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Phase 2 RCRA Facility Investigation/Corrective Measures Study Work Plan for Waste Management Area C

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Abstract: This work plan describes the Field work necessary to collect the data identified in RPP RPT 38152, Data Quality Objectives Report Phase 2 Characterization for Waste Management Area C Corrective Measures Study, and supports the Phase 2 Resource Conservation and Recovery Act of 1976 facility investigation/corrective measures study work plan and sampling and analysis plan activities for the single-shell tank Waste Management Area C.

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Phase 2 RCRA Facility Investigation/Corrective Measures Study Work Plan for Waste Management Area C

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EXECUTIVE SUMMARY

This work plan describes the field work necessary to collect the data identified in RPP-RPT-38152, *Data Quality Objectives Report Phase 2 Characterization for Waste Management Area C RCRA Field Investigation/Corrective Measures Study*, and supports the Phase 2 *Resource Conservation and Recovery Act of 1976* (RCRA) facility investigation/ corrective measures study (RFI/CMS) work plan and sampling and analysis plan activities for the single-shell tank Waste Management Area (WMA) C (Figure 1-1). As discussed in the *Hanford Federal Facility Agreement and Consent Order* (HFFACO) Action Plan (Ecology et al. 1989), the Phase 2 RFI/CMS work plan is prepared to present information on how the Phase 2 RFI/CMS processes will be conducted and eventually lead to proposed remedies for WMA C fulfilling HFFACO Milestone M-045-60 (*Federal Facility Agreement and Consent Order Change Control Form Change No. M-45-06-03, Modification of Tank Farm Corrective Measures and Interim Measures Milestones* [Ecology and DOE 2007]). This work plan also integrates with RPP-PLAN-37243, *Phase 2 RCRA Facility Investigation/Corrective Measures Study Master Work Plan for Single-Shell Tank Waste Management Areas* (Phase 2 Master Work Plan), as described in HFFACO Milestone M-045-58 and Appendix I, section 2.3 (Ecology and DOE 2007). This WMA C RFI/CMS uses the framework established in the Phase 2 Master Work Plan, which is the implementation plan for integrating the RCRA treatment, storage, and disposal unit closure process with the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* groundwater and soil operable unit remedial investigation/feasibility study process. The integration of these two processes will be implemented through management project teams as defined in DOE/RL-2007-20, *Hanford Integrated Groundwater and Vadose Zone Management Plan*. Groundwater has been impacted by some waste releases in WMA C. However, evaluations of groundwater contamination and remediation are not in the scope of this Phase 2 work plan. Investigating groundwater contamination under WMA C is part of the 200-BP-5 groundwater operable unit remedial investigation/feasibility study conducted by DOE-RL.

RPP-RPT-38152 called for site characterization to be performed at the 23 sites listed in Table ES-1 and shown on Figure ES-1. These characterization activities include the following:

a. Soil collection and analysis through direct push technology
b. Tissue sampling for ecological risk assessment
c. Drywell and groundwater monitoring well geophysical logging
d. Surface geophysical exploration (SGE).

Table ES-1 includes the sampling method, implementation design, and objective for each of the 23 sites selected for characterization in RPP-RPT-38152. Not shown in Table ES-1 or in Figure ES-1 is the development of a geophysical logging tool that can detect beta emitters, which is also included in this work plan.

Table ES-1. Sample Plan WMA C Phase 2 Characterization for RFI/CMS (6 sheets)

Map Design. Site	Group[a]	Location	Deployment	Number of Sampling Direct Pushes	Average Number of Samples[c]	Known or Suspected Event	Objective	Access Availability	Ecology/ Stakeholder Interest	Status as of November 2011
A	G3	Spare inlet 241-C-101	Direct push, slant	1-2	8	Tank over fill. Loss through spare inlet	Characterize C-101 release and refine conceptual models 1, 2, and 4	Fair	High	Sampled in FY 2011
B	G2	241-C-101, south side	Direct push, vertical or slant	1	8	Tank release	Characterize C-101 release and refine conceptual models 1 and 2	Good	High	Sampled in FY 2011
C	G4	241-C-203 and 200-UPR-E-137	(1) Direct push, slant; (2) 4 adjacent vertical direct pushes at Sites C and D combined to support placement of deep electrodes for 3D SGE; (3) Direct push slant, depending on SGE results[b]	1 or more, based on SGE results	8	Tank leak and/or tank over fill. Loss through spare inlet	Determine if C-200s actually leaked and refine conceptual models 1, 2, and 4; determine if any C-200 tank leaked during retrieval	Fair	Moderate to high	One slant direct push was logged in FY 2011; its companion slant direct push was sampled in FY 2012; SGE planned in 2013; additional sampling dependent on SGE results
D	G4	241-C-201 241-C-202 241-C-204	(1) 4 adjacent vertical direct pushes at Sites C and D combined to support placement of deep electrodes for 3D SGE; (2) Direct push, slant, depending on SGE results[b]	TBD based on SGE results	TBD	200 series tank leaks	Determine if C-200s actually leaked and refine conceptual models 1, 2, and 4; determine if any C-200 tank leaked during retrieval	Fair	Moderate, depending on C-203 results	SGE planned in 2013; sampling dependent on SGE results

Table ES-1. Sample Plan WMA C Phase 2 Characterization for RFI/CMS (6 sheets)

Map Design. Site	Group[a]	Location	Deployment	Number of Sampling Direct Pushes	Average Number of Samples[c]	Known or Suspected Event	Objective	Access Availability	Ecology/ Stakeholder Interest	Status as of November 2011
E	G2	Between 241-C-106 and 200-C-109	Direct push, vertical	1	8	Suspected release	Assess ^{60}Co and refine conceptual models 1, 2, and 4	Fair	High	Sampled in FY 2010
F	G2	Bldg C-801 chemical drain	Direct push, vertical	1	8	Suspected release site	Assess release of PUREX waste, ^{137}Cs and ^{99}Tc, and ^{60}Co and refine conceptual models 1, 2, and 4	Good	Moderate to high	Sampled in FY 2010
G	G2	Between Bldg C-801 and 241-C-103	Direct push, vertical	1	8	Suspected transfer line release site	Assess release and ^{60}Co and refine conceptual models 1, 2, and 4	Good	High	Sampled in FY 2009
H	G5	Northeast side of E-91	Direct push, vertical	1	8	Surface release	Surface exposures and assess ^{60}Co and surface release conceptual model	Good	High	Sampled in FY 2010
I	G5	Northeast side of E-115	Direct push, vertical or slant	1	8	Surface release	Surface exposures and assess ^{60}Co and surface release conceptual model, refine conceptual models 1, 2, and 4	Good	High	Sampled in FY 2010
J	G3	241-C-104	Direct push, slant	1	8	Tank release	Assess suspected release and refine conceptual models 1, 2, and 4	Fair	High	Sampled in FY 2011
K	G2	241-C-108	Direct push, vertical or slant	1	8	Transfer line leak, hot drywell (09-02)	Assess suspected release and refine conceptual models 1, 2, and 4	Poor due to retrieval operations	High	Deleted; replaced with site X to investigate C-105

Table ES-1. Sample Plan WMA C Phase 2 Characterization for RFI/CMS (6 sheets)

Map Design. Site	Group[a]	Location	Deployment	Number of Sampling Direct Pushes	Average Number of Samples[c]	Known or Suspected Event	Objective	Access Availability	Ecology/ Stakeholder Interest	Status as of November 2011
L	G2	241-C-103 and 241-C-106	Drywell logging and direct push, vertical	2	8	Potential transfer line leak and tank over fill	Update logging data for ^{60}Co, ^{137}Cs, uranium, and moisture and assess potential release and refine conceptual models 1, 2, and 4	Fair	Moderate	All drywells logged with SGLS; 73% moisture logged in FY 2009 through FY 2011. Sampled in FY 2009 and FY 2010
M	G7	241-C-104, -108, -109, -110, -111, and -112	Drywell logging	N/A	N/A		Update logging data for ^{60}Co, ^{137}Cs, uranium, and moisture	Fair to good	Moderate	44% of drywells logged with SGLS; 67% moisture logged in FY 2009 through FY 2011. Discontinue further logging
N	G8	UPR-86, UPR-82 and UPR-81	SGE	N/A	N/A		Test SGE, define plume at UPR-82 and -86; refine conceptual models 1, 2, and 4	Good	High	SGE work completed FY 2009 through FY 2011

Table ES-1. Sample Plan WMA C Phase 2 Characterization for RFI/CMS (6 sheets)

Map Design. Site	Group[a]	Location	Deployment	Number of Sampling Direct Pushes	Average Number of Samples[c]	Known or Suspected Event	Objective	Access Availability	Ecology/ Stakeholder Interest	Status as of November 2011
O	G9	WMA C	SGE	N/A	N/A		3D vision of suspected releases – may lead to supplemental sample locations	Good	High	Reanalysis of well-to-well data completed in FY 2011. Additional SGE to be deployed selectively (e.g., at sites C/D).
P	G1	UPR-81	Balance of direct pushes to complete characterization	3	8	Known release site	Characterize release and refine conceptual models 1, 2, and 4	Good	High	Sampled in FY 2009
Q	G6	UPR-82	(1) 4 adjacent direct pushes to support placement of strings of deep electrodes for 3D SGE per Map Design. Site N; (2) Direct push through center depending on SGE results[b]	1	8	Known release site	Test SGE: resolve depth with deep electrodes; define plume at UPR-82; refine conceptual models 1, 2, and 4	Poor due to shotcrete cover	High	SGE completed in FY 2011; direct push through center deleted
R	G2	241-C-301 Catch Tank	Direct push vertical	1	8	Unlined concrete catch tank	Assess potential catch tank release and refine conceptual models 1, 2, and 4	Good	Moderate to high	Sampled in FY 2010

Table ES-1. Sample Plan WMA C Phase 2 Characterization for RFI/CMS (6 sheets)

Map Design. Site	Group[a]	Location	Deployment	Number of Sampling Direct Pushes	Average Number of Samples[c]	Known or Suspected Event	Objective	Access Availability	Ecology/ Stakeholder Interest	Status as of November 2011
S	G5	UPR-72 and C-8 Drain	Direct push vertical	1	8	Buried radioactive material and French drain from 241-CR Building are in this area	Assess presence of buried material and potential releases to C-8 drain and refine conceptual models 1, 2, and 4	Good	Moderate to high	Deleted
T	TBD	TBD, based on SGE data for entire WMA	TBD, direct push vertical and/or slant	TBD	TBD	Previously unknown release sites	TBD	TBD	Moderate to high	Sampling dependent on SGE results
U	G3	C-110	Direct push, slant or vertical	1	8	Tank leak and/or tank over fill. Loss through spare inlet	Characterize C-110 release and conceptual models 1, 2, and 4	Fair	High	Sampled in FY 2010
V	G2	C-111	Direct push vertical	1	8	Tank leak and/or tank overfill. Loss through spare inlet	Characterize C-111 release and conceptual models 1, 2, and 4	Good	High	Deleted
W	G9	299-E27-4 299-E27-12, 299-E27-13, 299-E27-14, 299-E27-15	Log groundwater monitoring wells outside of WMA C	N/A	N/A		Log wells to collect data on U, ^{60}Co, ^{137}Cs, and moisture	Good	High	Logging data found for 299-E27-4 and -14. Logging of 299-E27-12, -13, and -15 deleted

Table ES-1. Sample Plan WMA C Phase 2 Characterization for RFI/CMS (6 sheets)

Map Design. Site	Group[a]	Location	Deployment	Number of Sampling Direct Pushes	Average Number of Samples[c]	Known or Suspected Event	Objective	Access Availability	Ecology/ Stakeholder Interest	Status as of November 2011
299-E27-20	TBD	Well 299-E27-20, adjacent to 299-E27-23	Analysis of archived soil samples	N/A	4	Previously unknown release site	Assess presence of potential release (^{99}Tc) to soil column impacting groundwater and conceptual models 1, 2, and 4	N/A	Moderate to high	Planned for FY 2013
X	TBD	C-105	Direct push, slant	1	8	Cascade line leak. Possible tank leak and/or tank over fill.	Investigate extent of high activity (10^7 pCi/g) ^{137}Cs plume in drywell 30-05-07 near tank C-105 and refine conceptual models 1, 2, and 4	Fair	Moderate to high	Planned for 2013

[a] Group refers to the expected work package associated with the characterization effort broadly defined as follows:

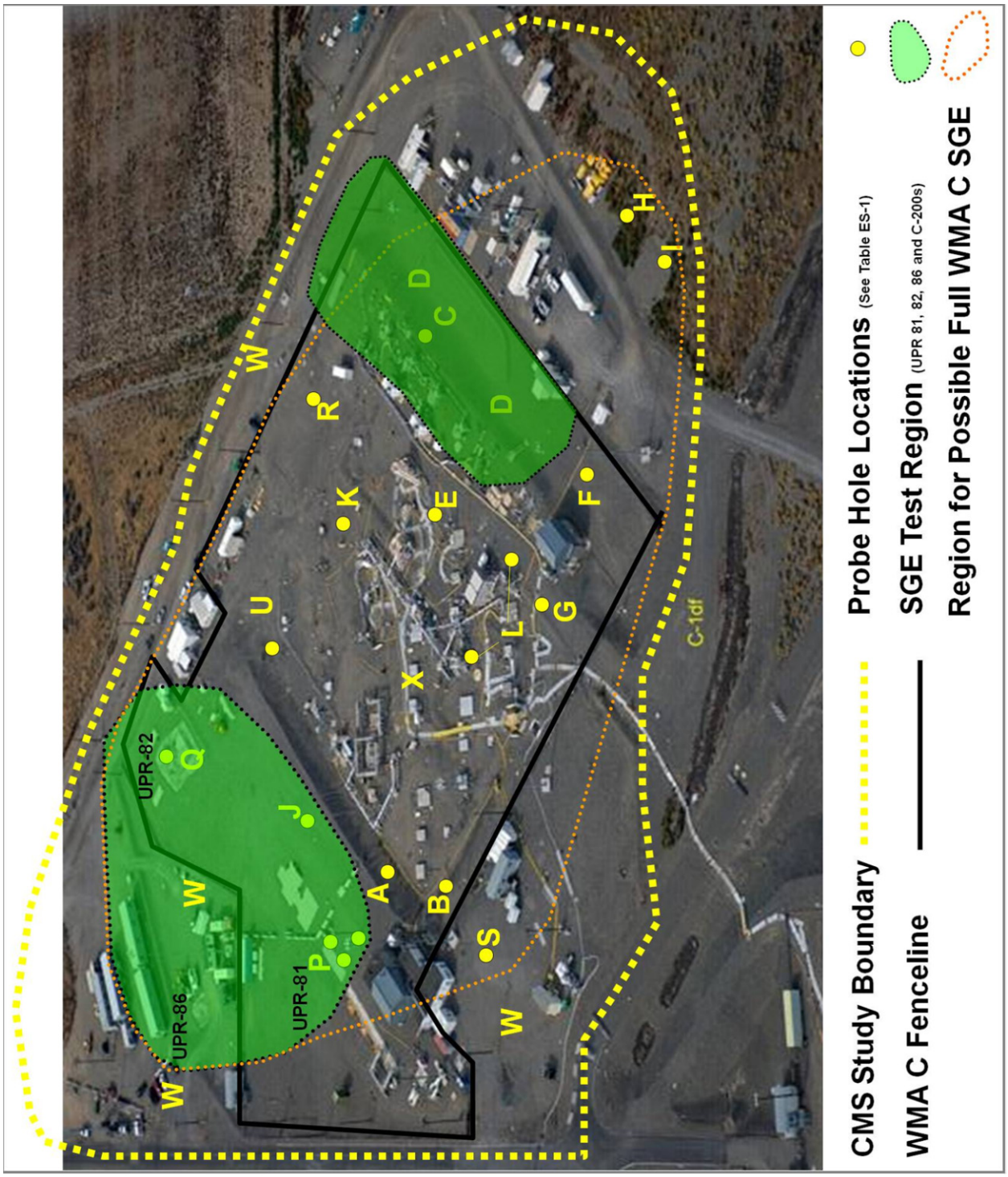
G1 = Direct push at UPR-81 (covered by existing work package).
G2 = Vertical direct pushes at nine investigative sites around the 100-series single-shell tanks.
G3 = Slant direct pushes at three investigative sites around the 100-series single-shell tanks.
G4 = Slant direct push at the C-200 Series tanks.
G5 = Outside the WMA, vertical direct push at the investigative sites.
G6 = Vertical direct push through gunite at UPR-82.
G7 = Drywell logging at select drywells.
G8 = Three separate SGE areas at the following locations: UPR-81, UPR-82, and UPR-86.
G9 = Deploy SGE at WMA C taking into account the results from testing at site N.

