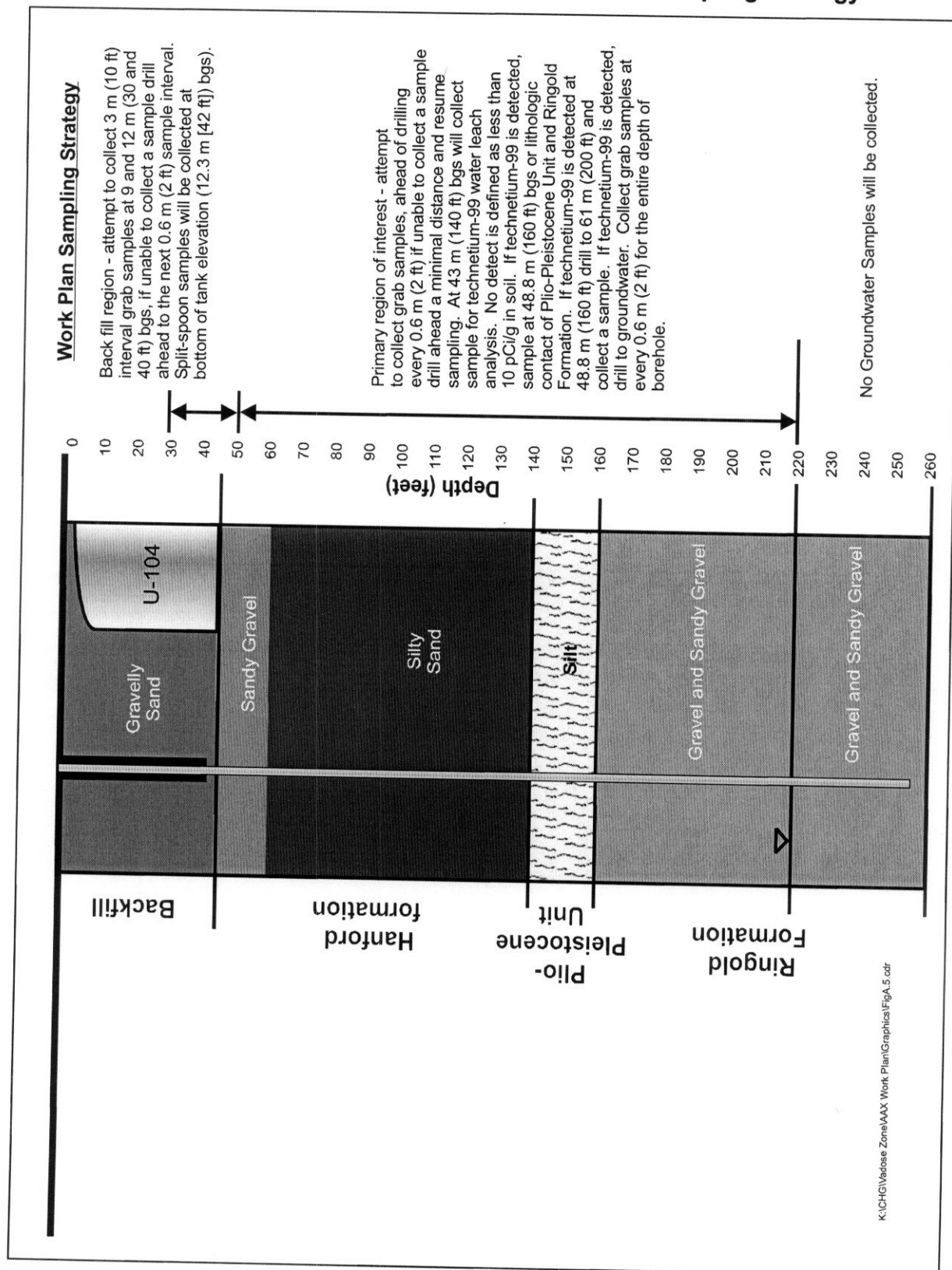


Figure A.5. Tanks U-104 and U-112 Borehole Sampling Strategy



A3.1.4 Groundwater Sampling Activities

No sampling of groundwater will be conducted for these characterization efforts unless contamination extends all the way to groundwater and drilling to groundwater is feasible (i.e., no refusal). If a groundwater sample is collected, analyses will be conducted in accordance with *RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area C at the Hanford Site* (PNNL-13024) and *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area U* (PNNL-13612).

A3.1.5 Field Reporting Activities

Field logs will be maintained to record all observations and activities conducted. A site representative will record the activities on a field activity report. Items for entry will include the following:

- Borehole number
- Site location drawings
- Drawings of the downhole tool strings
- Site personnel present
- Sampling types and intervals
- Zones noted by the health physics technician as elevated in radiological contaminants
- Instrument readings and the depth represented by those readings
- Specific information concerning borehole progress and completion.

All completed field records will be maintained and processed in accordance with approved CH2M HILL procedures.

A3.2 LABORATORY ANALYSIS (SUBTASK 2B OF SECTION 5.0)

The following sections describe the laboratory analyses required for the samples collected from the vertical boreholes. Laboratory analyses will be performed on sediment samples in accordance with this SAP. All analytical work prescribed by this SAP will be performed by qualified laboratories with approved quality assurance plans. If the primary contracting laboratory is unable to complete the analyses, it is the primary contracting laboratory's responsibility to subcontract the laboratory work to a qualified secondary laboratory. Samples for laboratory analysis will be placed in appropriate containers and properly preserved in accordance with SP 4-1, "Soil and Sediment Sampling" (DFS NW-SSPM-001), and in accordance with the quality assurance project plan (Appendix A of DOE/RL-99-36). All samples for laboratory analysis will be transported under chain of custody in accordance with the quality assurance project plan.

Sediment cuttings containing low-level and mixed radioactive waste will be contained, stored, and disposed of according to procedures defined in Appendix D of DOE/RL-99-36. Sediment cuttings containing hazardous waste and those containing unknown waste will be contained and disposed of at the mixed waste burial grounds in accordance with Appendix D of DOE/RL-99-36. Storage of archive samples will be done until approval to dispose of the samples is provided by the CH2M HILL technical representative.

Geologic logging for the vertical boreholes will be conducted as it was for the borehole 41-09-39 extension in WMA S-SX (*Preliminary Site-Specific SST Phase 1 RFI/CMS Work Plan Addendum for WMA S-SX* [HNF-4380]). Specifically, once sample material from the vertical boreholes is received at the laboratory, it will be geologically logged by an assigned geologist in general conformance with standard procedures. The assigned geologist will photograph the samples and describe the geologic structure, texture, and lithology of the recovered samples. Special attention is to be paid to the presence of contaminant alteration. If such a phenomenon is noted, that sample will be noted, preserved for more detailed physical, chemical, and mineralogic analyses, and recorded in the laboratory notebook.

Sediment subsamples for laboratory analysis will be defined by location in the sample after the field screening and geologic logging have been completed and indication of contamination locations have been identified. Approximately 23 sediment subsamples from each of the boreholes in WMA C will be chosen for screening analysis and approximately 12 sediment subsamples from each of the boreholes in WMA U will be chosen for screening analysis. The following criteria will be used to identify samples for laboratory analysis based on concurrence with Ecology:

- One background sample will be taken at 9 m (30 ft) bgs.
- One sample will be taken at 12.2 m (40 ft) bgs, at the level of the tank bottom.
- If drilled to groundwater, one sample will be taken at the Hanford formation and Hanford formation/Undifferentiated Plio-Pleistocene Silt/Ringold Formation Mud? [Pplz/R(?)] Unit interval contact at approximately 76.2 m (250 ft) bgs in WMA C.
- One sample will be taken at the Hanford formation interval and Plio-Pleistocene unit contact at approximately 43 m (140 ft) bgs in WMA U.
- Samples will be taken of any paleosols seen in the split-spoon drive samples.
- Samples will be taken in locations where elevated or altered gamma surveying or moisture content was measured during the geological and geophysical borehole logging process
- At least one sample will be taken every 0.6 m (2 ft) if samples have not already been taken, based on the above criteria to ensure continuous distribution and lithologic completeness.

Figures A.3 through A.5 show the samples identified for laboratory analyses. Worker safety considerations may limit the collection of samples at certain intervals. A 1:1 water extract of all samples shall undergo screening analyses. Screening analyses comprise the following:

- Nitrate analysis by the colorimetric method
- Electrical conductance
- Total organic carbon/total carbon
- gamma energy analysis

- pH
- Technetium-99.

These analyses, along with the gamma surveying and moisture content measurements performed during the field geophysical surveys and the laboratory geologic logging, will be used to determine the extent of further sample analysis. Table A.1 identifies the full complement of potential analyses and their respective laboratory preparation and analytical methods.

This paragraph and the remainder of this appendix identify which analysis will be conducted on which sample. If more than one preparation or analytical method is listed, the expertise of the laboratory geochemistry staff will be used to determine which methods will produce the best results and will provide the best understanding of the chemistry involved. For those methods that produce multiple constituents (i.e., inductively coupled plasma), all constituents identified will be reported. Every effort is to be made to meet regulatory holding times where appropriate. The planning process identified the need for volatile organic analysis and semivolatile organic analysis. An attempt will be made to perform these analyses; however, based on experience from WMA S-SX, it is unlikely that the holding time for volatile organic analysis can be met. If holding times cannot be met, analysis of these compounds will not be performed. Based on previous experience, it is anticipated that holding times for the semi-volatile organic analysis can be met.

Because the purpose of the new borehole analyses is to gain an understanding of the nature and extent of contamination, the fate and transport of the contaminants in the vadose zone and to produce RCRA-compliant data, the analysis of these subsamples comprises two levels.

The baseline level involves analysis of organic, inorganic, and radiochemical constituents in full conformance with DOE/RL-96-68 and with no modifications to methods (as defined by DOE/RL-96-68) without concurrence from the CH2M HILL technical representative and from Ecology. Substitutions and deviations to methods as defined in DOE/RL-96-68 will require concurrence from Ecology. The second level involves a research-type approach to the analyses. In this level, procedures may be modified or developed to gain a more comprehensive understanding of the dynamics involved. Although specific quality control criteria do not apply to this level, compliance with the other quality assurance requirements in DOE/RL-96-68 must still be met and research analysis will be initiated only following review and approval of the activities by the CH2M HILL technical representative.

The background subsample, backfill – Hanford formation contact subsample, Hanford formation H1 unit and Hanford formation H2 unit contact sample, peak gamma concentration sample, the two subsamples obtained at the Hanford formation and Plio-Pleistocene unit interval contact in WMA U, the Hanford formation interval and Undifferentiated Plio-Pleistocene Silt/Ringold Formation Mud? [Pplz/R(?)] Unit interval contact in WMA C will be analyzed for the constituents and properties identified in Table A.1. It is recognized that conditions may occur when all of the analyses identified in Table A.1 are not warranted (e.g., limited potential for data) and these occurrences will be evaluated on a case-by-case basis.

At the request of Ecology for boreholes located in close proximity to tanks, three samples at 9 m (30 ft), 12.2 m (40 ft), and 15.2 m (50 ft) at or near the base of the tank will be analyzed for volatile and semivolatile organics identified in Tables A.1 and A.2. No volatile or semivolatile organics sample will be collected for UPR-200-E-82 borehole.

**Table A.1. Constituents and Methods for Sediment Sample Analyses
for Waste Management Areas C, A-AX, and U (11 Sheets)**

CoC	CAS No.	Action Levels			Name/ Analytical Tech.	Target Required Quantitation Limits				Precision Water	Accuracy Water	Precision Soil	Accuracy Soil
		RR ^a pCi/g	C/I ^b pCi/g	GW ^{a,9} pCi/L		Water ^b Low Level	Water ^b High Level	Soil- Other Low Level	Soil-Other High Level				
Radionuclide						pCi/L	pCi/L	pCi/g	pCi/g				
Americium-241	14596-10-2	31	210	TBD	Americium Isotopic - Alpha Energy Analysis (AEA)	1	400	1	4000	+20%	70-130%	+35%	70-130%
Carbon-14	14762-75-5	5.2 ^f	33100	TBD	Carbon-14 - Liquid Scintillation	200	N/A	50	N/A	+20%	70-130%	+35%	70-130%
Cesium-137	10045-97-3	6.2	25	TBD	Gamma Energy Analysis	15	200	0.1	2000	+20%	70-130%	+35%	70-130%
Cobalt-60	10198-40-0	1.4	5.2	TBD	Gamma Energy Analysis	25	200	0.05	2000	+20%	70-130%	+35%	70-130%
Europium-152	14683-23-9	3.3	12	TBD	Gamma Energy Analysis	50	200	0.1	2000	+20%	70-130%	+35%	70-130%
Europium-154	15585-10-1	3	11	TBD	Gamma Energy Analysis	50	200	0.1	2000	+20%	70-130%	+35%	70-130%
Europium-155	14391-16-3	125	449	TBD	Gamma Energy Analysis	50	200	0.1	2000	+20%	70-130%	+35%	70-130%
Hydrogen-3	10028-17-8	359 ^f	14200	20000	Tritium - Liquid Scintillation	400	400	400	400	+20%	70-130%	+35%	70-130%
Neptunium-237	13994-20-2	2.5	62.2	TBD	Neptunium-237 - AEA	1	N/A	1	8000	+20%	70-130%	+35%	70-130%
Nickel-63	13981-37-8	4026	3008000	TBD	Nickel-63 - Liquid Scintillation	15	N/A	30	N/A	+20%	70-130%	+35%	70-130%
Plutonium-238	13981-16-3	37	483	15	Plutonium Isotopic - AEA	1	130	1	1300	+20%	70-130%	+35%	70-130%