[b] Sampling design details for Map Design. Sites D and Q and for future work at site C are applicable to only to probeholes installed for sampling. Additional probeholes will be placed to support logging/electrode placement.

[c] Value includes one surface sample.

3D = three-dimensional
Ecology = State of Washington Department of Ecology
FY = fiscal year
N/A = Not Applicable
PUREX = plutonium uranium extraction (plant)
RCRA = *Resource Conservation and Recovery Act of 1976*
RFI/CMS = RCRA facility investigation/corrective measures study
SGE = surface geophysical exploration
SGLS = spectral gamma logging system
TBD = to be determined
UPR = unplanned release site
WMA = Waste Management Area

Figure ES-1. Surface Facilities, Candidate Sample Locations, and Surface Geophysical Exploration Interrogation Areas



Since the issuance of RPP-RPT-38152 in 2008, field investigation actions have been completed at many of the 23 sites, and ensuing tank leak loss studies have yielded new information about

WMA C tank history and conditions. Analysis of the newly available results and information has prompted efforts to modify and optimize the remaining WMA C site investigation. Key changes documented in this revised work plan include the following.

- Evaluation of fieldwork completed to date indicates that remaining borehole investigations near the C-200 Tanks (Sites C and D) will be better targeted if preceded by deployment of SGE across the area. The results of the SGE deployment will be evaluated with available soil analytical information to focus subsequent borehole installations and soil investigations.

- In 2003 groundwater monitoring well 299-E27-23 was installed southeast of 200-UPR-E-86. The RCRA groundwater monitoring results at this location show elevated levels of ^{99}Tc. Just prior to the installation of 299-E27-23, and immediately adjacent to it, borehole 299-E27-20 was drilled, then decommissioned after refusal was met in the aquifer. Vadose zone samples taken every 5 ft during the drilling of borehole 299-E27-20 were archived. Several of these samples will be retrieved from archives and analyzed for evidence of a nearby vadose zone source of ^{99}Tc.

- The planned investigation at Site V was driven by the belief that tank 241-C-111 had leaked tank waste to the soil. However, recent tank leak loss studies documented in RPP-ASMT-39155, *Tank 241-C-111 Leak Assessment Report* conclude that tank waste losses from tank 241-C-111 are a result of evaporation. As a result, the State of Washington Department of Ecology (Ecology) and the U.S. Department of Energy (DOE) have determined that installation of a direct push borehole at Site V is unlikely to yield information useful to the WMA C RFI/CMS. Therefore, installation of the borehole at Site V is deleted from the work plan.

- In accordance with Section 3.5.2 of this work plan, analytical results obtained to date from nine soil investigation locations have been evaluated to determine whether an opportunity exists to optimize the investigation at the remaining sites. As a result of this evaluation, and as documented in Letter 11-TPD-020, "Organic Analyses Optimization for Waste Management Area (WMA) C," and Letter 11-NWP-053, "Re: Organic Analyses Optimization for Waste Management Area (WMA) C," DOE and Ecology have agreed to optimize the WMA C investigation and focus on constituents of highest concern. The remaining soil samples will be analyzed for a reduced suite of organic analytes.

- Sulfide is eliminated as a soil investigation chemical of potential concern based on the removal of sulfide as a constituent associated with single-shell tank waste. Implementation of these changes will result in more sample volume being available for the constituents of highest concern, allowing for use of lower detection limits and improved quality control.

Soil samples for chemical analysis will be collected using direct push technology at 17 of the sites identified in Table ES-1. The number of sampling direct pushes ranges from 1 to 3 at each site for a total of up to 28 direct pushes. Furthermore, application of SGE using deep electrodes

has been undertaken at Site N, and SGE technology using surface and/or deep electrodes is being deployed elsewhere at WMA C to guide soil investigations within the WMA C data quality objectives boundary (e.g., at Sites C and D). Additionally, spectral gamma and moisture logging has been performed at accessible drywells around tanks 241-C-103, 241-C-104, 241-C-106, and 241-C-108 through 241-C-112 in accordance with RPP-RPT-38152. As with the SGE technology, spectral gamma and moisture logging may be performed at other locations at WMA C to guide soil investigations within the WMA C data quality objectives boundary. The specific timing and scope of the WMA C soil investigation work is contingent on available funding and prioritization of the investigative work relative to other tank farm activities, such as waste retrieval operations.

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LIST OF TERMS

Abbreviations and Acronyms

3D	three-dimensional
ALARA	as low as reasonably achievable
amsl	above mean sea level
ARAR	applicable or relevant and appropriate requirements
ASME	American Society of Mechanical Engineers
BCG	biota concentration guide
BGO	bismuth-germanium oxide
bgs	below ground surface
CCU	Cold Creek Unit
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	*Code of Federal Regulations*
CMA	corrective measures alternative
CMI	corrective measures implementation
CMS	corrective measures study
COC	contaminants of concern
COPC	contaminants of potential concern
COPEC	contaminants of potential ecological concern
CPERA	Central Plateau ecological risk assessment
CPP	CERCLA Past Practice
CW	coating waste from PUREX or REDOX Plants
CWA	*Clean Water Act of 1972*
DOE	U.S. Department of Energy
DQO	data quality objectives
DST	double-shell tank
Ecology	State of Washington Department of Ecology
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
FY	Fiscal Year
GC/ECD	gas chromatography/electron capture detection
GC/FID	gas chromatography/flame ionization detection
GC/MS	gas chromatography/mass spectroscopy

GEA	gamma energy analysis
GPR	ground-penetrating radar
H3/CCU/RF	Hanford formation/Cold Creek unit/Ringold Formation
HASQARD	*Hanford Analytical Services Quality Assurance Requirements Documents*
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
HLW	high-level waste
HMS	Hanford Meteorological Station
HRGC/HRMS	high resolution gas chromatography/high resolution mass spectrometry
HRR	high-resolution resistivity
HWMA	*Hazardous Waste Management Act*
IAEA	International Atomic Energy Agency
IX	ion exchange
KUT	potassium, uranium, thorium
MCL	maximum contaminant level
MTCA	*Model Toxics Control Act of 1989*
NCRP	National Council on Radiation Protection and Measurements
NEPA	*National Environmental Policy Act of 1969*
NRC	U.S. Nuclear Regulatory Commission
ORP	U.S. Department of Energy, Office of River Protection
OWW	organic wash waste from PUREX Plant
PAS	PUREX acidified sludge
PCB	polychlorinated biphenyl
PNNL	Pacific Northwest National Laboratory
PUREX	plutonium uranium extraction (plant)
QAPD	*Quality Assurance Program Description*
RCAP	RCRA Corrective Action Program
RCBRA	River Corridor Baseline Risk Assessment
RCRA	*Resource Conservation and Recovery Act of 1976*
RCW	Revised Code of Washington
REDOX	reduction-oxidation (plant)
RESRAD	RESidual RADioactivity (computer program)
RFI/CMS	RCRA facility investigation/corrective measures study
RI/FS	remedial investigation/feasibility study
RL	U.S. Department of Energy, Richland Operations Office

RPP	RCRA Past Practice
SAP	sampling and analysis plan
SDWA	*Safe Drinking Water Act of 1974*
SGE	surface geophysical exploration
SGLS	spectral gamma logging system
Sr/RE	strontium/rare earth
SST	single-shell tank
SVOC	semivolatile organic compound
TBP	Tributyl Phosphate
TFPC	241-A Tank Farm Process Condensate
TIC	tentatively identified compound
TOC	Tank Operations Contractor
TSD	treatment, storage, and disposal
UPR	unplanned release
VOC	volatile organic compound
WAC	*Washington Administrative Code*
WIDS	Waste Information Data System
WMA	waste management area

Waste Type

1C/CW	first cycle decontamination waste mixed with cladding removal waste
BNW	Battelle Northwest
CWP1	PUREX cladding waste, aluminum clad fuel (1956-1960)
CWP2	PUREX cladding waste, aluminum clad fuel (1961-1972)
FeCN	ferrocyanide
HLO	Hanford 300-Area Laboratories
MW2	bismuth phosphate metal waste (1950-1956)
P1	PUREX HLW (1956-1962)
P2	PUREX HLW (1963-1967)
PSN	PUREX HLW supernate
PSS	PUREX sludge wash supernate
RSN	REDOX HLW supernate
TFeCN	ferrocyanide precipitate

METRIC CONVERSION CHART

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

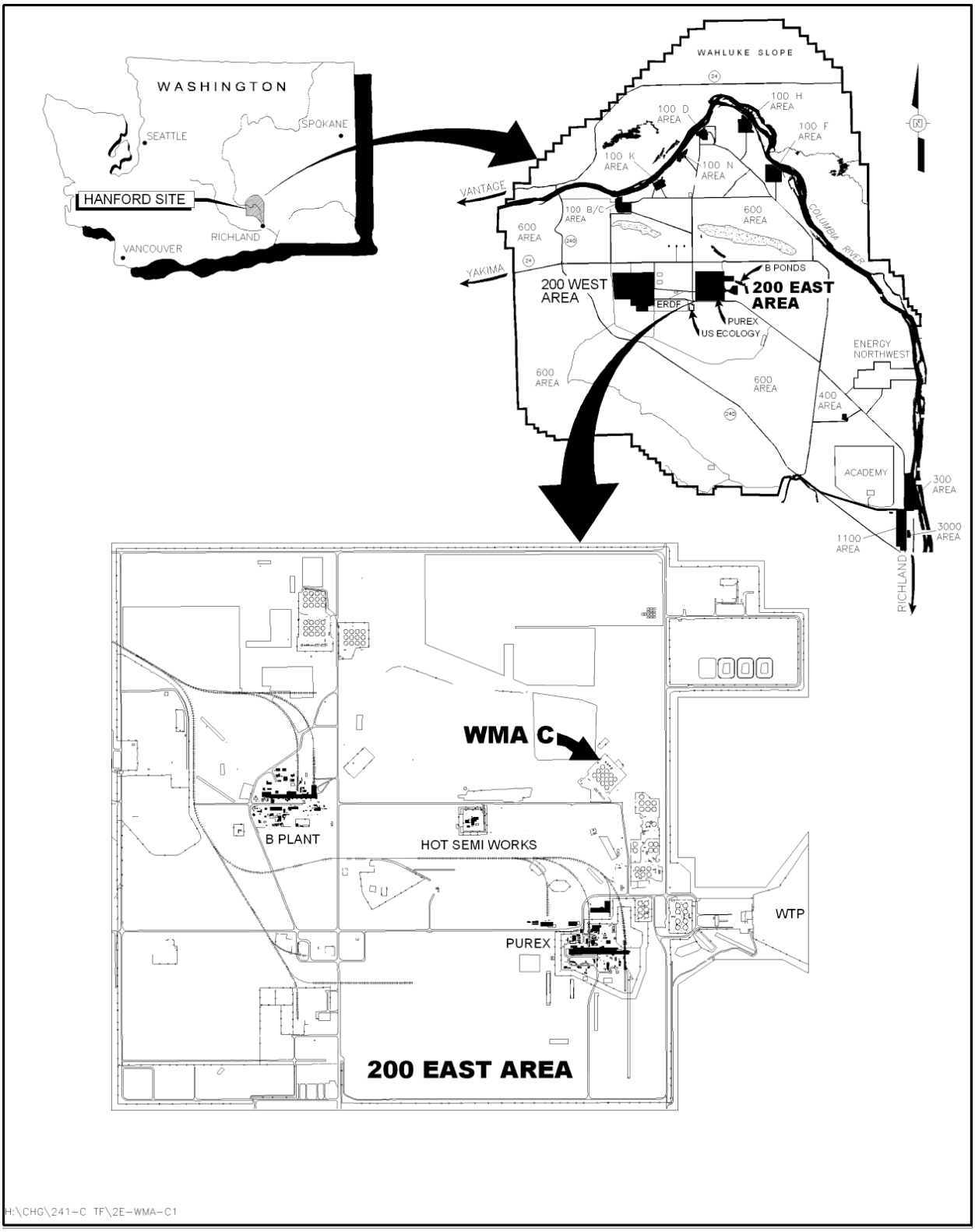
1. INTRODUCTION

This work plan describes the field work necessary to collect the data identified in RPP-RPT-38152, *Data Quality Objectives Report Phase 2 Characterization for Waste Management Area C RCRA Field Investigation/Corrective Measures Study*, and supports the Phase 2 *Resource Conservation and Recovery Act of 1976* (RCRA) Facility Investigation/ Corrective Measures Study (RFI/CMS) work plan and sampling and analysis plan activities for the single-shell tank (SST) Waste Management Area (WMA) C (Figure 1-1). The content and structure of this work plan follow the RCRA RFI/CMS work plan format established in OSWER Directive 9902.3-2A, *RCRA Corrective Action Plan (Final)*, with modifications to concurrently satisfy the additional *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) requirements in accordance with Appendix I of the *Hanford Federal Facility Agreement and Consent Order* (HFFACO) (Ecology et al. 1989).

As discussed in the HFFACO Action Plan, the Phase 2 RFI/CMS work plan is prepared to collect characterization data under the Phase 2 RFI/CMS process that eventually leads to proposed remedies for WMA C. This document fulfills the requirements of HFFACO Milestone M-045-60 (*Federal Facility Agreement and Consent Order Change Control Form Change No. M-45-06-03, Modification of Tank Farm Corrective Measures and Interim Measures Milestones* [Ecology and DOE 2007]). This work plan also integrates with RPP-PLAN-37243, *Phase 2 RCRA Facility Investigation/Corrective Measures Study Master Work Plan for Single-Shell Tank Waste Management Areas* (Phase 2 Master Work Plan) as described in HFFACO Milestone M-045-58 and Appendix I, section 2.3 (Ecology and DOE 2007). The RFI/CMS process uses the framework established in the Phase 2 Master Work Plan, which is the implementation plan for integrating the RCRA treatment, storage, and disposal (TSD) unit closure process with the CERCLA groundwater and operable unit remedial investigation/feasibility study (RI/FS) process including the groundwater program. The integration between the vadose zone program and the groundwater program is described in Chapter 5 of the Phase 2 Master Work Plan.

In 2007 the U.S. Department of Energy (DOE) and State of Washington Department of Ecology (Ecology) concluded negotiations on HFFACO milestone changes for completing the Phase 1 RFI/CMS process with HFFACO Milestone M-045-55. These negotiations also included the development of a clear vision for the planning and execution of Phase 2 final RCRA RFI/CMS process which also takes into account integration with other site groundwater and vadose zone cleanup efforts on the Hanford Central Plateau (Ecology and DOE 2007). The resulting HFFACO change package was approved in December 2007. The modification of milestones M-045-55, M-045-58 and M-045-60 and addition of milestones M-045-61 and M-045-62 established a framework for completion of corrective measures within WMA C (M-045-60 through M-045-62) and a Phase 2 Tank Farm Corrective Action Master Work Plan (M-045-58 and amended HFFACO Appendix I, Section 2.3) to define the overall corrective action completion approach and sequence for other tank farms or WMAs.

Figure 1-1. Location Map of Waste Management Area C in the 200 East Area at the U.S. Department of Energy Hanford Site



As a part of HFFACO change package M-45-06-03, milestone M-045-60 called for the submittal of this Phase 2 WMA C RFI/CMS work plan and accompanying Phase 2 WMA C sampling and analysis plan (SAP) by December 31, 2008. A new milestone was added for submittal of the Phase 2 RFI/CMS report for WMA C (M-045-61) and for submittal of the WMA C Corrective Measures Implementation Plan (M-045-62). Finally, HFFACO Appendix I, Section 2.3, was modified to describe the contents of RPP-PLAN-37243, which provides the conceptual process and sequencing approach for all SST farms and selection criteria for implementing Phase 2 RCRA corrective action.

Consistent with Part One, Article IV, Paragraph 19 of the HFFACO, this work plan addresses all aspects of contamination, including material subject to regulation under the *Atomic Energy Act of 1954*. However, the inclusion of information about such material in the plan does not confer authority to Ecology under RCRA or the *Revised Code of Washington* (RCW) 70.105, "Hazardous Waste Management," over otherwise exempt spent, byproduct, and special nuclear material regulated under the *Atomic Energy Act of 1954*.