Table A.1. Constituents and Methods for Sediment Sample Analyses for Waste Management Areas C, A-AX, and U (11 Sheets)

CoC	CAS No.	Action Levels				Name/ Analytical Tech.	Target Required Quantitation Limits				Precision Water	Accuracy Water	Precision Soil	Accuracy Soil
		RR ^a pCi/g	CI ^b pCi/g	GW ^{c, g} pCi/L			Water ^b Low Level	Water ^b High Level	Soil- Other Low Level	Soil-Other High Level				
Radionuclide (Cont'd)							pCi/L	pCi/L	pCi/g	pCi/g				
Plutonium-239/240	PU-239/240	34	243	15		Plutonium Isotopic - AEA	1	130	1	1300	+20%	70-130%	+35%	70-130%
Total Radioactive Strontium	SR-RAD	4.5	2500	8		Total Radioactive Strontium - Gas Proportional Counting (GPC)	2	80	1	800	+20%	70-130%	+35%	70-130%
Technetium-99	14133-76-7	5.7 ^f	410000	900		Technetium-99 - Liquid Scintillation	15	400	15	4000	+20%	70-130%	+35%	70-130%
Thorium-232	TH-232	1	5.1	15		Thorium Isotopic - AEA (pCi) ICPMS (mg)	1	.002 mg/L	1	0.02 mg/Kg	+20%	70-130%	+35%	70-130%
Uranium-234	13966-29-5	160	1200	15		Uranium Isotopic - AEA (pCi) ICPMS (mg)	1	.002 mg/L	1	0.02 mg/Kg	+20%	70-130%	+35%	70-130%
Uranium-235	15117-96-1	26	100	15		Uranium Isotopic - AEA (pCi) ICPMS (mg)	1	.002 mg/L	1	0.02 mg/Kg	+20%	70-130%	+35%	70-130%
Uranium-238	U-238	85	420	15		Uranium Isotopic - AEA (pCi) ICPMS (mg)	1	.002 mg/L	1	0.02 mg/Kg	+20%	70-130%	+35%	70-130%

**Table A.1. Constituents and Methods for Sediment Sample Analyses
for Waste Management Areas C, A-AX, and U (11 Sheets)**

CoC	CAS No.	Action Levels			Name/ Analytical Tech.	Target Required Quantitation Limits				Precision Water	Accuracy Water	Precision Soil	Accuracy Soil
		Meth B	Meth C			mg/Kg	mg/Kg	mg/L	mg/L				
Chemical													
Organics													
Ethyl alcohol	64-17-5	None	None	None	Non-Halogenated VOA - 8015c – GC	5	N/A	5	N/A	e	e	e	e
n-Butyl alcohol	71-36-3	8000	350	160	Non-Halogenated VOA - 8015 - GC	5	N/A	5	N/A	e	e	e	e
Methyl alcohol (methanol)	67-56-1	40000	160000	400	Non-Halogenated VOA - 8015M - GC modified for hydrocarbons	1	N/A	1	N/A	e	e	e	e
Kerosene (paraffin hydrocarbons)	8008-20-6	200000 ^h	200000 ^h	200000 ^h	Non-Halogenated VOA - 8015M - GC modified for hydrocarbons	0.5	0.5	5	5	e	e	e	e
Carbon tetrachloride	56-23-5	7.69	224	0.0337	Volatile Organics - 8260 - GCMS	0.005	0.005	0.005	0.005	e	e	e	e
2-Propanone (Acetone)	67-64-1	8000	32000	80	Volatile Organics - 8260 - GCMS	0.02	0.02	0.02	0.02	e	e	e	e
Chloroform	67-66-3	164	3200	0.717	Volatile Organics - 8260 - GCMS	0.005	0.005	0.005	0.005	e	e	e	e
Benzene	71-43-2	34.5	1380	0.151	Volatile Organics - 8260 - GCMS	0.005	0.005	0.005	0.005	e	e	e	e
1,1,1-trichlorethane	71-55-6	72000	288000	720	Volatile Organics - 8260 - GCMS	0.005	0.005	0.005	0.005	e	e	e	e

Table A.1. Constituents and Methods for Sediment Sample Analyses for Waste Management Areas C, A-AX, and U (11 Sheets)

CoC	CAS No.	Action Levels			Name/ Analytical Tech.	Target Required Quantitation Limits				Precision Water	Accuracy Water	Precision Soil	Accuracy Soil
		Meth B	Meth C			Water ^b Low Level	Water ^b High Level	Soil- Other Low Level	Soil-Other High Level				
Chemical			mg/Kg	mg/Kg		mg/L	mg/L	mg/Kg	mg/Kg				
Organics (Cont'd)													
Dichloromethane (methylene chloride)	75-09-2	133	5330	0.583	Volatile Organics - 8260 - GCMS	0.005	0.005	0.005	0.005	e	e	e	e
Carbon Disulfide	75-15-0	8000	32000	80	Volatile Organics - 8260 - GCMS	0.005	0.005	0.005	0.005	e	e	e	e
1,1-dichloroethane	75-34-3	8000	32000	80	Volatile Organics - 8260 - GCMS	0.01	0.01	0.01	0.01	e	e	e	e
1,1-dichloroethene	75-35-4	1.67	66.7	0.00729 ^f	Volatile Organics - 8260 - GCMS	0.01	0.01	0.01	0.01	e	e	e	e
1,2-dichloropropane	78-87-5	14.7	588	0.0643	Volatile Organics - 8260 - GCMS	0.005	0.005	0.005	0.005	e	e	e	e
2-butanone	78-93-3	48000	192000	480	Volatile Organics - 8260 - GCMS	0.01	0.01	0.01	0.01	e	e	e	e
1,1,2-trichloroethane	79-00-5	17.5	702	0.0768	Volatile Organics - 8260 - GCMS	0.005	0.005	0.005	0.005	e	e	e	e
1,1,2-trichloroethylene	79-01-6	90.9	3640	0.398	Volatile Organics - 8260 - GCMS	0.005	0.005	0.005	0.005	e	e	e	e
1,1,2,2-tetrachloroethane	79-34-5	5	200	0.0219	Volatile Organics - 8260 - GCMS	0.005	0.005	0.005	0.005	e	e	e	e
Ethyl benzene	100-41-4	8000	32000	80	Volatile Organics - 8260 - GCMS	0.005	0.005	0.005	0.005	e	e	e	e
1,2-dichloroethane	107-06-2	11	440	0.0481	Volatile Organics - 8260 - GCMS	0.005	0.005	0.005	0.005	e	e	e	e

**Table A.1. Constituents and Methods for Sediment Sample Analyses
for Waste Management Areas C, A-AX, and U (11 Sheets)**

CoC	CAS No.	Action Levels			Name/ Analytical Tech.	Target Required Quantitation Limits				Precision Water	Accuracy Water	Precision Soil	Accuracy Soil
						Water ^b Low Level	Water ^b High Level	Soil- Other Low Level	Soil-Other High Level				
Chemical		Meth B	Meth C	mg/Kg		mg/L	mg/Kg	mg/Kg					
		mg/Kg	mg/Kg										
Organics (Cont'd)													
4-methyl-2-pentanone	108-10-1	6400	25600	64	Volatile Organics - 8260 - GCMS	0.01	0.01	0.01	0.01	e	e	e	e
Toluene	108-88-3	16000	64000	160	Volatile Organics - 8260 - GCMS	0.005	0.005	0.005	0.005	e	e	e	e
Chlorobenzene	108-90-7	1600	6400	16	Volatile Organics - 8260 - GCMS	0.005	0.005	0.005	0.005	e	e	e	e
1,1,2,2-tetrachloroethene	127-18-4	19.6	784	0.0858	Volatile Organics - 8260 - GCMS	0.005	0.005	0.005	0.005	e	e	e	e
2-hexanone	591-78-6	None	None	64	Volatile Organics - 8260 - GCMS	0.02	0.02	0.02	0.02	e	e	e	e
cis-1,3-dichloropropene	10061-01-5	5.56	96	0.0243 ⁱ	Volatile Organics - 8260 - GCMS	0.005	0.005	0.005	0.005	e	e	e	e
Trans-1,3-dichloropropene	10061-02-6	5.56	96	0.0243 ⁱ	Volatile Organics - 8260 - GCMS	0.005	0.005	0.005	0.005	e	e	e	e
Xylene (total)	1330-20-7	160000	640000	1600	Volatile Organics - 8260 - GCMS	0.005	0.005	0.005	0.005	e	e	e	e
Dibenz[a,h]anthracene	53-70-3	0.137 ^f	5.48	0.0012 ^o	Semi-Volatiles - 8270 - GCMS	0.01	0.05	0.33	1	e	e	e	e
Hexachloroethane	67-72-1	71.4	320	0.625	Semi-Volatiles - 8270 - GCMS	0.01	0.05	0.33	1	e	e	e	e
Hexachlorobutadiene	87-68-3	12.8	64	0.0561 ^f	Semi-Volatiles - 8270 - GCMS	0.01	0.05	0.33	1	e	e	e	e

**Table A.1. Constituents and Methods for Sediment Sample Analyses
for Waste Management Areas C, A-AX, and U (11 Sheets)**

CoC	CAS No.	Action Levels			Name/ Analytical Tech.	Target Required Quantitation Limits				Precision Water	Accuracy Water	Precision Soil	Accuracy Soil
		Meth B mg/Kg	Meth C mg/Kg	mg/Kg		Water ^b Low Level	Water ^b High Level	Soil- Other Low Level	Soil-Other High Level				
Chemical				mg/Kg		mg/L	mg/L	mg/Kg	mg/Kg				
Organics (Cont'd)													
Pentachlorophenol	87-86-5	8.33	333	0.0729 ^f	Semi-Volatiles - 8270 - GCMS	0.01	0.05	0.33	1	e	e	e	e
2-methylphenol (o-cresol)	95-48-7	4000	16000	80	Semi-Volatiles - 8270 - GCMS	0.01	0.05	0.33	1	e	e	e	e
1,2-dichlorobenzene	95-50-1	7200	28800	72	Semi-Volatiles - 8270 - GCMS	0.01	0.05	0.33	1	e	e	e	e
Nitrobenzene	98-95-3	40	160	0.8	Semi-Volatiles - 8270 - GCMS	0.01	0.05	0.33	1	e	e	e	e
4-methylphenol (p-cresol)	106-44-5	400	1600	8	Semi-Volatiles - 8270 - GCMS	0.01	0.05	0.33	1	e	e	e	e
1,4-dichlorobenzene	106-46-7	41.7	1670	0.0182 ^f	Semi-Volatiles - 8270 - GCMS	0.01	0.05	0.33	1	e	e	e	e
Pyridine	110-86-1	80	320	1.6	Semi-Volatiles - 8270 - GCMS	0.02	0.1	0.66	2	e	e	e	e
Hexachlorobenzene	118-74-1	0.625	25	0.00547 ^g	Semi-Volatiles - 8270 - GCMS	0.01	0.05	0.33	1	e	e	e	e
1,2,4-trichlorobenzene	120-82-1	800	3200	8	Semi-Volatiles - 8270 - GCMS	0.01	0.05	0.33	1	e	e	e	e
2,4-Dinitrotoluene	121-14-2	160	640	3.2	Semi-Volatiles - 8270 - GCMS	0.01	0.05	0.33	1	e	e	e	e
Tributyl phosphate	126-73-8	None	None	None	Semi-Volatiles - 8270 - GCMS	0.1	0.5	3.3	5	e	e	e	e

**Table A.1. Constituents and Methods for Sediment Sample Analyses
for Waste Management Areas C, A-AX, and U (11 Sheets)**

CoC	CAS No.	Action Levels			Name/ Analytical Tech.	Target Required Quantitation Limits				Precision Water	Accuracy Water	Precision Soil	Accuracy Soil
		Meth B	Meth C	mg/Kg		Water ^b Low Level	Water ^b High Level	Soil- Other Low Level	Soil-Other High Level				
Chemical				mg/Kg		mg/L	mg/L	mg/Kg	mg/Kg				
Organics (Cont'd)													
1,3-dichlorobenzene	541-73-1	41.7	1670 ^j	0.018 ^d	Semi-Volatiles - 8270 - GCMS	0.01	0.05	0.33	1	e	e	e	e
Benzo(a)pyrene	50-32-8	0.137 ^f	5.48	0.0012 ^e	Semi-Volatiles - 8270 - GCMS	0.01	0.05	0.33	1	e	e	e	e
2,4,5-Trichlorophenol	95-95-4	8000	32000	160	Semi-Volatiles - 8270 - GCMS	0.01	0.05	0.33	1	e	e	e	e
Gamma-BHC (Lindane)	58-89-9	0.769	30.8	0.00673	Pesticides - 8081 - GC	0.00005	N/A	0.00165	N/A	e	e	e	e
Dieldrin	60-57-1	0.0625	2.5	0.000547 ^o	Pesticides - 8081 - GC	0.0001	N/A	0.0033	N/A	e	e	e	e
Endrin	72-20-8	24	96	0.48	Pesticides - 8081 - GC	0.0001	N/A	0.0033	N/A	e	e	e	e
Heptachlor	76-44-8	0.222	8.89	0.00194	Pesticides - 8081 - GC	0.00005	N/A	0.00165	N/A	e	e	e	e
Aldrin	309-00-2	0.0588	2.35	0.000515 ⁱ	Pesticides - 8081 - GC	0.00005	N/A	0.00165	N/A	e	e	e	e
Alpha-BHC	319-84-6	0.159	6.35	0.00139 ⁱ	Pesticides - 8081 - GC	0.00005	N/A	0.00165	N/A	e	e	e	e
Beta-BHC	319-85-7	0.556	2.22	0.00486	Pesticides - 8081 - GC	0.00005	N/A	0.00165	N/A	e	e	e	e
Toxaphene	8001-35-2	0.909	36.4	0.00795 ^o	Pesticides - 8081 - GC	0.005	N/A	0.165	N/A	e	e	e	e