1.1 PURPOSE, SCOPE, AND OBJECTIVES

This work plan presents background information, existing contaminant distribution data, and the approach that will be used for characterization and corrective action decision-making for WMA C. The potentially applicable technologies and the need for treatability studies are discussed in Chapter 5.

This work plan addresses only WMA C and its surrounding vicinity as defined in RPP-RPT-38152. Waste Management Area C, which is a RCRA WMA, includes the 241-C Tank Farm (C Farm) that consists of the following:

a. Twelve 100-series SSTs, each with 535,000-gal capacity
b. Four 200-series SSTs, each with 55,000-gal capacity
c. Waste transfer lines
d. Multiple drywells around each 100-series SST used as leak detection systems
e. Tank ancillary equipment, including diversion boxes, catch tanks, and related structures
f. Associated unplanned releases (UPR) to the soil.

This work plan contains SAPs for the Phase 2 corrective action process (Appendixes A and B). The soil SAP includes a quality assurance project plan and the sampling specifications for the characterization activities in the field (Appendix A). Previous characterization efforts (RPP-35484, *Field Investigation Report for Waste Management Areas C and A-AX*) and historical information (RPP-ENV-33418, *Hanford C-Farm Leak Assessments Report: 241-C-101, 241-C-110, 241-C-111, 241-C-105, and Unplanned Waste Releases*) associated with WMA C were used in the development of this work plan. Data-gathering activities included compiling and reviewing existing process-knowledge information. Waste Management Area C site characterization data also have been gathered and evaluated. This existing information and

the new characterization data that will be acquired as part of this Phase 2 sampling approach for this work plan will be used in the Phase 2 RFI/CMS report for WMA C due to Ecology on December 31, 2014 under HFFACO Milestone M-045-61.

The results from sampling and other characterization activities will be used to update the contaminant distribution models as needed and to support the CMS decision-making process. This work plan focuses on identifying and gathering the characterization information that will be needed for evaluating the selection of the preferred remedy(ies) from the CMS alternatives. Results of the characterization activities will be used for evaluating risk to potential receptors and for the CMS alternative analyses.

To focus the activities needed for future remedy selection for WMA C, this Phase 2 RFI/CMS work plan has incorporated the following.

a. Information-gathering activities are continuing, including location and characterization of releases, throughout the RFI/CMS process. As characterization results become available, they will be compared with information concerning operational history and construction details. This approach will allow for any subsequent data collection needs to be adapted as needed. Data gathering requirements are tailored to accommodate the characteristics of the entire WMA C and integration with the groundwater program, tank closure, and adjacent operable units, as appropriate.

b. Potential corrective measures alternatives (CMA) are identified and described. Potential remedies associated with WMA C initially are identified in the work plan. Corrective measures alternatives analysis will be completed in the Phase 2 RFI/CMS report for WMA C (HFFACO Milestone M-045-61) using data collected from both Phases 1 and 2 field characterization and risk evaluation activities.

Following approval of this work plan, the major elements (RFI/CMS steps) are requirements that are not expected to change; therefore, the work plan should not change. Specific work scope elements might require modification or refinement as the work progresses. Changes that do not affect the overall intent of the approved work plan or schedule can be made in the field and documented in the daily log books that are maintained in the field as stated in Section 12.4 of the HFFACO Action Plan (Ecology et al. 1989). Alternatively, and if agreed to by the U.S. Department of Energy, Office of River Protection (ORP) and the lead regulatory agency, unit managers' meetings or predecessor primary documents requiring ORP and lead regulatory agency approval also can be used to document changes. Changes to the project schedule that affect assigned HFFACO M-045 interim milestones will require approval through the HFFACO (Ecology et al. 1989) change control process.

Supporting characterization data acquired during the field investigation that will be used for corrective measures decision-making for WMA C will be presented in the Phase 2 RFI/CMS report.

1.2 DATA QUALITY OBJECTIVES PROCESS FOR WASTE MANAGEMENT AREA C

EPA/240/B-06/001, *Guidance on Systematic Planning Using Data Quality Objectives Process EPA QA/G-4*, was used to identify the data needs described in this work plan. The primary participants in this process were the Tank Operations Contractor (TOC), Ecology, and ORP. However, to ensure integration with other activities within the 200 East Area (RPP-PLAN-37243, Chapter 5), U.S. Environmental Protection Agency (EPA); U.S. Department of Energy, Richland Operations Office (RL); and Plateau Remediation Contractor also participated in the process but did not attend every workshop. This data quality objectives (DQO) process established the assumptions and global issues associated with Phase 2 characterization activities at WMA C. The Tribal Nations and Oregon stakeholders were provided informational meetings and sent the DQO and Revision 0 of this document for their review. The Phase 2 WMA C DQO summary report (RPP-RPT-38152) summarizes the outcome of the DQO process for WMA C during the Phase 2 RFI/CMS process.

1.3 DOCUMENT STRUCTURE

This Phase 2 RFI/CMS work plan is organized to present information as follows:

- **Chapter 1** – *Introduction*
- **Chapter 2** – *Background and Setting*
- **Chapter 3** – *Waste Management Area C Site Characterization Efforts*
- **Chapter 4** – *Work Plan Rationale and Approach*
- **Chapter 5** – *RCRA Facility Investigation/Corrective Measures Study Process*
- **Chapter 6** – *Schedule*
- **Chapter 7** – *Project Management and Program Integration*
- **Chapter 8** – *References*

Appendix A contains the SAP for the Phase 2 characterization activities for soils planned for the vadose zone in WMA C, while Appendix B contains the sampling and analysis instructions for collecting tissue samples from small mammals. The sampling and analysis tasks presented in this sampling and analysis instructions guide are specific to small mammal collection and analysis to obtain data for use in dietary exposure modeling in the ecological risk assessment for WMA C. Attachments 1 through 4 support Appendixes A and B and provide TFC-PLN-02, "Quality Assurance Program Description" (QAPD) (Attachment 1), the general health and safety plan (Attachment 2), an information management overview (Attachment 3), and the waste management plan (Attachment 4).

1.4 QUALITY ASSURANCE

The DOE document DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Documents* (HASQARD) establishes the quality requirements for environmental data collection, including sampling and analysis, in support of the SST RCRA Corrective Action Program (RCAP). The HASQARD applies specifically to field and laboratory activities associated with evaluating subsurface contaminant impacts involving 200 Areas SST WMA releases to the environment. The HASQARD complies with the requirements of EPA/240/B-01/003, *EPA Requirements for Quality Assurance Project Plans EPA QA/R-5*. The HASQARD also identifies technical procedural requirements that will describe field data collection and sampling and analysis requirements to be implemented during the investigation. Technical procedures will be identified in the SAP to address the requirements of the HASQARD (DOE/RL-96-68). The HASQARD provides a framework of the general requirements that apply to RCAP characterization and remedial efforts.

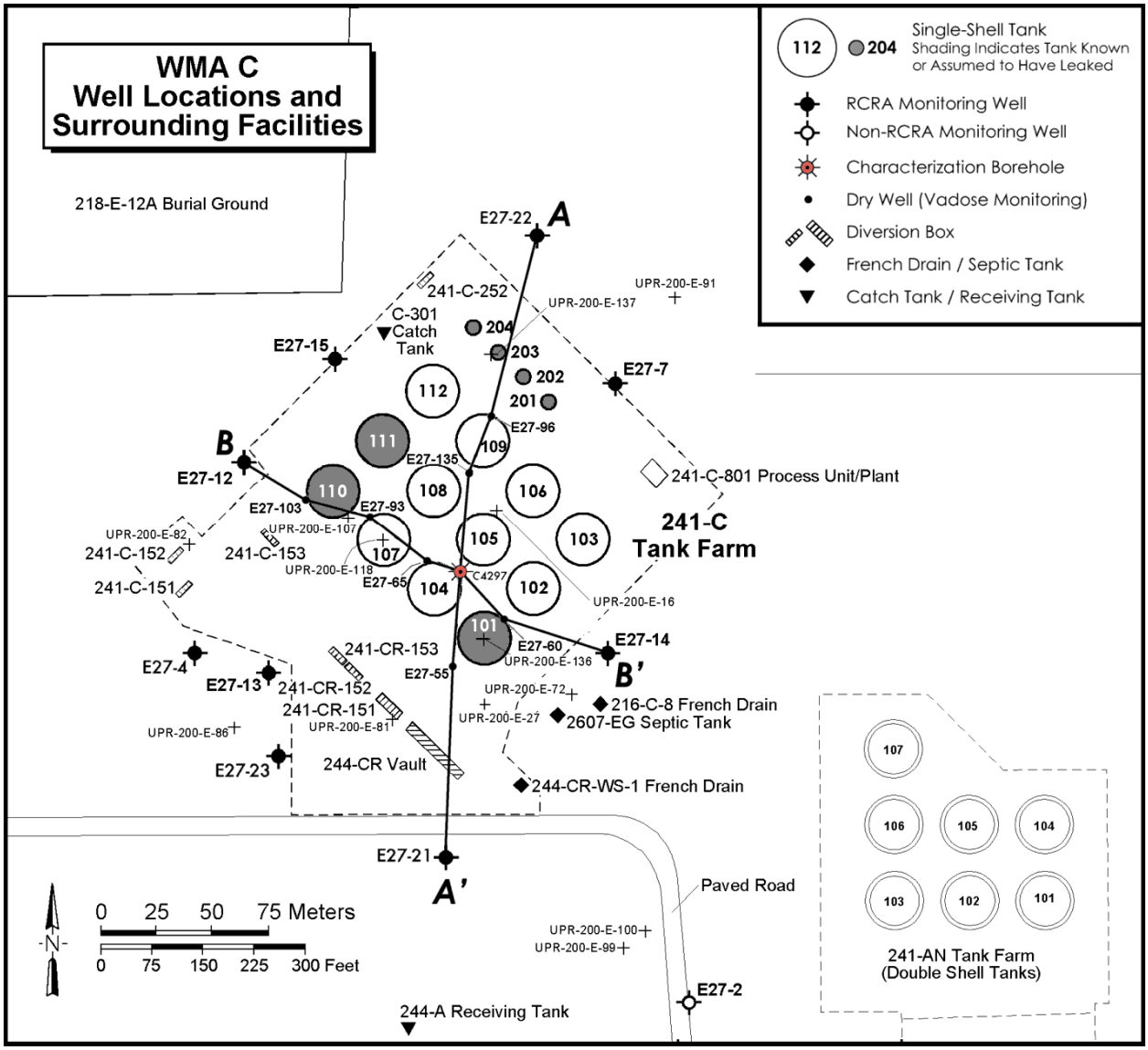
The TOC quality assurance document, the QAPD, establishes quality assurance requirements not covered in specific field and laboratory activities. This document is provided in Attachment 1 of this work plan. The QAPD incorporates the requirements of ASME NQA-1, *2004 Quality Assurance Requirements for Nuclear Facility Applications (QA)*, including NQA-1a-2005 and NQA-1b-2007 Addenda as required by the TOC contract with ORP.

2. BACKGROUND AND SETTING

This section provides background and site setting information relevant to SST WMA C. A thorough review of the documents relevant to SST WMA C process history, waste inventory, vadose zone studies, and groundwater studies was conducted as part of the DQO process and is presented in the Phase 2 WMA C DQO summary report (RPP-RPT-38152).

Figure 2-1 shows the location of WMA C and its surrounding facilities. Previous field investigation of borehole C4297 is also noted in Figure 2-1. Section 3.2.1 and RPP-35484 provide additional field characterization results for Phase 1.

Figure 2-1. Waste Management Area C and Nearby Facilities



2.1 GEOGRAPHIC SETTING

This section describes the topography, climate, demography, and ecology of the Hanford Site, specifically the Central Plateau that includes 200 East Area where SST WMA C is located.

2.1.1 Topography

The WMAs were always located downhill from the waste generating facilities to allow gravity flow in the pipelines from the facilities to the tanks. Figure 2-2 provides a topographic map of WMA C along with two topographic profiles (C-101 to C-103 and C-110 to C-112). These profiles show a stair-step elevation drop trending from the higher elevations in the southwest to lower elevations in the northeast.

2.1.2 Climate

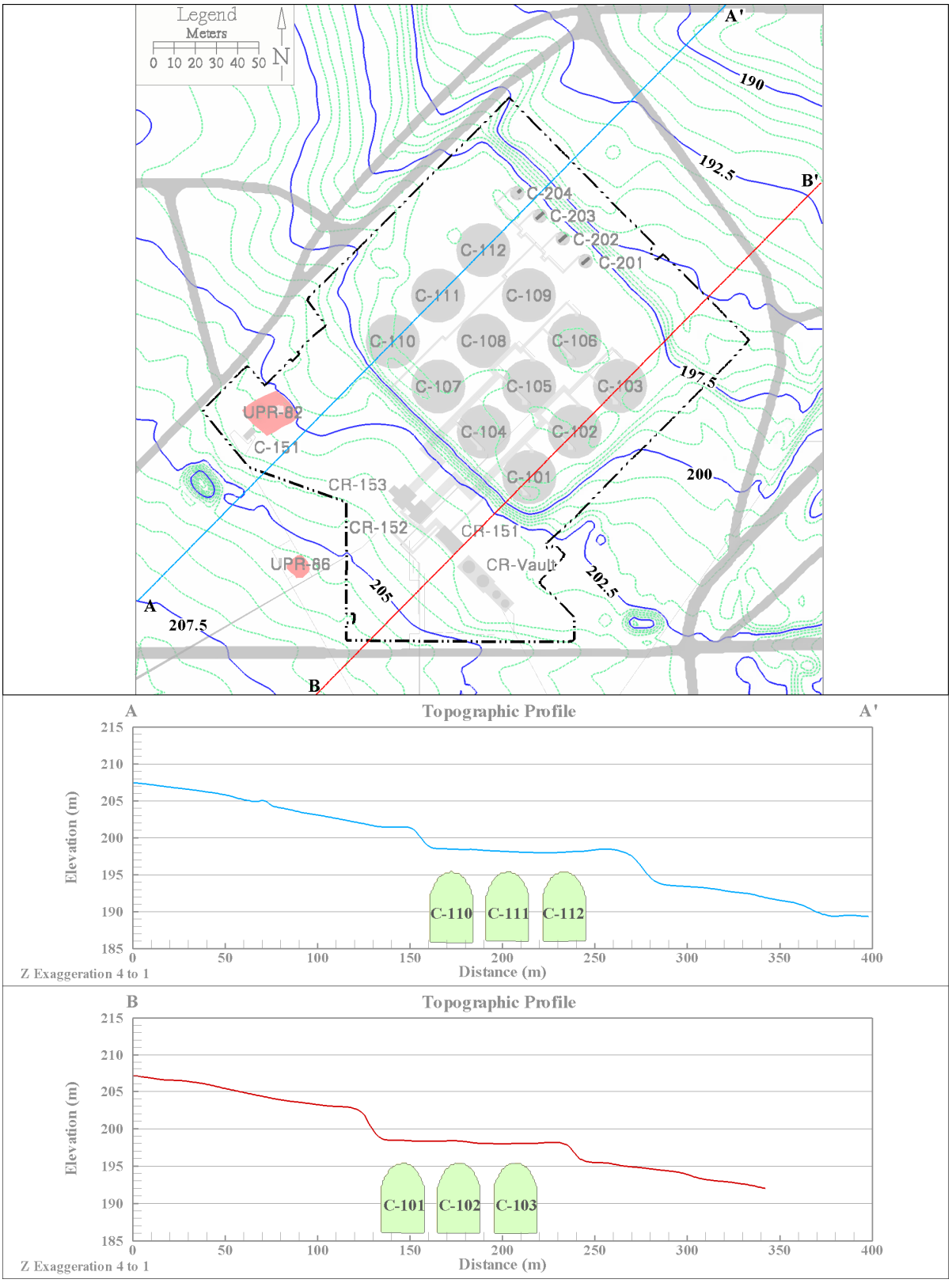
The information in this section is a summary; additional detail can be found in the annual climatological data summary reports, which have been issued since 1993. The most recent report is PNNL-15160, *Hanford Site Climatological Data Summary 2004 with Historical Data*. Additional information can be found in PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization*.

The climate at the Hanford Site can be classified as either mid-latitude semiarid or mid-latitude desert, depending on which climatological classification system is used. Large diurnal temperature variations are common, resulting from intense solar heating and nighttime cooling. Daytime high temperatures in June, July, and August can exceed 100°F. Winters are cool with occasional precipitation that makes up about 44% of the yearly total. During the winter, outbreaks of cold air associated with modified arctic air masses can reach the area and cause temperatures to drop below 0°F. Overcast skies and fog occur predominantly during the late fall and winter months.