**Table A.1. Constituents and Methods for Sediment Sample Analyses
for Waste Management Areas C, A-AX, and U (11 Sheets)**

CoC	CAS No.	Action Levels		Name/ Analytical Tech.	Target Required Quantitation Limits						Precision Water	Accuracy Water	Precision Soil	Accuracy Soil
		Meth B	Meth C		Water ^b Low Level	Water ^b High Level	Soil- Other Low Level	Soil-Other High Level						
Chemical		mg/Kg	mg/Kg		mg/L	mg/L	mg/Kg	mg/Kg	100	100	+20%	70-130%	+35%	70-130%
Organics (Cont'd)														
Total Organic Carbon	TOC	N/A	N/A	None	TOC - 9060- Combustion	1	1		100	100				
Polychlorinated biphenyls (PCBs)	1336-36-3	0.13	5.19	0.00114 ^o	PCBs - 8082 - GC	0.0005	0.005		0.0165	0.1	e	e	e	e
Inorganics														
Ammonia/ammonium	7664-41-7	2720000	109000000	27100	Ammonia - 350.Nd	0.05	800	0.5	8000	e	e	e	e	e
Phosphate	14265-44-2	N/A	N/A	None	Anions - 9056 - IC	0.5	15	5	40	e	e	e	e	e
Nitrate	14797-55-8	128000	512000	2560	Anions - 9056 - IC	0.25	10	2.5	40	e	e	e	e	e
Nitrite	14797-65-0	8000	32000	160	Anions - 9056 - IC	0.25	15	2.5	20	e	e	e	e	e
Sulfate	14808-79-8	25000 ^k	25000 ^k	25000	Anions - 9056 - IC	0.5	15	5	40	e	e	e	e	e
Chloride	16887-00-6	25000 ^k	25000 ^k	25000	Anions - 9056 - IC	0.2	5	2	5	e	e	e	e	e
Fluoride	16984-48-8	96 ^k	200 ^k	96	Anions - 9056 - IC	0.5	5	5	5	e	e	e	e	e
Bromide	24959-67-9	N/A	N/A	None	Anions - 9056 - IC	0.25	N/A	2.5	N/A	e	e	e	e	e
Chromium VI	18540-29-9	400	1600	8	Chromium (hex) - 7196 - Colorimetric	0.01	4	0.5	200	e	e	e	e	e
Mercury	7439-97-6	24	96	0.48	Mercury - 7470 - CVAA	0.0005	0.005	N/A	N/A	e	e	e	e	e
Mercury	7439-97-6	24	96	0.48	Mercury - 7471 - CVAA	N/A	N/A	0.2	0.2	e	e	e	e	e

**Table A.1. Constituents and Methods for Sediment Sample Analyses
for Waste Management Areas C, A-AX, and U (11 Sheets)**

CoC	CAS No.	Action Levels			Name/ Analytical Tech.	Target Required Quantitation Limits				Precision Water	Accuracy Water	Precision Soil	Accuracy Soil
						Target Required Quantitation Limits							
						Water ^b Low Level	Water ^b High Level	Soil- Other Low Level	Soil-Other High Level				
Chemical		Meth B	Meth C	mg/Kg		mg/L	mg/L	mg/Kg	mg/Kg				
		mg/Kg	mg/Kg										
Inorganics (Cont'd)													
Lead	7439-92-1	25000 ^b	25000 ^b	N/A	Metals - 6010 - ICP	0.1	0.2	10	20	e	e	e	e
Nickel	7440-02-0	1600	6400	32	Metals - 6010 - ICP	0.04	0.04	4	4	e	e	e	e
Silver	7440-22-4	400	1600	8	Metals - 6010 - ICP	0.02	0.02	2	2	e	e	e	e
Antimony	7440-36-0	321	1281	6	Metals - 6010 - ICP	0.06	0.12	6	12	e	e	e	e
Arsenic	7440-38-2	6.5 ^m	66.7	0.00583°	Metals - 6010 - ICP	0.1	0.2	10	20	e	e	e	e
Barium	7440-39-3	5600	22400	112	Metals - 6010 - ICP	0.2	0.2	20	20	e	e	e	e
Beryllium	7440-41-7	0.233	9.3	0.00203°	Metals - 6010 - ICP	0.005	0.01	0.5	1	e	e	e	e
Cadmium	7440-43-9	40	160	0.8	Metals - 6010 - ICP	0.005	0.01	0.5	1	e	e	e	e
Chromium (total)	7440-47-3	1600	3500	None	Metals - 6010 - ICP	0.01	0.01	1	2	e	e	e	e
Copper	7440-50-8	2960	11800	59.2	Metals - 6010 - ICP	0.025	0.025	2.5	2.5	e	e	e	e
Selenium	7782-49-2	400	1600	8 ^f	Metals - 6010 - ICP	0.1	0.2	10	20	e	e	e	e

**Table A.1. Constituents and Methods for Sediment Sample Analyses
for Waste Management Areas C, A-AX, and U (11 Sheets)**

CoC	CAS No.	Action Levels			Name/ Analytical Tech.	Target Required Quantitation Limits				Precision Water	Accuracy Water	Precision Soil	Accuracy Soil
						Target Required Quantitation Limits							
						Water ^b Low Level	Water ^b High Level	Soil- Other Low Level	Soil-Other High Level				
Chemical		Meth B	Meth C	mg/Kg		mg/L	mg/L	mg/Kg	mg/Kg				
		mg/Kg	mg/Kg										
Inorganics (Cont'd)													
Lead	7439-92-1	25000 ^h	25000 ^h	N/A	Metals - 6010 - ICP (TRACE)	0.01	N/A	1	N/A	e	e	e	e
Silver	7440-22-4	400	1600	8	Metals - 6010 - ICP(TRACE)	0.005	N/A	0.5	N/A	e	e	e	e
Antimony	7440-36-0	32l	128l	6	Metals - 6010 - ICP(TRACE)	0.01	N/A	1	N/A	e	e	e	e
Arsenic	7440-38-2	6.5 ^m	66.7	0.00583°	Metals - 6010 - ICP(TRACE)	0.01	N/A	1	N/A	e	e	e	e
Barium	7440-39-3	5600	22400	112	Metals - 6010 - ICP(TRACE)	0.005	N/A	0.5	N/A	e	e	e	e
Cadmium	7440-43-9	40	160	0.8	Metals - 6010 - ICP(TRACE)	0.005	N/A	0.5	N/A	e	e	e	e
Chromium (total)	7440-47-3	1600	3500	None	Metals - 6010 - ICP(TRACE)	0.01	N/A	1	N/A	e	e	e	e
Selenium	7782-49-2	400	1600	8	Metals - 6010 - ICP(TRACE)	0.01	N/A	1	N/A	e	e	e	e
PH	pH	N/A	N/A	None	pH - 9045 - Electrode	N/A	N/A	N/A	N/A	e	e	e	e
Sulfides	18496-25-8	N/A	N/A	None	Sulfide - 9030 - Colorimetric	0.5	N/A	5	N/A	e	e	e	e
Cyanide	57-12-5	1600	6400	32	Total Cyanide - 9010 - Colorimetric	0.005	0.005	0.5	0.5	e	e	e	e

**Table A.1. Constituents and Methods for Sediment Sample Analyses
for Waste Management Areas C, A-AX, and U (11 Sheets)**

CoC	CAS No.	Action Levels	Name/ Analytical Tech.	Target Required Quantitation Limits				Precision Water	Accuracy Water	Precision Soil	Accuracy Soil	
				Water ^b Low Level	Water ^b High Level	Soil- Other Low Level	Soil-Other High Level					
Inorganics (Cont'd)												
Uranium (total)	7440-61-1	240 ⁿ	960 ⁿ	4.8	Uranium Total - Kinetic Phosphorescence Analysis	0.0001	0.02	1	0.2	+20%	70-130%	+35% 70-130%

^aRR - Rural Residential, C/I - Commercial Industrial, GW - Groundwater Protection Radionuclide values from WDOH "Hanford Guidance for Radiological Cleanup." WDOH/320-015.

Radionuclide values are calculated using parameters from WDOH guidance.

^bWater values for sampling QC (e.g., equipment blanks/inlets) or drainable liquid (if recovered).

^cAll four-digit numbers refer to "Test Methods for Evaluating Solid Waste" (EPA SW-846).

^d"Methods of Analysis of Water and Waste" (EPA-600/4-79-020).

^ePrecision and Accuracy Requirements as identified and defined in the referenced U.S. Environmental Protection Agency procedures.

^fIf quantitation to action level lower than nominal RDL is required, prior notification/concurrence with the laboratory will be required to address special low-level detection limits.

^gThe 100 times GW rule does not apply to residual radionuclide contaminants. GW protection is demonstrated through technical evaluation using RESRAD (DOE/RL-96-17, Rev. 2).

^hThis value is based upon MTCA Method A values.

ⁱValue based upon most restrictive dichlorobenzene compound.

^jValue based upon most restrictive groundwater protection RAGs.

^kValue based upon most restrictive antimony compound.

^lDefault to background.

^mValue based upon uranium soluble salts value.

ⁿDetection limits below this value not achievable by listed technology. No routine technology likely available to achieve this detection limit.

Table A.2. Constituents and Methods for Organic Analysis of Borehole Sediment Samples

Analysis/ Constituent	Preparation Method	Preparation Procedure Number	Analytical Method	Analytical Procedure Number
VOA	Bulk Sediment	Note 1	GC/MS	SW846-8260
SVOAs with TICs	Bulk Sediment	Note 1	GC/MS	SW846-8270

Note 1: Preparation/extraction procedures for VOA and SVOA analysis will depend on the types of organic compounds present in the sediment.

GC = gas chromatography

MS = mass spectrometry

SVOA = semi-volatile organic analysis

VOA = volatile organic analysis

The remaining samples will be analyzed for specific constituents listed in Table A.1 depending on the results of the nitrate, electrical conductivity, total organic carbon/total carbon, and pH screening analyses. A review of the screening analyses results with technical representatives along with Ecology will be conducted before performing additional analyses. Screening analysis may be used to determine whether alternative analytical techniques with lower detection limits should be used for specific radionuclides of concern. The screening criteria and associated analytical requirements are identified as follows:

- Gamma-emitting radioisotopes by gamma energy analysis
- Metals and radioisotopes by inductively coupled plasma-mass spectrometry
- Tritium and strontium-90 by the liquid scintillation method
- Particle size distribution
- Carbon-14.

At the request of Ecology, a minimum of two samples collected within the Hanford formation will be analyzed for metals as identified in Table A.1.

The data obtained from the above analyses will be used to evaluate the location of contamination plumes in the sediment column. The results of the above analyses will also be used to determine if additional analyses are warranted. Additional analyses would be performed based on the judgment and expertise of the responsible Pacific Northwest National Laboratory geochemist, with concurrence from the CH2M HILL technical representative and Ecology. The following analyses would be performed as additional analyses:

- Cation exchange capacity
- Mineralogy
- Matric potential
- Distribution coefficient
- Bulk density
- Moisture retention
- Saturated hydraulic conductivity.

Tables A.1 and A.2 identifies the analyses and laboratory methods to be used for the sample analyses. For the chemical and radiological constituents, the preferred methods are those listed in *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (EPA SW-846) or *Standard Test Methods for Materials* (ASTM 1998). The requested constituents may be analyzed by laboratory-specific procedures, provided that the procedures are validated and conform to requirements in DOE/RL-96-68. Both the EPA SW-846 methods and the Pacific Northwest National Laboratory methods listed in Tables A.1 and A.2 are based on techniques from “Methods of Soil Analysis.” Therefore, these procedures should be comparable.

PART II

NEAR-SURFACE CHARACTERIZATION

The following is a discussion of the field tasks and associated subtasks required for the sampling and sample analysis associated with the near-surface characterization in WMA C. The tasks are generally parallel to those addressed for the vertical boreholes.

A4.0 PROJECT MANAGEMENT (TASK 1 OF CHAPTER 5.0)

Project management will be followed as described in the Phase 1 RFI/CMS work plan (DOE/RL-99-36).

A5.0 GEOLOGIC AND VADOSE ZONE INVESTIGATION (TASK 2 OF CHAPTER 5.0)

As with installation of the vertical boreholes, the geologic and vadose zone investigation task for the near-surface characterization has two subtasks: Subtask 2a, field activities, and Subtask 2b, laboratory analysis. The following subsections describe each of the subtasks with a field activity component.

A5.1 FIELD ACTIVITIES (SUBTASK 2A OF CHAPTER 5.0)

The field activities addressed in this subtask that are required to support the geologic and vadose zone investigation are geophysical surveying, sediment sampling, and reporting.