Weather conditions are monitored and recorded at the Hanford Meteorological Station (HMS), located between the 200 East and 200 West Areas at ~733 ft elevation. Data from the HMS are representative of the general climatic conditions for the region and describe the specific climate of the 200 Areas. Real-time and historical data from the HMS can be obtained on the Internet at http://hms.pnl.gov/hms.htm.

The Cascade Range to the west of the Hanford Site greatly affects the temperature, wind, and precipitation in the region. Air masses that reach the Pasco Basin are changed as they pass over the region's relatively complex topography. The mountains limit the maritime influence of the Pacific Ocean, making the climate of eastern Washington drier and with greater temperature extremes than the coastal region. In addition to this rain shadow effect, the Cascade Mountains are a source of cold air drainage, which has a considerable effect on the wind regime of the site.

Figure 2-2. Elevation Contour Map of Waste Management Area C with Topographic Profiles Running through Waste Management Area C



Daily maximum temperatures vary from a normal maximum of 35°F in late December and early January to 96°F in late July. On the average, 52 days during the summer months have maximum temperatures of 90°F or higher and 12 days with maxima of 100°F or higher. From mid-November through early March, average daily minimum temperatures are below freezing (≤32°F), with the daily minima in late December and early January averaging 21°F. During the winter, on average, 3 days have minimum temperatures of 0°F or lower; however, only about one winter in two experiences such temperatures. The record maximum temperature is 113°F, and the record minimum temperature is –23°F.

Between 1946 and 2007, annual precipitation at the HMS averaged 17.3 cm (6.81 in.) and varied between 7.6 cm (3 in.) and 31.3 cm (12.3 in.). The wettest season on record was the winter of 1996–1997 with 14.1 cm (5.4 in.) of precipitation; the driest season was the summer of 1973 when only 0.1 cm (0.03 in.) of precipitation was measured. Most precipitation occurs during the late autumn and winter, with more than half of the annual amount occurring from November through February. Days with more than 1.3 cm (0.50 in.) precipitation occur on average less than once each year. Rainfall intensities of 1.3 cm/hr (0.5 in./hr) persisting for 1 hour are expected once every 10 years. Rainfall intensities of 2.5 cm/hr (1.0 in./hr) for 1 hour are expected only once every 500 years.

About 38% of the precipitation during December through February falls as snow. Winter monthly average snowfall ranges from 0.5 in. in March to 5.0 in. in January. Only one winter in four is expected to accumulate as much as 5.9 in. of snow on the ground. During these winters, 4 days, on average, have 6.0 in. (or more) of snow on the ground. However, the 1964–1965 winter had 35 days with snow on the ground, 32 of which were consecutive.

Prevailing wind direction on the 200 Area plateau is from the northwest in all months of the year. Secondary maxima occur for southwesterly winds. Summaries of wind direction indicate that winds from the northwest quadrant occur most often during the winter and summer. During the spring and fall, the frequency of southwesterly winds increases with a corresponding decrease in northwest flow. Winds blowing from other directions (e.g., northeast) display minimal variation from month to month. Monthly average wind speeds are lowest during the winter months, averaging 6 to 7 mph, and highest during the summer, averaging 8 to 9 mph.

Wind speeds that are well above average are usually associated with southwesterly winds. However, the summertime drainage winds are generally northwesterly and frequently reach 30 mph. These winds are most prevalent over the northern portion of the Hanford Site.

2.1.3 Demography

An estimated total of 177,900 people lived in Benton County and 80,500 lived in Franklin County April of 2011, totaling 258,400, an increase of almost 35% from the Census 2000 figure (Office of Financial Management [OFM] 2011a, Queried 02/08/2012, [April 1 official population estimates], http://www.ofm.wa.gov/pop/april1/default.asp). According to the 2000 Census, population totals for Benton and Franklin counties were 142,475 and 49,347, respectively (*Poverty Thresholds in 2000, by Size of Family and Number of Related Children Under 18 Years* [U.S. Census 2001]). Both Benton and Franklin counties grew at a faster pace

than Washington as a through the first decade of the century. The population of Benton County grew 21.3%, up from 142,475 during 2000. The population of Franklin County grew 53%, up from 49,347 during 2000 (OFM 2011a).

The distribution of the Tri-Cities population in April 2011 by city is as follows: Richland, 49,090; Pasco, 61,000; and Kennewick, 74,665. The combined populations of Benton City, Prosser, and West Richland totaled 21,125 in April 2011. The unincorporated population of Benton County was 33,020. In Franklin County, incorporated areas other than Pasco had a total population of 5,835. The unincorporated population of Franklin County was 13,665 (OFM 2011a).

In April 2011, Benton and Franklin counties accounted for 3.8% of Washington's population. The population demographics of Benton and Franklin counties are quite similar to those found within Washington. In general, the population of Benton and Franklin counties is somewhat younger than that of Washington as a whole. The 0- to 14-year-old age group accounts for 24.5% of the total bi-county population compared with 19.3% for Washington. The population in Benton and Franklin counties under the age of 35 is 52.6%; it is 46.8% for the State of Washington (Office of Financial Management [OFM] 2011b, Queried 02/08/2012, [Intercensal and postcensal estimates of April 1 population by age and sex for the state and counties], http://www.ofm.wa.gov/pop/coagemf/default.asp).

Additional Hanford area demographic data are available from PNNL-14428, *Hanford Area 2000 Population*. This document includes 2000 Census estimates for the resident population by distance and compass direction within an 80-km (50-mi) radius of the Hanford Site. Population distributions are reported relative to five reference points centered on meteorological stations within major operating areas of the Hanford Site: the 100-F, 100-K, 200, 300, and 400 Areas. Data are presented in both graphical and tabular format and are provided for total populations residing within 80 km (50 mi) of the reference points, as well as for Native American, Hispanic and Latino, total minority, and low-income populations.

2.2 ECOLOGY

This section summarizes the ecology of the Hanford Site (Section 4.4 of PNNL-6415), emphasizing plant and animal activities that may affect exposure pathways. The primary impact would be through roots penetrating and animals burrowing through surface barriers into a disposal facility. Secondarily, the types of plants and animals and their density can affect net groundwater recharge, which is greatly influenced by surface vegetation and burrowing.

PNNL-6415 details both the terrestrial and aquatic ecology of the Hanford Site and presents extensive listings of plant and animal species, while this section considers only terrestrial ecological effects because all SSTs are not located near significant aquatic ecological systems. The Hanford Site consists of primarily undeveloped land. Chemical processing facilities, shutdown nuclear reactors, and supporting facilities occupy only about 6% of the site. Most of the Hanford Site has not experienced tillage or agricultural grazing since the early 1940s.

The Hanford Site is characterized as a shrub-steppe ecosystem that is adapted to the mid-latitude semiarid climate of the region. These ecosystems are typically dominated by a shrub overstory with a grass understory. In the early 1800s, dominant plants in the area were big sagebrush (*Artemisia tridentata*) and an understory consisting of perennial Sandberg's bluegrass (*Poa sandbergii*) and bluebunch wheatgrass (*Pseudoregneria spicata*). Other species included threetip sagebrush, bitterbrush, gray rabbitbrush, spiny hopsage, bluebunch wheatgrass, needle-and-thread grass, Indian rice grass, and prairie June grass.

With the advent of settlement, livestock grazing and agricultural production contributed to colonization by non-native vegetation species that currently dominate portions of the landscape. Although agriculture and livestock production were the primary subsistence activities at the turn of the century, these activities ceased when the Hanford Site was designated in 1943. No farming has occurred on the Hanford Site since the government took control of the site.

The dominant non-native species, cheatgrass, is an aggressive colonizer and has become well established across the site. Over the past decade, several knapweed species also have become persistent invasive species in areas not dominated by shrubs. Range fires that historically burned through the area during the dry summers eliminated fire-intolerant species (e.g., big sagebrush) and allowed more opportunistic and fire-resistant species to establish. Of the 590 species of vascular plants recorded for the Hanford Site, approximately 20% are non-native. Wildfires are frequent on the Hanford Site. Three large wildfires in the past two decades have burned over 15% of the site.

All WMAs in the tank farm system are actively managed to prevent vegetation, insects, and wildlife from using the WMA as habitat, including WMA C. Herbicides and pesticides are used on a regular basis and fences are placed around the perimeter to keep larger animals out. Without a source of food within the WMA, smaller animals are less likely to enter. PNNL-6415 provides a more complete description of the plant, insect, and animal life outside the WMAs.

2.3 GEOLOGY AND HYDROGEOLOGIC CONDITIONS

Since the Hanford Site started operating in the early 1940s, a large volume of information on the geology, seismology, and volcanology of the site has been collected and evaluated. As part of DOE/ORP-2005-01, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site*, a geologic data package (RPP-23748, *Geology, Hydrogeology, Geochemistry, and Mineralogy Data Package for the Single-Shell Tank Waste Management Areas at the Hanford Site*) was prepared that describes the geology, hydrology, and geochemistry of the region, site, and WMAs. Most of the data included in the geologic data package were collected by (or used by) several projects between about 1980 and the present. Those projects include the Basalt Waste Isolation Project, the Skagit Hanford Nuclear Project, the Energy Northwest safety analysis, several performance assessments, and numerous regulatory-driven geologic and hydrologic characterizations, assessments, and monitoring projects.

The technical aspects of all of these projects, and thus the data, interpretations of the data, and conclusions, have been scrutinized by one or more regulatory agencies and stakeholder groups

including the U.S. Nuclear Regulatory Commission (NRC), the National Academy of Sciences, the Defense Nuclear Facilities Safety Board, the EPA, the U.S. Geological Survey, the Washington State Departments of Ecology and Health, the Oregon Department of Energy, and the Yakama, Nez Perce, and Wanapum Indian Nations, and the Confederated Tribes of the Umatilla Indian Reservation. For additional information relating to geology, hydrology, and geochemistry of the Hanford Site, see RPP-23748 and PNNL-15955, *Geology Data Package for the Single-Shell Tank Waste Management Areas at the Hanford Site*. More information specific to WMA C is available in RPP-35484.

The descriptions in these reports were brought up to date by WHC-SD-EN-TI-012, *Geologic Setting of the 200 East Area: An Update*. In addition, DOE/RL-2002-39, *Standardized Stratigraphic Nomenclature for Post-Ringold Formation Sediments within the Central Pasco Basin* provides the new standardized nomenclature that was applied to this investigation. Post-basalt strata beneath the tank farm include (in descending order): (1) recent deposits, (2) Hanford formation, and (3) Cold Creek unit (CCU) and/or Ringold Formation. The most recent and comprehensive investigations on the interpreted geology of C Farm includes those reported in RPP-14430, *Subsurface Conditions Description of the C and A-AX Waste Management Area*, RPP-18290, *241-C Tank Farm Geologic and Stratigraphic Analysis*; RPP-23748, PNNL-15955, and RPP-35484. This document follows the standardized stratigraphic nomenclature recommended in DOE/RL-2002-39; therefore, the names for post-Ringold Formation stratigraphic units may differ from the terminology used in previous reports.

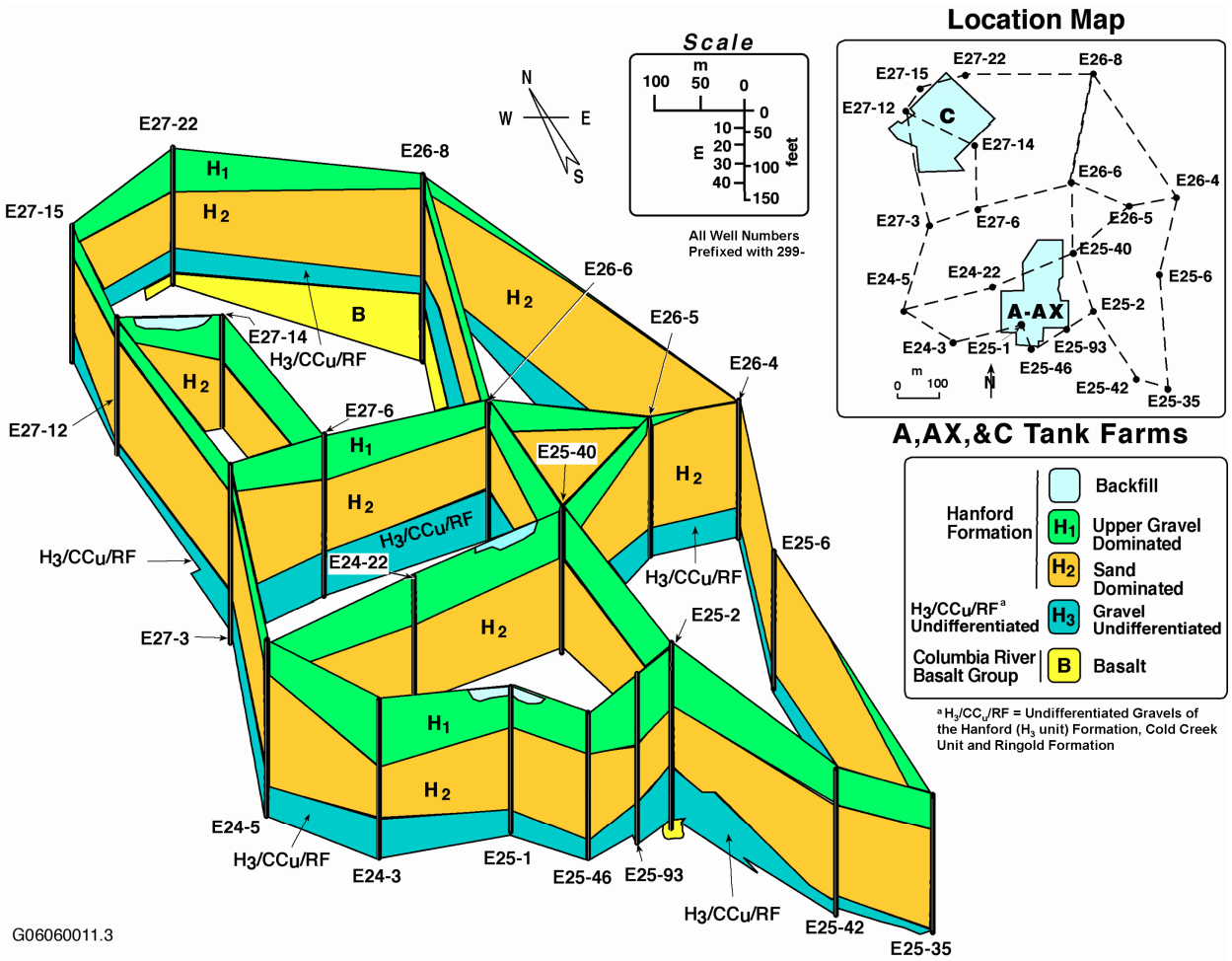
2.3.1 Geology

The geology of the major stratigraphic units underlying the C Farm and vicinity is well understood as a result of several decades of site characterization activities. It has been described in numerous reports (HW-61780, *Subsurface Geology of the Hanford Separation Areas;* ARH-LD-132, *Geology of the 241-C Tank Farm*; RPP-14430, and RPP-35484). The main source of information about the geologic strata underlying the Hanford Site and the tank farms is data from the drilling of boreholes and the analyses of the sediments and contaminants within them (e.g., PNNL-14656, *Borehole Data Package for Four CY 2003 RCRA Wells 299-E27-4, 299-E27-21, 299-E27-22, and 299-E27-23 at Single-Shell Tank, Waste Management Area C, Hanford Site, Washington*). More detailed discussion of the borehole-specific geologic and geochemical characteristics of WMA C vadose zone are provided in RPP-23748 and PNNL-15955.

Three major stratigraphic units underlie the C Farm, including (in ascending order) the igneous Columbia River Basalt Group, and two sedimentary units, the undifferentiated H3 unit of the Hanford formation/Cold Creek unit/Ringold Formation (H3/CCU/RF) and the Hanford formation. Figure 2-3 shows a fence diagram of these units underlying WMAs C and A-AX. Figure 2-4 shows the cross sections through WMA C as located on Figure 2-1. The undifferentiated H3/CCU/RF unit directly above the Columbia River Basalt Group is labeled as undifferentiated because two or three major stratigraphic units may have commingled, and clear distinctions between them cannot be made. These include the H3 subunit of the Hanford formation, the Cold Creek unit, and the Ringold Formation's Wooded Island member. The water

table occurs within the H3/CCU/RF. Finally, backfill materials consisting of poorly sorted cobbles, pebbles, and coarse to medium sand derived from the H1 subunit of the Hanford formation, are distributed around the tanks and tank infrastructure. Overall, the vadose zone is ~250 ft thick at WMA C.