A5.1.1 Exploratory Activity

One area has been identified for the Phase 1 near-surface vadose zone soil characterization. The area is east and north of diversion box 241-C-152 in the C tank farm. Because of the high cesium content near the surface, the area directly related to the unplanned release will not be investigated. Using gamma survey data to define the lateral limits of the plume, direct push technology will be used to investigate lateral extent of technetium-99 leak area using direct push technology. The direct push technology pushes would focus on distribution along the pipe and perpendicular to the pipeline. Depending on technology used, soil sample size may constitute only analyzing for water leachable constituents such as nitrate as an indicator for technetium-99 migration and non destruct GEA prior to water extraction. Soil sampling size directly impacts amount of analysis. A minimum of 30 grams of sample is required to do key Tier 1 analysis. With between 150 to 200 grams can do entire suite. Perform gamma logging in all direct-push holes.

A total of 20 push sites have been identified.

The shallow investigation of this area will comprise collecting sediment samples at approximately 20 locations. Sediment samples would be attempted from the tank farm surface to refusal using direct-push technology. Although near-surface characterization is focused typically

on the upper 4.6 m (15 ft), the sampling methods have the capability to sample deeper and provide additional data for the characterization effort.

Direct-push deployment at the shallow zone characterization locations would include the following.

- Shallow soil characterization will be carried out using a truck-mounted direct-push technology-based system.
- Deployment and interrogation with a gross-gamma/spectral gamma probe. The depth of investigation will be determined by the depth to which the direct-push boring can be advanced using a standard deployment truck. The probe will be deployed using the gross gamma mode with the tool advanced at approximately 2 cm/sec (0.8 in./sec). Based on regulatory requirements, if in the upper 5 m (15 ft) the downhole instrument indicates a potential cesium-137 concentration of 3.7 pCi/g or greater, logging will be shifted to the spectral mode to determine the presence and level of concentration of cesium-137; below 5 m (15 ft) bgs the threshold limit for spectral gamma determinations will be 20 pCi/g. In zones where cesium-137 is present at concentrations greater than 20 pCi/g, spectral gamma readings will be taken at 0.5-m (1.5-ft) intervals.
- The graphical log developed using the gross and spectral gamma measurements will be used to select intervals to be sampled.
- The sampling push is to be made in a location that is no more than 0.7 m (2 ft) from the site of the gamma push.
- A single point sampler will be used to collect the required samples. Sampling intervals will be selected from those horizons with a cesium-137 concentration of 20 pCi/g or greater. In the event that horizons are penetrated that would yield samples having a greater than 50 mrem/hr dose rate at 30 cm (12 in.) (based on calculations using sampler size and cesium-137 concentration) a sample will be collected from the first interval below the high rate zone having a dose rate of less than 50 mrem/hr. No sample will be collected from zones where the gamma instrument exhibits excessive deadtime.
- The samples would be transported to the laboratory and analyzed for the contaminants of concern identified in Table A.1.

The samples selected for analysis would be subject to screening analyses, which consist of nitrate analysis by colorimetric method, pH, electric conductance, and gamma energy analysis. Based on the results of the screening, the samples would be analyzed for the remaining contaminants of concern identified in Table A.1.

A5.1.2 Field Quality Control

After the samples are screened, these samples will be transported to the Pacific Northwest National Laboratory Applied Geology and Geochemistry group for analysis. All material removed from the push holes will be sent to the laboratory for possible future analysis. Samples will be contained in airtight sample containers after their initial screening by the health

physics technician and are to be kept under refrigeration. This process is used to retain sediment moisture in as close to field condition as possible and prevent chemical and physical changes from occurring. All samples will be transported to the laboratory under refrigeration to further limit alteration of sediment moisture.

Field quality control samples also will be submitted for the full spectrum of chemical and radionuclide analyses. These quality control samples will consist of the following:

- Equipment rinseate blanks: One equipment rinseate blank per each type of sampler or, if multiple types of samplers are used, once per type of sampler.

A5.1.3 Geophysical Surveying Activities

Prior to sediment sampling using the direct push, downhole gross gamma and spectral gamma geophysical surveying will be conducted to ascertain the gamma-emitting radionuclide concentration in the surrounding sediments. After each push with the direct push or each borehole with the hollow-stem auger, decommissioning will occur.

A5.1.4 Field Reporting Activities

Field logs will be maintained to record all observations and activities conducted. A site representative will record the activities on a field activity report. Items for entry will include the following:

- Direct push or borehole number
- Site location drawings, including distances from known locations
- Drawings of the downhole tool strings for direct push
- Site personnel present
- Sampling types and intervals
- Zones noted by the health physics technician as elevated in radiological contaminants
- Instrument readings and the depth represented by those readings
- Specific information concerning borehole completion.

All completed field records will be maintained and processed in accordance with approved CH2M HILL Hanford Group, Inc. procedures.

A5.2 LABORATORY ANALYSIS (SUBTASK 2B OF CHAPTER 5.0)

The following sections describe the laboratory analyses required for the samples collected from the near-surface characterization.

A5.2.1 Near-Surface Characterization Sediment Sample Analysis Requirements

A total of approximately 20 site locations have been identified for the near-surface characterization effort. Once received at the laboratory, these samples shall undergo analysis using the analytical methods listed in Table A.1. This analysis may be sample-limited. Therefore, hold points have been inserted into the process to allow the laboratory and CH2M

HILL Hanford Group, Inc. technical staff to collaborate and review data before each new round of analyses. Analyses may be reprioritized based on the results of other measurements.

Based on the results of the screening analyses that were identified in the vertical boreholes, and spectral gamma surveys performed during the field geophysical surveys, and the geologic logging and field notes, geological technical experts, CH2M HILL Hanford Group, Inc. technical staff, the laboratory technical staff, and decision-makers (Ecology and the U.S. Department of Energy) will convene to determine what, if any, additional analyses should be conducted. Some of the determining criteria will be the amount and integrity of the remaining sample, screening analytical results, and regulatory requirements. Based on these decisions, additional analyses will be performed.

PART III LATERAL CHARACTERIZATION

The following sections provide a discussion of the field tasks and associated subtasks required for the sampling and sample analysis associated with the spectral gamma characterization in WMA A-AX. The tasks are generally parallel to those addressed for the vertical boreholes.

A6.0 PROJECT MANAGEMENT (TASK 1 OF CHAPTER 5.0)

Project management will be followed as described in the Phase 1 RFI/CMS work plan (DOE/RL-99-36).

A7.0 GEOLOGIC AND VADOSE ZONE INVESTIGATION (TASK 2 OF CHAPTER 5.0)

As with installation of the vertical boreholes, the geologic and vadose zone investigation task for the spectral gamma characterization has two subtasks: Subtask 2a, field activities, and Subtask 2b, laboratory analysis. The following subsections describe each of the subtasks with a field activity component.