Figure 2-3. Fence Diagram Showing Cross Sections through Waste Management Areas A-AX and C

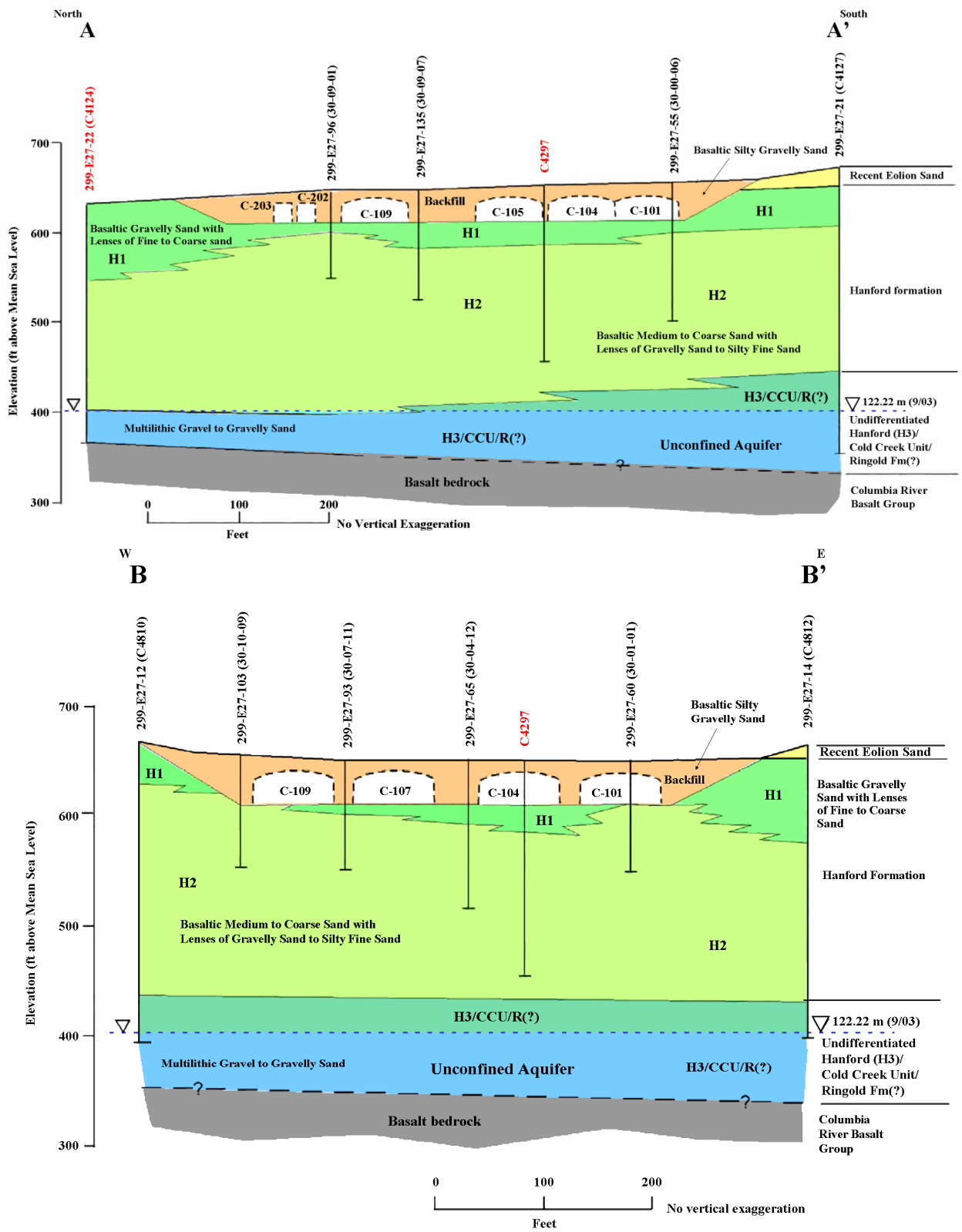


Reference: PNNL-15955, *Geology Data Package for the Single-Shell Tank Waste Management Areas at the Hanford Site.*

Of these, the backfill, Hanford formation, and the undifferentiated H3/CCU/RF make up the vadose zone. The unconfined aquifer is generally contained within the undifferentiated H3/CCU/RF. All major stratigraphic units are inferred to be essentially continuous in this area, although unit thicknesses vary and some subunits are not continuous. General characteristics of each sedimentary unit descending from the surface down beneath WMA C are as follows:

Hanford Formation. The Hanford formation is a cataclysmic flood deposit that is between 140 and 240 ft thick and thickens slightly toward the south and west. It consists of three subunits (H1, H2, and H3) that are distinguished by a change in the dominant particle-size distribution. The upper unit, H1, deposited in a high-energy environment, is loose sandy gravel to gravelly

Figure 2-4. Cross Sections A-A' and B-B' Through Waste Management Area C (Cross-Section Locations on Figure 2-1)



sand and composed of poorly sorted basaltic, sandy gravels to silty sandy gravels. It is between 30 and 100 ft thick in the area, thinning concentrically toward the middle of 241-A Tank Farm (A Farm) and generally thinning toward the north (e.g., at C Farm) (RPP-14430 and RPP-35484). The H2 unit deposited in a lower-energy environment is predominantly a sand-dominated sequence composed of mostly horizontal to tabular cross-bedded sands to gravelly sands. Thin silt lenses are occasionally present that occur on a scale too small to correlate between boreholes. The H2 unit is between 95 and 200 ft thick in the area and generally thickens to the west with localized minimums on the west side of A Farm and the east side of 241-AX Tank Farm (AX Farm). RPP-18290 and PNNL-14656 identified a third unit (H3) of the Hanford formation, which is usually reserved for a clast-supported, gravel-dominated facies at the base of the Hanford formation (DOE/RL-2002-39). However, at C Farm, the overall texture of this unit is still predominantly sand, with only a minor component of pebbly to slightly pebbly sand. The H3 unit of RPP-18290 and PNNL-14656 does not contain appreciably more gravel than the H2 unit. Otherwise, thicknesses increase toward the east up to a maximum of ~50 ft on the east side of AX Farm. At C Farm, the H3 unit may be present as part of the undifferentiated H3/CCU/RF.

Undifferentiated Hanford Formation/Cold Creek Unit/Ringold Formation. Waste Management Areas A-AX and C lie along the edge of a paleochannel that eroded much or all of the Ringold Formation during CCU and/or Hanford time. Because of the difficulty in distinguishing reworked Ringold Formation gravels and pre-Missoula mainstream Columbia River gravels from original Ringold Formation gravels, these units are undifferentiated here (H3/CCU/R).

Gravelly facies immediately overlying basalt within most of the study area belong to the H3/CCU/R. The H3/CCU/R consists of predominantly sandy pebble- to cobble-sized gravel with occasional boulders. Mineralogically, the sand fraction consists of 15 to 60% basalt grains with generally less than 1 wt% calcium carbonate. The total thickness of this unit is less than 27 m (90 ft), based on a limited number of boreholes where the upper and lower boundaries are represented. The top of H3/CCU/R ranges from about 120 to 130 m (390 to 425 ft) elevation above mean sea level.

2.3.2 Vadose Zone

The geology of the vadose zone underlying WMA C forms the media through which the contaminants move and provides the basis with which to interpret and extrapolate the physical and geochemical properties that control the migration and distribution of contaminants. Of particular interest are the interrelationships between the coarser- and finer-grained facies, and the degree of contrast in their physical and geochemical properties. While the exact distribution of these alternating units is not known, their contrast appears to have a strong influence on the distribution of leak and recharge waters and dissolved tank waste constituents.

Natural recharge from meteoric water (precipitation and snowmelt) and vadose zone hydrology are among the most important factors that control contaminant movement to the groundwater. The state of knowledge on recharge, matric potential, moisture content, and vadose zone hydraulic properties is discussed in the following sections. The section concludes with a

discussion of the unconfined aquifer properties for WMA C. A determination of the unsaturated flow characteristics in the region of these WMAs was based on the information in Section 3.1.3 of RPP-35484.

2.3.3 Recharge

Moisture movement through the vadose zone is important because it is the driving force for migration of most contaminants to the groundwater. Radioactive and hazardous wastes in the soil column from liquid-waste disposals, unplanned leaks, solid waste burial, and underground tank storage are potential sources of continuing and future vadose zone and groundwater contamination. Contaminants may continue to move downward for long periods [tens to hundreds of years depending on recharge rates and the distribution coefficient (K_d) of the contaminant] after termination of liquid waste disposal.

The WMAs were constructed with a gravelly sand surface layer that has been maintained free of vegetation with the use of herbicides. These conditions promote higher rates of infiltration of meteoric water that are expected to continue until the time of WMA closure. Interim measures to control infiltration have been implemented at the WMAs and an evaluation of accelerated corrective measures is being conducted under a RCRA corrective action program. Tank farm surfaces are covered with gravelly sand to provide radiation shielding for site workers and sprayed with herbicides to prevent vegetation growth. Bare gravel surfaces, however, enhance the net infiltration of meteoric water compared to undisturbed, naturally vegetated surfaces. Infiltration is further enhanced in the tank farms by the effect of percolating water being diverted by the impermeable, sloping surface of the tank domes. An umbrella effect is created by the buried tank domes, which for the larger 100-series tanks at WMA C are 75 ft in diameter. Water that is shed from the tank domes flows down the tank walls into the underlying sediments. Sediments adjacent to the tanks, while remaining unsaturated, can attain elevated moisture levels (WHC-SA-2680-FP, *Effect of Moisture-Dependent Anisotropy and Enhanced Recharge Around Underground Storage Tanks*). Other sources of recharge include unintentional surface spills, infiltration of surface runoff, leaking waterlines, and leaks from ancillary tank-related equipment.

Natural recharge can vary greatly, depending on factors such as climate, vegetation, surface condition, and soil texture. Studies conducted at the Hanford Site suggest that recharge rates can range from less than 0.1 mm/yr on a variety of soil and vegetative combinations to greater than 130 mm/yr on bare basalt outcrops or bare, gravel-covered waste sites ("Variations in Recharge at the Hanford Site," Gee et al. 1992). Data from experimental sites such as the Field Lysimeter Test Facility and the prototype Hanford barrier (crib B-57) suggest that recharge through gravels can range from 15 to 70% of precipitation, with the lower amount occurring under vegetated conditions [PNNL-11367, *Hanford Prototype-Barrier Status Report: FY 1996*; PNL-10285, *Estimated Recharge Rates at the Hanford Site*; and "Estimating Recharge Rates for a Groundwater Model Using a GIS" (Fayer et al. 1996)]. With a long-term annual average precipitation of 160 mm, the higher percentage translates into a recharge rate of ~100 mm/yr and was observed on sandy gravels that were kept free of vegetation (PNNL-14744, *Recharge Data Package for the 2005 Integrated Disposal Facility Performance Assessment*). Drainage is ~70 mm/yr from bare sand and ~100 mm/yr from sandy gravel under Hanford Site climatic conditions. There has been no direct measurement of recharge on tank farm gravels, which are

known to contain a larger amount of fines compared to clean gravels. Thus, it is likely that the tank farms experience a recharge rate that ranges between that observed for bare sand and the rate for clean gravels (i.e., 70 to 100 mm/yr).

Recharge estimates based on environmental tracer techniques [Open File Report 94-514, *Using Chloride and Chlorine-36 as Soil-Water Tracers to Estimate Deep Percolation at Selected Locations on the US Department of Energy Hanford Site, Washington*; and "Geochemical Estimates of Paleorecharge in the Pasco Basin: Evaluation of the Chloride Mass Balance Technique" (Murphy et al. 1996)] are generally consistent with those based on lysimeter studies. However, the tracer techniques are not applicable to disturbed sites such as the tank farms.

2.3.4 Groundwater

The Hanford Groundwater Protection Program has extensively monitored the groundwater in and around WMA C as part of the 200-BP-5 operable unit. At WMA C, groundwater monitoring is conducted for compliance with *Washington Administrative Code* (WAC) 173-303-400, "Dangerous Waste Regulations" (and by reference Title 40, *Code of Federal Regulations* [CFR], Part 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," Subpart F, "Ground-Water Monitoring") because WMA C is a *Hazardous Waste Management Act* (HWMA) (RCW 70.105) TSD unit. Data from groundwater monitoring wells are used to support the 200-BP-5 CERCLA groundwater operable unit. The unconfined aquifer at WMA C is found within the undifferentiated H3/CCU/RF unit. Both water level and general direction of groundwater flow in this region have been altered many times throughout Hanford Site operations history by high-volume wastewater discharges to various ponds (DOE/RL-2008-01, *Hanford Site Groundwater Monitoring for Fiscal Year 2007*; PNNL-16436, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*).

In the 1980s, a groundwater mound in this area was maintained by liquid discharge to B Pond east-northeast of WMA C, elevating the water table and imposing a southwestern trend in groundwater flow under WMA C (PNNL-15837, *Data Package for Past and Current Groundwater Flow Contamination beneath Single-Shell Tank Waste Management Areas*).

The aquifer properties beneath WMA C, including hydraulic properties, aquifer thickness, current flow directions, and flow rates are discussed in this section. The discussion focuses on the unconfined aquifer that extends from the water table to the top of basalt. Most of the information in this section is from PNNL-15837; PNNL-13024, *RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area C at the Hanford Site*; PNNL-16436; DOE/RL-2008-01; and RPP-23748.

Between 1944 and the mid 1990s, the volume of artificial recharge from Hanford Site operations wastewater disposal was significantly greater than recharge from precipitation. An estimated 1.68×10^{12} L (4.44×10^{11} gal) of liquid was discharged to disposal ponds, trenches, and cribs during this period. Wastewater discharge has decreased since 1984 and currently contributes a volume of recharge in the same range as the estimated natural recharge from precipitation. Because of the reduction in discharges, groundwater levels are falling, particularly around the operational areas (PNNL-15070, *Hanford Site Groundwater Monitoring for Fiscal Year 2004*).

Several wells extend through the unconfined aquifer in the 200 East Area to the top of the basalt and can be used to determine the thickness of the aquifer. RPP-23748 contains a list of wells near the 200 East Area SST WMAs that penetrate through the entire unconfined aquifer and have water level measurements from March 2005. In Fiscal Year (FY) 2008 a new well, 299-E27-155, was drilled to basalt and installed southwest of WMA C. Based on local and regional data the thickness of the uppermost aquifer increases from north to south as the top of basalt dips into the Cold Creek syncline. The unconfined aquifer thickness ranges from 29 to 61 ft beneath WMA C based on water levels from groundwater monitoring wells and on regional mapping of the top of basalt (PNNL-14656) (Table 2-1).

Table 2-1. Thickness of the Unconfined Aquifer Beneath Waste Management Area C

Well Name	Elevation of Top of Basalt[a,b] (m amsl)	Elevation of Water Table[c] (m amsl)	Aquifer Thickness (m)
Waste Management Area C			
299-E26-8	113.02	122.00	8.98
299-E27-22	112.38[d]	122.18	9.80

[a] Elevation of top of basalt, except where noted.
[b] Top of basalt elevation from PNNL-13024, *RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area C at the Hanford Site*; PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200 East Area and Vicinity, Hanford Site, Washington*; RPP-14430, *Subsurface Conditions Description of the C and A-AX Waste Management Area*, and Hanford Well Inventory System.
[c] March 2005 data, except where noted.
[d] July 2005.

amsl = above mean sea level.

References:
PNNL-15837, *Data Package for Past and Current Groundwater Flow Contamination Beneath Single-Shell Tank Waste Management Areas*
RPP-23748, *Geology, Hydrogeology, Geochemistry, and Mineralogy Data Package for the Single Shell Tank Waste Management Areas at the Hanford Site*.

Current general groundwater flow directions and general flow rates are given in Table 2-2 for WMA C (PNNL-15670, *Hanford Site Groundwater Monitoring for Fiscal Year 2005*). The general flow rate has been unchanged since FY 2005. The most current groundwater flow direction is southwest to south-southwest with a flow rate of 0.09 m/day, based on contaminant migration of sulfate (DOE/RL-2008-01) (see Section 3.2.2). The water table is very flat over all of the 200 East Area; the flow directions given in Table 2-3 were estimated using in-situ methods and plume tracking in addition to interpreting water level data on a local scale (PNNL-15837). No recent published results of detailed hydrologic testing (e.g., tracer dilution tests, constant-rate pumping tests) are available for wells at WMAs C and A-AX. However, recent data are available from slug testing at several wells (see Table 2-3).

The range of velocities for WMA C is the same in Tables 2-2 and 2-3 because the same hydraulic conductivity values were used.

Table 2-2. General Groundwater Flow Directions and Flow Rates for Single-Shell Tank Waste Management Area C in the 200 East Area

Groundwater Flow Direction	Gradient	Groundwater Flow Rate[a,b] (m/day)
SW - SSW	0.0001	0.7 to 2.4

[a] Groundwater flow rates are calculated using the Darcy equation.
[b] The multi-stress slug test was used for the calculation of groundwater flow rate for Waste Management Area C.

Reference: PNNL-15670, *Hanford Site Groundwater Monitoring for Fiscal Year 2005.*

Table 2-3. Results from Slug Testing of Wells at Waste Management Area C

Well	Hydraulic Conductivity (m/d)	Calculated Groundwater Flow Rate (m/d)
Waste Management Area C		
299-E27-22[a,b] (75.1 – 75.9)	1,900 – 2,100[c]	0.7[d]
299-E27-22[a,b] (76.8 – 77.4)	0.04[c]	0.00003[d]
299-E27-22[a,b] (81.4 – 81.7)	6,000 – 6,900[c]	2.3[d]
299-E27-23[e]	100 – 108[c]	0.036[d]

[a] PNNL-14656, *Borehole Data Package for Four CY 2003 RCRA Wells 299-E27-4, 299 E27-21, 299-E27-22, and 299 E27-23 at Single-Shell Tank, Waste Management Area C, Hanford Site, Washington*.
[b] Numbers in parentheses are depth intervals tested (meters below ground surface).
[c] High K (oscillatory) analysis method.
[d] Estimated, using maximum hydraulic conductivity from this table and effective porosity of 0.3 and hydraulic gradient of 0.0001 from PNNL-15670, *Hanford Site Groundwater Monitoring for Fiscal Year 2005*.
[e] PNNL-13378, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 1999;* PNNL-13514*, Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2000*; PNNL-14186, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year* 2002; PNNL-14804, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2003*.

Reference: PNNL-15837, *Data Package for Past and Current Groundwater Flow Contamination Beneath Single-Shell Tank Waste Management Areas*.

Multi-stress slug tests have been done at specific depth intervals in one well at WMA C. The results of those tests (Table 2-3) indicate the ranges in hydraulic conductivity that can be expected within a single well. The data show that the hydraulic conductivity and the calculated flow velocity can be expected to vary by several orders of magnitude within a single well. One similar test was performed at WMA T in the 200 West Area in a well for the Ringold Formation (member of Wooded Island unit E) sediments. The range of hydraulic conductivity in that well was 0.73 to 8.21 m/d. The aquifer for WMA C is in the undifferentiated H3/CCU/RF unit, and the magnitude and range of the hydraulic conductivities is much larger than that found for the Ringold Formation.

Several slug tests were completed prior to 1997 in wells near the 200 East Area SST farms. The hydraulic conductivities obtained from the earlier slug test ranged from 7 to 119 m/d and were generally lower than those measured in the more recent tests (PNNL-15837). The differences are the result of different testing and analysis methods used over time; different assumed values

for certain parameters, such as effective porosity; and natural variation in lithologic properties that affect the hydraulic properties.

After the beginning of Hanford Site operations during 1943, the water table rose about 27 m (89 ft) under the U Pond disposal area in the 200 West Area and about 9.1 m (30 ft) under B and Gable Mountain disposal ponds near the 200 East Area. The volume of water that was discharged to the ground at the 200 West Area was actually less than that discharged at the 200 East Area. However, the lower hydraulic conductivity of the aquifer near the 200 West Area inhibited groundwater movement in this area resulting in a higher groundwater mound.

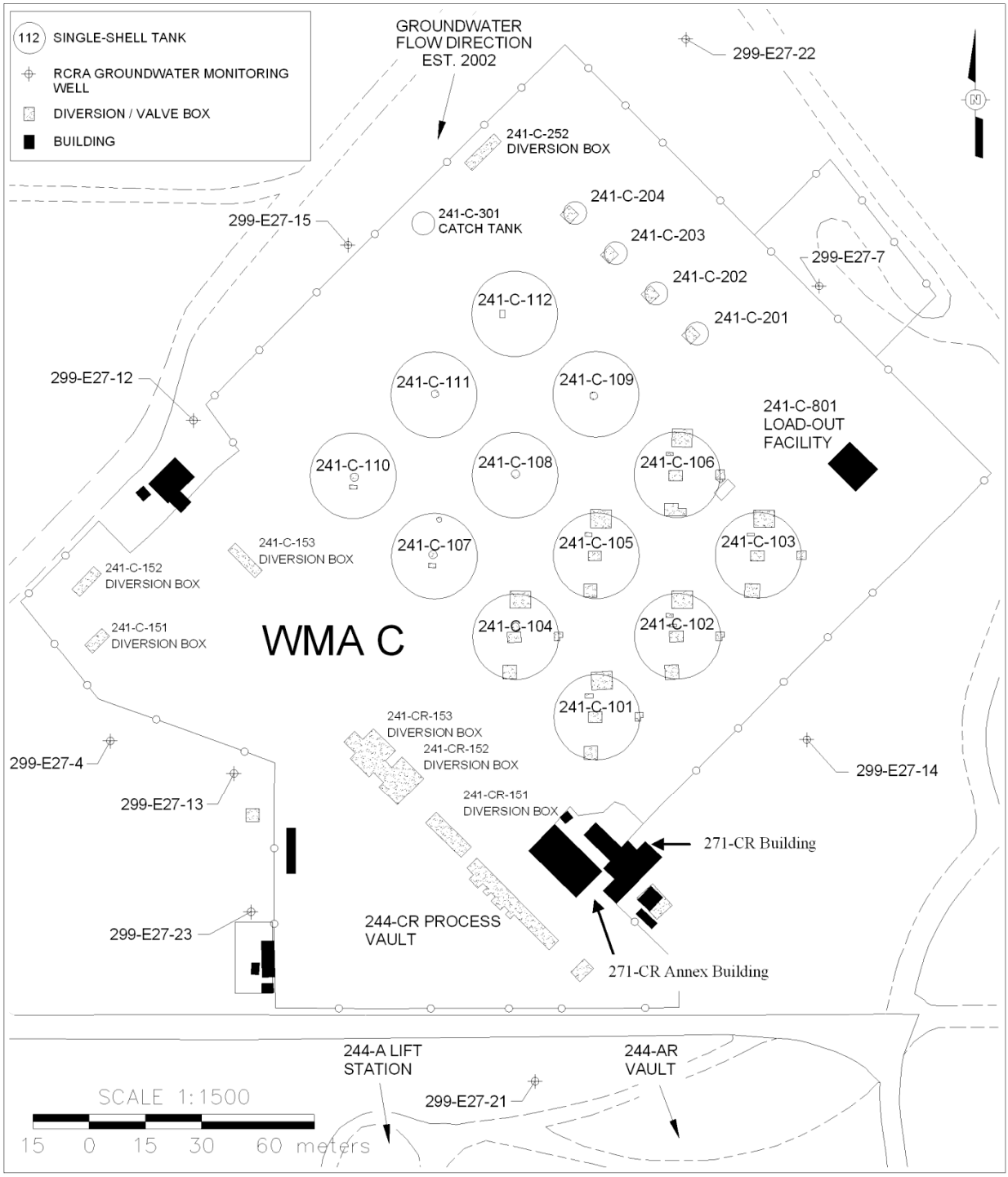
The presence of the groundwater mounds locally affected the direction of groundwater movement, causing radial flow from the discharge areas. PNL-5506, *Hanford Site Water Table Changes, 1950 Through 1980 – Data Observations and Evaluation*, documented changes in water table elevations between 1950 and 1980. Until about 1980, the edge of the mounds migrated outward from the sources over time. Groundwater levels have declined over most of the Hanford Site since 1984 because of decreased wastewater discharges (PNNL-14548, *Hanford Site Groundwater Monitoring for Fiscal Year 2003*; DOE/RL-2008-01).

Horizontal hydraulic conductivities of sand and gravel facies within the Ringold Formation generally range from ~1 to 100 m/day, compared to 10 to 3,000 m/day for the Hanford formation and the coarse-grained multilithic facies of the CCU (pre-Missoula gravels) (DOE/RW-0164, *Consultation Draft: Site Characterization Plan, Reference Repository Location, Hanford Site, Washington*; PNNL-13641, *Uncertainty Analysis Framework – Hanford Site-Wide Groundwater Flow and Transport Model*; PNNL-14058, *Prototype Database and User's Guide of Saturated Zone Hydraulic Properties for the Hanford Site*). Because the Ringold Formation sediments are more consolidated and partially cemented, they are ~10 to 100 times less permeable than the sediments of the overlying Hanford formation. Before wastewater disposal operations at the Hanford Site, the uppermost aquifer was mainly within the Ringold Formation, and the water table extended into the Hanford formation at only a few locations [*Geology and Ground-Water Characteristics of the Hanford Reservation of the U.S. Atomic Energy Commission, Washington* (Newcomb et al. 1972)]. However, wastewater discharges raised the water table elevation across the site. The general increase in groundwater elevation caused the unconfined aquifer to extend upward into the Hanford formation over a larger area, particularly near the 200 East Area. This resulted in an increase in groundwater velocity because of both the greater volume of groundwater and the higher permeability of the newly saturated Hanford formation sediments.

2.4 WASTE MANAGEMENT AREA C DESCRIPTION

Since the Hanford Site started operating in the early 1940s, a large volume of information related to WMA C operations has been collected and evaluated. Waste Management Area C encompasses the C Farm located in the east central portion of the 200 East Area (Figure 1-1 and Figure 2-5) including soil and groundwater contaminated by C Farm operations. The C Farm was constructed from 1944 to 1945, and began operations in the late 1940s. In general, the WMA C boundary is represented by the fenceline surrounding the C Farm.

Figure 2-5. Location Map of Waste Management Area C and Surrounding Area



The C Farm contains twelve 100-series tanks and four 200-series tanks. The 100-series tanks are 23 m (75 ft) in diameter, have a 5-m (15 ft) operating depth, and have an operating capacity of 1,892,700 L (530,000 gal) each. The 200-series tanks are 6 m (20 ft) in diameter with a 7.32-m (24 ft) operating depth and an operating capacity of 208,000 L (55,000 gal) each. Typical tank

configuration and dimensions are shown in Figure 2-6. Only tanks 241-C-101 (C-101) through 241-C-106 (C-106) have the concrete pits as shown in Figure 2-6. The other 100-series tanks are equipped with centrally located saltwell pump pits. The tanks sit below grade with at least 2 m (7 ft) of soil cover to provide shielding from radiation exposure to operating personnel. Tank pits are located on top of the tanks and provide access to the tank, pumps, and monitoring equipment.

The SSTs were constructed in place with 3/8-in.-thick carbon steel (ASTM A283 Grade C) lining the bottom and 1/4-in.-thick carbon steel lining the sides of a reinforced-concrete shell. The tanks have concave bottoms (center of tanks lower than the perimeter) and a curving intersection of the sides and bottom, where the carbon steel plate is 5/16-in. thick. The inlet and outlet lines are located near the top of the liners (Figure 2-6). There are four inlet lines on each tank, which are also known as nozzles. Pipelines from the diversion boxes to tanks C-101, 241-C-104 (C-104), 241-C-107 (C-107), 241-C-108 (C-108), 241-C-110 (C-110), and 241-C-111 (C-111) are supported by concrete viaducts, as shown in Figure 2-7. The viaduct has a 4-in. high curb running along both edges. The curbing stops about 11 ft 10 in. from the tank wall. At about 9 ft 10 in. from the tank wall, the viaduct surface steps down and the void space between the pipes and the viaduct surface is grouted. At this point the viaduct begins fanning out from 2 ft 8 in. wide to 7 ft 4 in. wide to support the spread placement of the fill lines through the tank wall. The concrete viaduct terminates 2 in. from the tank wall; the void space is filled with 2-in. asphalt-impregnated felt (drawing W-74108, *Hanford Engineer Works Building No. 241-T-U-B & C Concrete Details of Pipe Supports*).

Tanks C-101, C-104, C-107, and C-110 each have one outlet line to the next tank in series. Tanks 241-C-102 (C-102), 241-C-105 (C-105), C-108, and C-111 each have one additional inlet line and one outlet line. Tanks 241-C-103 (C-103), C-106, 241-C-109 (C-109), and 241-C-112 (C-112) each have one additional inlet line from the previous tank in the series. The lines connecting each tank are also referred to as “cascade” lines since they allowed transfer of fluids between tanks using gravity flow.

To support the transfer and storage of waste within WMA C SSTs, there is a complex waste transfer system of pipelines (transfer lines), diversion boxes, vaults, valve pits, and other miscellaneous structures. Collectively, these are referred to as ancillary equipment, as shown in Figure 2-8.

The 244-CR Process Tank Vault (244-CR vault) is located south of the tanks. The vault is a two-level, multi-cell, reinforced-concrete structure constructed below grade (DOE/RL-92-04, *PUREX Source Aggregate Area Management Study Report*), which contains four underground tanks along with overhead piping and equipment. Two tanks (TK-CR-001 and TK-CR-011) have a capacity of 170,343 L (45,000 gal) each. The other two tanks (TK-CR-002 and TK-CR-003) have capacities of 55,494 L (14,700 gal) each. This vault and associated diversion boxes 241-CR-151, 241-CR-152, and 241-CR-153 were constructed in 1951 and ceased operating in 1988. A schematic of the 244-CR vault is shown in Figure 2-9.

Figure 2-6. Typical Configuration and Dimensions of Single-Shell Tanks in Waste Management Area C