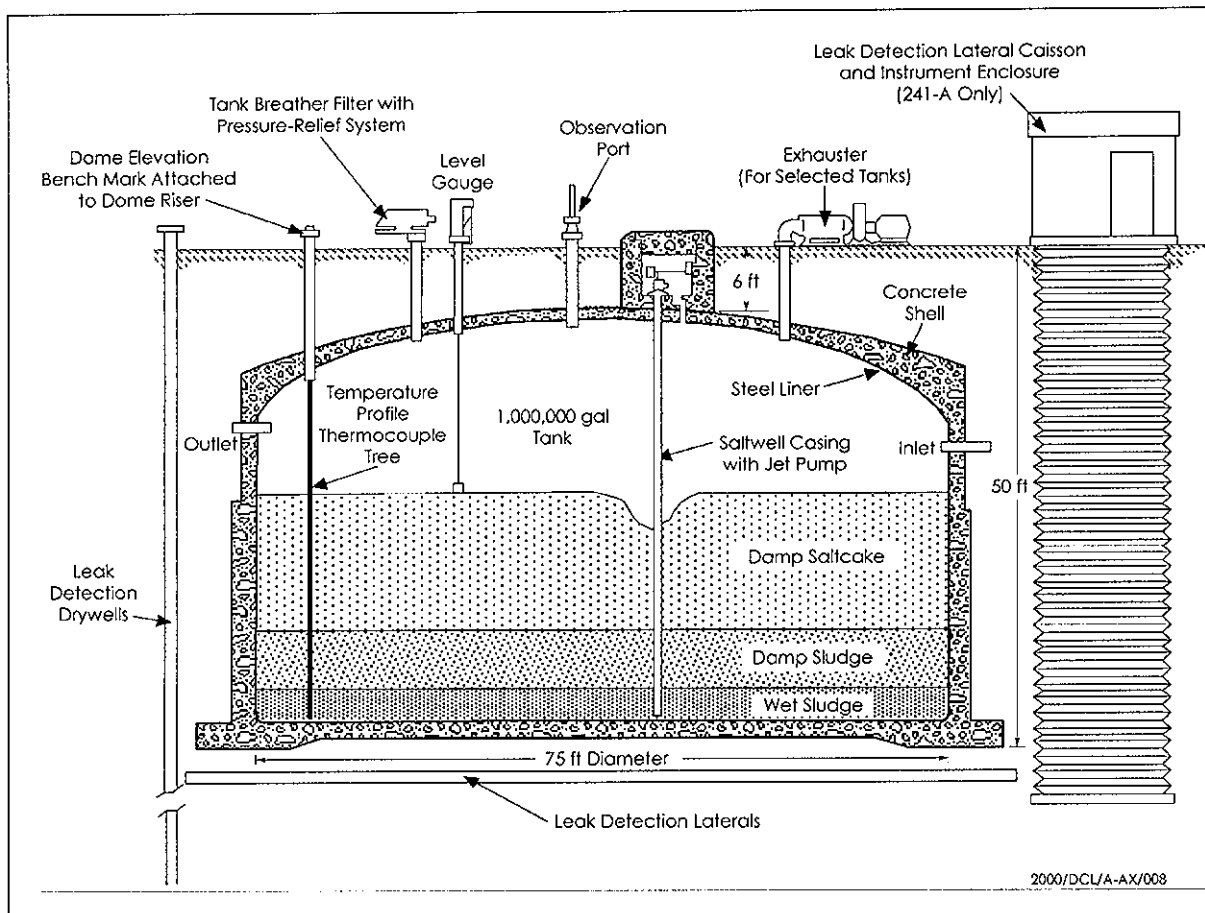
A7.1 FIELD ACTIVITIES (SUBTASK 2A OF CHAPTER 5.0)

The field activities addressed in this subtask that are required to support the geologic and vadose zone investigation are geophysical surveying, and reporting.

A7.1.1 Exploratory Activity

Loss of tank integrity for tanks A-104 and A-105 were demonstrated in 1965 by the occurrence of gross gamma measurements in several laterals (Figure A.6) that underlie these two tanks. In this report it has been concluded that a relatively small loss of tank waste to the vadose zone has occurred in each tank, a conclusion that, in the case of tank A-105, is considerably smaller than the volume estimates provided in *Waste Tank Summary Report for Month Ending January 31, 2003* (HNF-EP-0182). The basis for the smaller volume estimate is the lack of measured cesium-137 contamination in the drywells surrounding tank A-105. Given the estimated waste loading at the time of the leak, a large volume release should have distributed measurable cesium-137 over an area large enough to intersect the drywell locations.

Figure A.6. Schematic Showing the Construction of a Typical Single-Shell Tank at A Tank Farm with a 1 Mgal Capacity (after DOE/RL-88-21)



The most direct means of measuring cesium-137 in the vadose zone is to relog the laterals underlying the tanks to collect spectral gamma data. The gamma emitting radionuclides that created the initial measured radiation were short-lived fission products (e.g., ruthenium-106). The data to be collected in the relogging effort will determine the concentrations of specific gamma-emitting radionuclides still present in the vadose zone near the laterals. By now, the primary gamma-emitting radionuclide should be cesium-137. If minimal concentrations of cesium-137 are found in laterals measurements about 3 m (10 ft) from the leak location, then the released tank waste volume will be constrained to a minimal value.

A7.1.2 Geophysical Surveying Activities

Lateral gamma geophysical logging will be conducted to ascertain the gamma-emitting radionuclide concentrations.

A7.1.3 Laboratory Analysis (Subtask 2B of Section 5.0)

No laboratory analysis will be conducted under this survey of the laterals. Appropriate quality assurance and quality control procedures will be followed.

PART IV

SAMPLING PERFORMED IN CONJUNCTION WITH THE INSTALLATION OF RCRA GROUNDWATER MONITORING WELLS

A8.0 PROPOSED RCRA GROUNDWATER MONITORING WELL SEDIMENT SAMPLE ANALYSIS (SUBTASK 2B OF CHAPTER 5.0)

Drill cutting samples will be collected in conjunction with the installation of one RCRA groundwater monitoring well. The proposed RCRA groundwater monitoring well will be located north or northeast of the C tank farm. Drill cuttings will be collected from this well to total depth of borehole (i.e., basalt). Selected portions of the cuttings will be analyzed for their chemical and physical characteristics support to closure risk assessments. A detailed description of the work associated with the installation of these monitoring wells has been developed (PNNL-13024). Only details associated with analysis of sediment drill cuttings are addressed in this SAP.

Samples for analysis will be from each stratigraphic unit, stratigraphic contacts, weathered bedding structures, and lithologic facies changes.

Drill cutting samples from WMA U RCRA groundwater monitoring well already have been collected and analyzed.

A9.0 REFERENCES

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