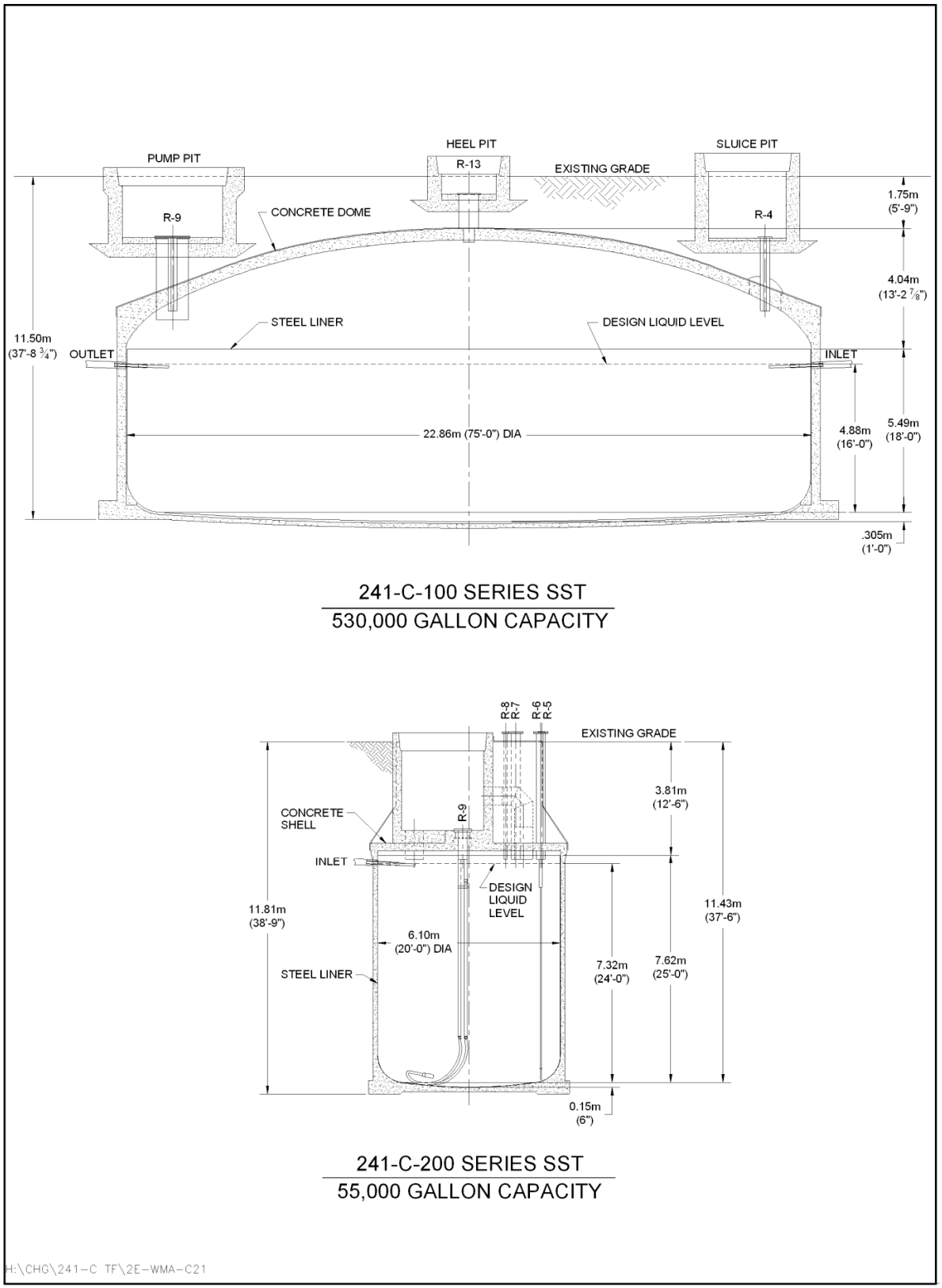
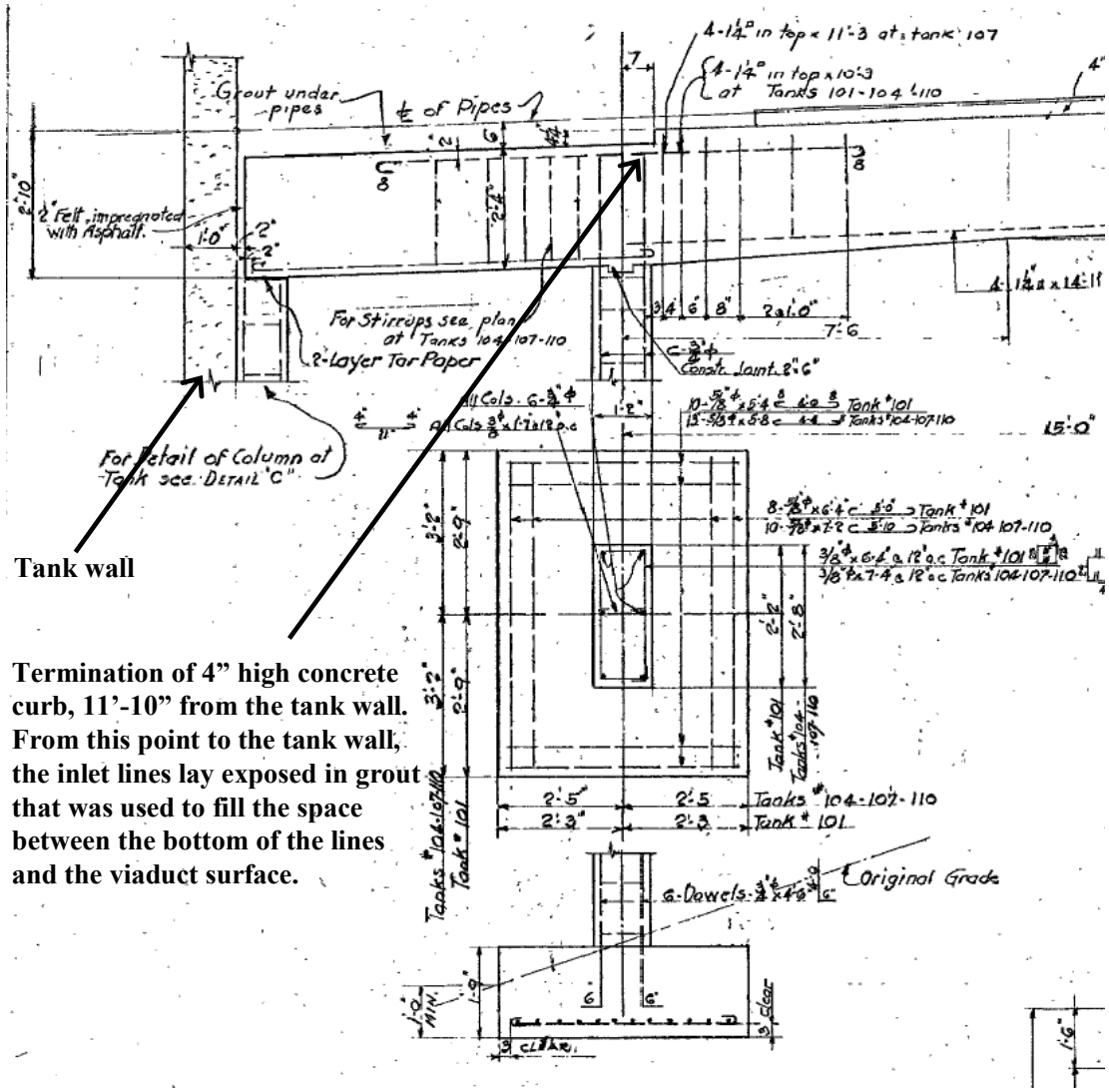


Figure 2-7. Concrete Viaduct Supporting Pipelines



The routing of liquid waste from the operations buildings to the tank farms was accomplished using underground transfer lines, diversion boxes, and valve pits. The diversion boxes housed jumpers (remote pipeline connectors) where waste could be routed from one transfer line to another. The diversion boxes are below-ground, reinforced-concrete boxes that were designed to contain any waste that leaked from the high-level waste (HLW) transfer line connections. The interior surfaces of diversion boxes were coated with a chemically resistant paint (INDC-356-VOL3, *Construction Hanford Engineer Works U.S. Contract Number W-7412-ENG-1 Du Pont Project 9536 History of the Project, Volume III*, page 923). If waste leaked into a diversion box, it generally drained by gravity to nearby catch tanks where any spilled waste was stored and then pumped to SSTs (DOE/RL-92-04). Figure 2-10 shows a schematic of a typical diversion box. There are seven diversion boxes labeled 241-C-151, 241-C-152, 241-C-153, 241-C-252, 241-CR-151, 241-CR-152, and 241-CR-153 located in the C Farm. An eighth diversion box, 241-C-154, is located across from the C Farm at the former 201-C Hot (or Strontium) Semiworks site.

Figure 2-8. Tank Infrastructure at Waste Management Area C

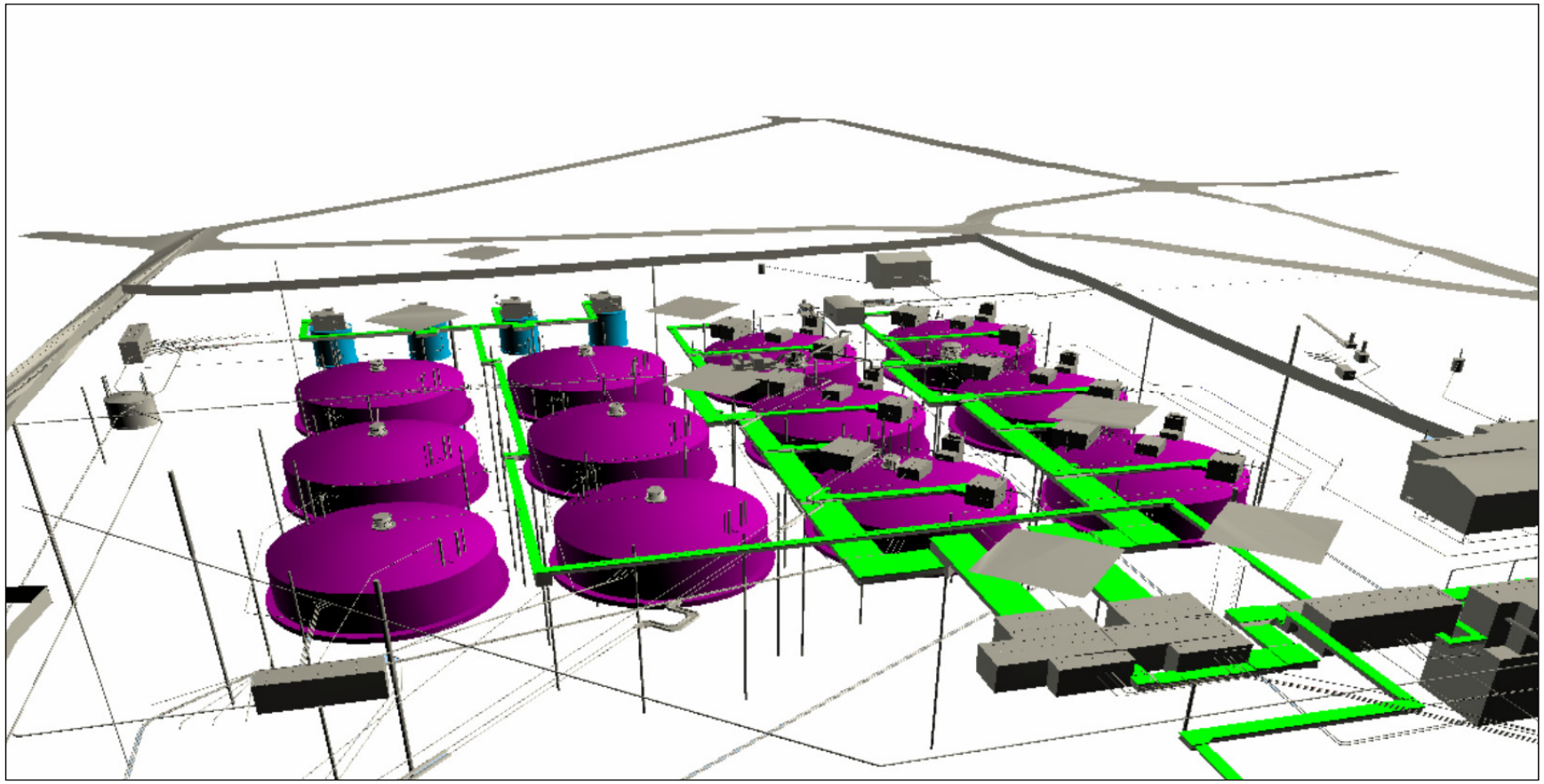


Figure 2-9. Schematic of the 244-CR Vault in Waste Management Area C

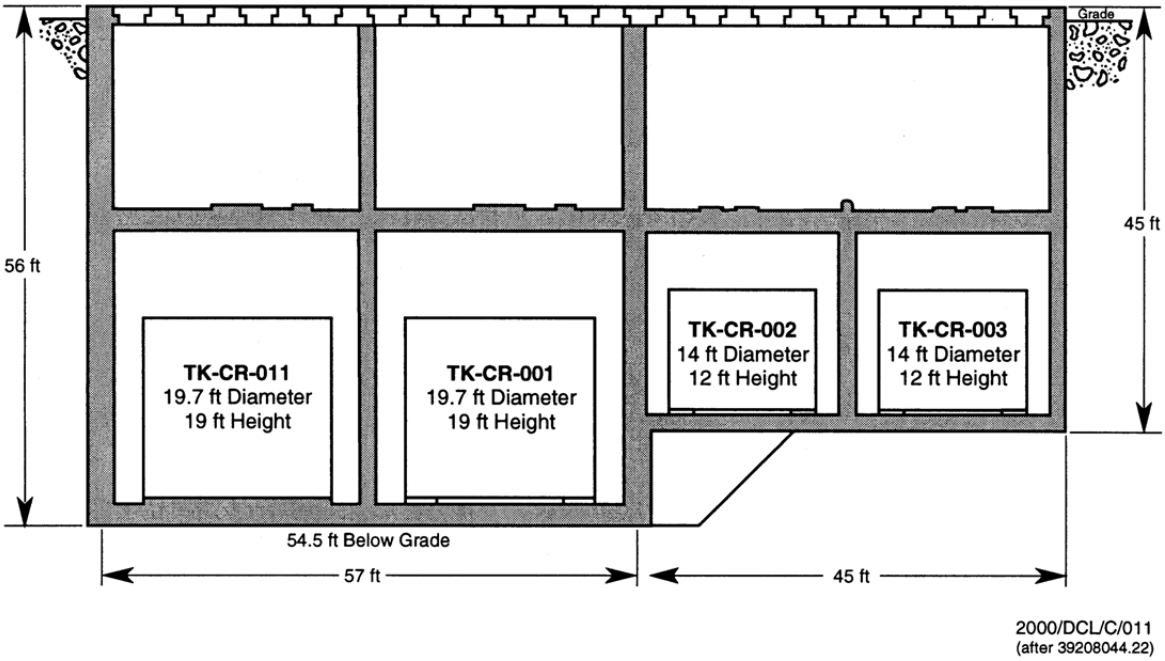
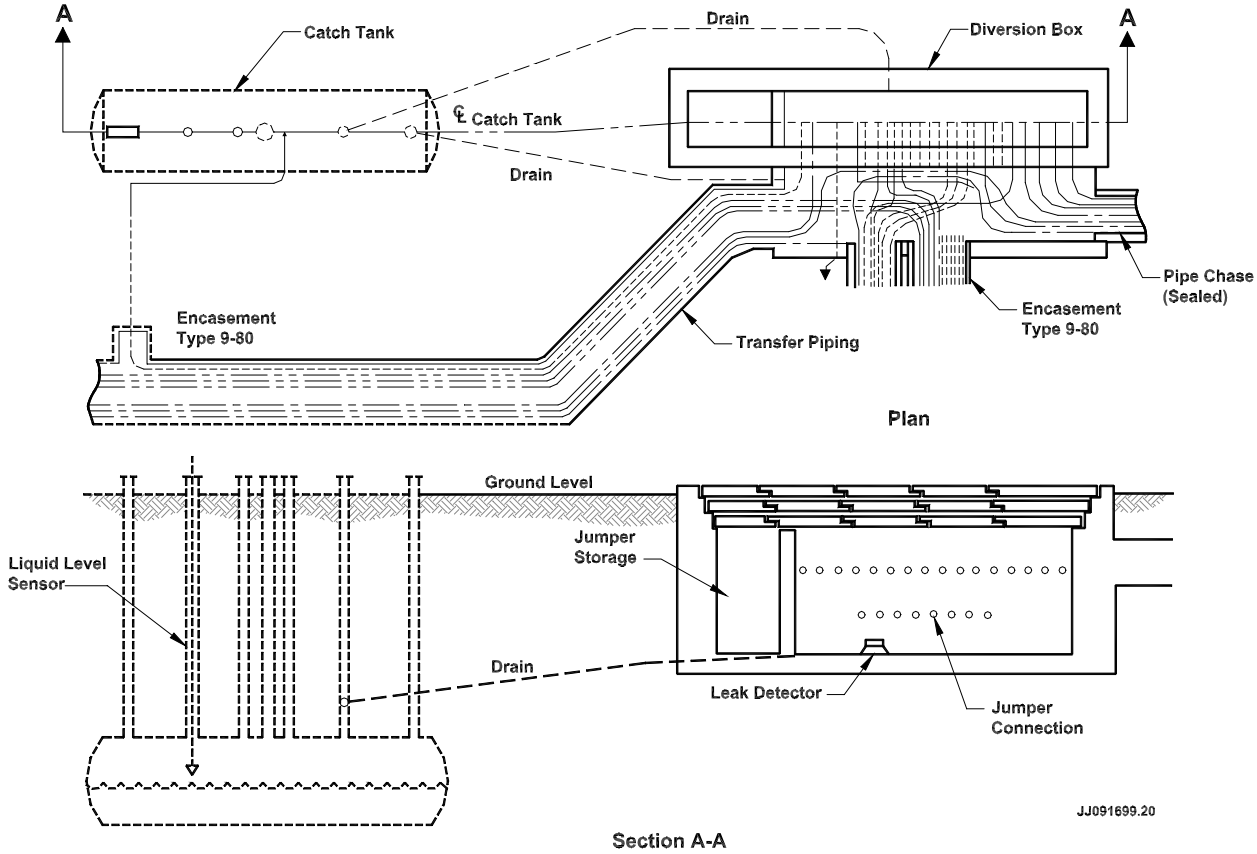


Figure 2-10. Schematic of a Typical Diversion Box Transfer System



There are three valve boxes and one valve pit in the C Farm. A fourth valve box is located at the former 201-C Hot (or Strontium) Semiworks site. The valve boxes and pit contained valve assemblies that were used for routing the liquid waste through transfer lines. There is a valve box associated with the C-801 load-out facility with a drain to a drywell on the north side of C Farm (H-2-4581, *Valve Pit Liner Arrangement*). There is a valve box located on the south side of tank C-112 at the 6 o'clock position and a valve box located on the south side of tank C-111 at the 6 o'clock position (H-2-2909, *Piping Arrangement & Details First Cycle Waste Scavenging 241-C Tank Farm*). These two valve boxes drained directly to the soil. There is one valve pit in the C Farm located at about the 9 o'clock position next to tank C-103 (H-2-73876, *Piping Plan 241-C Tank Farm*). This valve pit is a below-ground culvert with a reinforced-concrete floor with a drain to tank C-103.

2.4.1 History of Waste Management Area C

Waste Management Area C was constructed from 1944 to 1945 and originally consisted of the twelve 100-series tanks, four 200-series tanks, catch tank 241-C-301, four diversion boxes (241-C-151, 241-C-152, 241-C-153, and 241-C-252) and interconnecting pipelines. Waste Management Area C was originally designated to receive waste from the planned 221-C Bismuth Phosphate Plant. However, the 221-C Bismuth Phosphate Plant was canceled shortly after excavating the plant foundation. To utilize the tanks in WMA C, diversion box 241-B-154 was installed to enable connections from the 221-B Bismuth Phosphate Plant to either the 241-B (B Farm) or C Tank Farms (HW-10475 C-DEL, *Hanford Technical Manual Section C*, pages 906 and 910). Two pipelines (8902 and V130) were installed in late 1945 from diversion box 241-B-154 to diversion boxes 241-C-151 and 241-C-152 to enable use of the tanks in WMA C (H-2-432, *Piping Between 241B and 241C*). Construction of WMA C was completed and turnover of the tank farm structures to operations occurred on February 10, 1945 (HW-7-1388-DEL, *Hanford Engineer Works Monthly Report February 1945*, page 16, and INDC-356-VOL3, page 840).

Following completion of construction, the tanks in WMA C were not utilized until March 1946, starting with receipt of waste into the 100-series tanks, and receipt of waste in the 200-series tanks in September 1947. The operating history of the 100-series and 200-series tanks in WMA C is uniquely different and discussed separately in Sections 2.4.1.1 and 2.4.1.2. Additional facilities were constructed in WMA C in 1951 and 1952 and are also discussed in Sections 2.4.1.1 and 2.4.1.2.

2.4.1.1 100-Series Tanks.

Bismuth Phosphate Plant Wastes: The 100-series tanks in WMA C began to receive metal waste from the bismuth phosphate process conducted in the 221-B Plant starting on March 12, 1946 (HW-7-3751-DEL, *Hanford Engineering Works Monthly Report March 1946*, page 20). By November 1947, tanks C-101 through C-106 were filled with bismuth phosphate metal waste (HW-8267-DEL, *Hanford Works Monthly Report November 1947*, page 29). Tanks C-107 through C-112 received first cycle decontamination waste mixed with cladding removal waste (designated as 1C/CW) from the 221-B Plant starting on April 24, 1946 (HW-7-4004-DEL, *Hanford Engineering Works Monthly Report April 1946*, page 20) and were filled by

September 14, 1948 (HW-11226-DEL, *Hanford Works Monthly Report September 1948*, page 32).

Precipitation of some components (e.g., phosphate, plutonium, and aluminum) in the 1C/CW waste occurred while this waste was stored in tanks C-107 through C-112. Floating head suction pumps were installed in these SSTs, and waste transfer pipelines and jumpers were installed in 1951 to enable removal of the 1C/CW supernate (H-2-2021 sheet 2, *Outside Lines First Cycle Evaporation 200 East Plot Plan*, and H-2-2076, *Project – Engineering – Division First Cycle Evaporation 241 B, C, BX & BY Tank Pump Arr'g't. & Details*). The floating head suction pump allowed the 1C/CW supernate to be transferred from these tanks, while leaving the 1C/CW sludge in the tank. The 1C/CW supernate contained in tanks C-107 through C-112 was transferred to tank 241-B-106 and then processed in the 242-B Evaporator from April 1952 (HW-27838, *Waste Status Summary Period: April, May and June, 1952*, page 9) to August 1952 (HW-27839, *Waste Status Summary Period: July, August and September 1952*, page 20). The concentrated 1C/CW supernate generated in the 242-B Evaporator was stored in tanks 241-B-105, 241-B-107, 241-B-108 and 241-B-109. Removal of the 1C/CW supernate left some 1C/CW solids in each tank. The supernate was removed from tanks C-107 through C-112 to enable the use of these tanks for storage of waste from the 221-U Tributyl Phosphate (TBP) Plant.

New facilities were constructed in WMA C in 1951 and 1952 to allow removal of the stored metal waste in tanks C-101 through C-106 (and C-201 through C-204 as discussed in Section 2.4.1.2). New pump pits, sluice pits, and heel pits were constructed atop these SSTs for installing waste retrieval equipment through tank risers. The 244-CR vault was installed for acidification, dissolution of solids, and blending the retrieved metal waste slurries. Diversion boxes 241-CR-151, 241-CR-152, and 241-CR-153 along with concrete-encased pipelines were installed for transferring metal wastes from the SSTs to the 244-CR vault. A control room, the 271-CR building, was also constructed for operation of the 244-CR vault equipment.

Beginning in October 1952, the metal waste supernates and solids stored in tanks C-101 through C-106 were sluiced to the 244-CR vault for acidification, dissolution of solids, blending, and transfer through the cross-site transfer pipelines to the 241-WR Diversion Station Vault (241-WR vault) in the 200 West Area (HW-26047-DEL, *Hanford Works Monthly Report for October 1952*, page Ed-4). Some metal waste supernates from tank 241-BY-109 (241-BY Tank Farm [BY Farm] metal waste supernate receiver tank) were also transferred periodically from May 1954 (HW-32110, *Separations Section Waste – Status Summary May 31, 1954*, page 4) through November 1954 (HW-33904, *Separations Section*, *Waste – Status Summary for November 1954*, page 4) to tank C-104 for blending in the 244-CR vault. From the 241-WR vault, the acidic metal waste solutions were processed in the 221-U TBP Plant for uranium extraction and nitric acid recovery (HW-19140, *Uranium Recovery Technical Manual*, chapters II and XIII). Nitric acid recovered in the TBP Plant was returned to the 241-WR vault and transferred to the 244-CR (and 244-BXR, 244-TXR, and 244-UR) vaults for use in acidifying and dissolving metal waste slurries retrieved from the SSTs. Metal waste removal from tanks C-101 through C-106 was completed in April 1955 (SD-WM-TI-302, *Hanford Waste Tank Sluicing History*, page 84).

Tributyl Phosphate Plant Waste: Tanks C-101 through C-112 were refilled with waste from the 221-U TBP Plant as the 1C/CW and metal waste was removed from these tanks. The TBP Plant waste began to be received in these tanks in November 1952 (HW-27840, *Waste Status Summary Separations Section Period: October, November and December, 1952*, page 20). With the exception of tank C-104, all of the 11 other 100-series tanks were reported to be filled with TBP Plant waste by early 1954. Tank C-104 received TBP Plant waste from tank C-112 in October 1955 (HW-39850, *Separations Section Waste – Status Summary for October 1955*, page 4), since this tank was being used for metal waste storage until late 1954.

In November and December 1955 (HW-40208, *Separations Section Waste – Status Summary for November 1955*, page 4; and HW-40816, *Separations Section Waste – Status Summary for December 1955*, page 4), TBP Plant supernatant waste was transferred from tank C-109 to the 244-CR vault for precipitation of cesium and strontium using ferrocyanide (so-called In-Farm scavenging).[1] In late December 1955, TBP Plant supernatant waste was transferred from tank C-101 to the 244-CR vault for In-Farm scavenging. The TBP Plant waste along with the ferrocyanide (FeCN) precipitate was discharged to tank C-109 for settling of the precipitate, with the supernate then transferred to 216-BC-4 crib (HW-44784, *Radioactive Contamination in Liquid Wastes Discharged to Ground at Separations Facilities through June 1956*, page 20). Tank C-101 was then refilled with TBP Plant supernatant waste from tank C-104 in January 1956 (HW-41038, *Separations Section Waste – Status Summary for January 1956*, page 4).

In January 1956, TBP Plant supernatant waste was transferred from tank C-111 to 244-CR vault for In-Farm scavenging of ^{137}Cs and ^{90}Sr. Tank C-111 then served primarily as one of the settling tanks for FeCN (designated as waste type TFeCN) resulting from In-Farm scavenging operations conducted in the 244-CR vault (HW-41812, *Separations Section Waste – Status Summary for February 1956*, page 4). In February 1956, the TBP Plant supernatant waste was transferred from tanks C-108 and C-110 to 244-CR vault for FeCN scavenging of cesium and strontium (HW-41812, page 4). In March and April 1956, the TBP Plant supernatant waste was transferred from tanks C-112 and C-105 to 244-CR vault for In-Farm scavenging, and then tank C-112 was used to receive TFeCN waste (HW-42394, *Separations Section Waste – Status Summary for March 1956*, page 4, and HW-42993, *Separations Section Waste – Status Summary for April 1956*, page 4).

In September and October 1956, TBP Plant supernate was transferred from tank C-101 to 244-CR vault for In-Farm scavenging (HW-45738, *Separations Section Waste – Status Summary for September 1956*, page 4, and HW-46382, *Chemical Processing Department Waste – Status Summary October 1, 1956 – October 31, 1956*, page 4). The TBP Plant waste along with the ferrocyanide precipitate (designated as TFeCN waste) was discharged to tank C-112 for settling of the precipitate with the supernat tank, then transferred to 216-BC-10 crib (HW-48518, *Radioactive Contamination in Liquid Wastes Discharged to Ground at Separations Facilities Through December 1956*, page 19). In October 1956, part of the TBP Plant supernatant waste in tank C-107 was In-Farm scavenged (HW-46382, page 4). The TBP Plant supernatant wastes in tanks C-102, C-103, and C-106 were In-Farm scavenged in April and May 1957 (HW-50127,

[1] The 241-C tanks were sometimes referred to as tank 241-CR tanks when used in conjunction with the 244-CR vault for In Farm scavenging operations.

Chemical Processing Department Waste – Status Summary April 1, 1957 – April 30, 1957, page 4 and HW-50617, *Chemical Processing Department Waste Status Summary May 1, 1957 – May 31, 1957*, page 4).

Tank C-101 continued to be used through 1957 as the feed tank to the In-Farm scavenging process conducted in the 244-CR vault. Tank C-101 received TBP Plant supernate and 242-B Evaporator bottoms wastes from the tanks listed in Table 2-4. The scavenged waste was transferred to tank C-108, C-109, C-111, and C-112 for settling of the TFeCN precipitate before discharge to the 216-BC trenches and cribs. The In-Farm scavenging of TBP Plant wastes was completed in January 1958.

Table 2-4. 221-U Tributyl Phosphate Plant Supernatant and 242-B Evaporator Bottoms Wastes Transferred to Tank 241-C-101

Tank	Volume (gal)	Date	Reference
241-BY-101	455,000	June 1957	HW-51348, page 5
241-BY-102	717,000	June 1957	HW-51348, page 5
241-BY-101	227,000	July 1957	HW-83906 C RD, page 64
241-BY-103	551,000	July 1957	HW-83906 C RD, page 64
241-BY-103	162,000	August 1957	HW-83906 C RD, page 72
241-B-101	228,000	August 1957	HW-83906 C RD, page 72
241-B-102	424,000	August 1957	HW-83906 C RD, page 72
241-B-103	297,000	August 1957	HW-83906 C RD, page 72
241-B-107	265,000	September 1957	HW-83906 C RD, page 80
241-B-108	399,000	September 1957	HW-83906 C RD, page 80
241-B-109	403,000	September 1957	HW-83906 C RD, page 80
241-B-106	379,000	October 1957	HW-83906 C RD, page 88
241-B-112	495,000	October 1957	HW-83906 C RD, page 88
241-BX-110	88,000	October 1957	HW-83906 C RD, page 88
241-BX-110	113,000	November 1957	HW-83906 C RD, page 97
241-BX-111	511,000	November 1957	HW-83906 C RD, page 97
241-BX-108	484,000	November 1957	HW-83906 C RD, page 97
241-BX-109	243,000	December 1957	HW-83906 C RD, page 104

References:
HW-51348, *Chemical Processing Department Waste Status Summary June 1, 1957 – June 30, 1957 Planning and Scheduling – Production Operation*.
HW-83906 C RD, *Chemical Processing Dept 200 W Area Tank Farm Inventory and Waste Reports January 1957 Through December 1958*.

Plutonium Uranium Extraction (PUREX), B Plant, Reduction-Oxidation (REDOX), and Miscellaneous Wastes: Following the period of TBP waste storage, the C-100 series tanks were used to store a wide variety of waste types as indicated by Table 2-5. The calendar year in which the specific waste types were received into each tank is listed in Table 2-5.

Waste receipt into each tank was intermittent. The following is a simplified description of the waste types received into the C-100 series tanks from 1956 through 1978 (WHC-MR-0132, *A History of the 200 Area Tank Farms*).

With the exception of tanks C-103 and C-106, coating waste from the PUREX Plant was generally received by all of the C-100 series tanks during 1956 to 1962. Tank C-102 continued to receive coating waste from the PUREX Plant until 1968 and also received waste from the thorium recovery process conducted at the PUREX Plant in 1966. Waste from washing the solvent in the PUREX Plant (organic wash waste [OWW]) was generally received into tanks C-102 (1968 to 1969), C-103 (1973), and C-104 (1969 to 1972); however, tanks C-110 and C-111 also received OWW in 1956. Tank C-104 also received waste from the thorium recovery process conducted at the PUREX Plant in 1970. The OWW contained normal paraffin hydrocarbon, TBP, monobutyl phosphate, and dibutyl phosphate organic compounds. The supernatant fraction of the CW and OWW wastes were transferred via tanks in the 241-BX Tank Farm (BX Farm) to the BY Farm for evaporation in the In-Tank Solidification system. Settled solids from the CW and OWW wastes accumulated in the C-100-series tanks.

Waste from the 201-C Hot Semiworks (aka Strontium Semiworks) building was received into tanks C-107, C-108, C-109, C-111, and C-112 from 1961 through 1967. The Hot Semiworks separated strontium from rare earth fission products from 1960 to 1967 and in 1967 conducted a campaign to separate the rare earth elements from an HLW stream. After radiolytic decay of the rare earth fission products, the Hot Semiworks wastes were transferred via tanks in the C and BX Farms to the BY Farm for evaporation in the In-Tank Solidification system.

Tanks C-101 (1963 to 1964), C-103 (1957, 1963 to 1966), C-105 (1963, 1968 to 1970), and C-106 (1957 and 1963) were used to store PUREX HLW supernate (PSN) from 241-A and 241-AX tanks. Tanks C-105 (1971 to 1976) and C-106 (1969 to 1971) also received PUREX sludge wash supernate (PSS) from 244-CR vault and from 241-A and 241-AX tanks. Tank C-105 also received REDOX HLW supernate (RSN) from 241-SX and 241-TX tanks (1970 and 1971). The PSN, PSS, and RSN wastes were transferred to B Plant for ion exchange (IX) processing to separate cesium. Tanks C-107 through C-112 (1970) received waste from the B Plant IX process. Tank C-106 also received waste from the B Plant strontium separation process (1974 to 1978).

Several other miscellaneous waste streams were routed to tanks C-103 (1973 to 1976), C-104 (1973 to 1976), C-107 (1973), and C-108 (1973). These include N Reactor decontamination waste and waste from research activities at the Hanford 300-Area Laboratories (HLO waste type), also known as Battelle Northwest (BNW waste type). The Hanford 300-Area Laboratories is now the Pacific Northwest National Laboratory (PNNL).

Table 2-5. Waste Types Received into 241-C 100-Series Tanks (1956 to 1978)

Year	C-101	C-102	C-103	C-104	C-105	C-106	C-107	C-108	C-109	C-110	C-111	C-112
1956	TFeCN			CW	CW					OWW	OWW	TFeCN
1957			PSN	CW	CW	PSN/OWW		TFeCN	TFeCN		CW/TFeCN	TFeCN
1958				CW	CW							
1959					CW				CW		CW	
1960	CW	CW	CW		CW			CW			CW	CW
1961		CW					CW	CW			CW	HS
1962		CW					CW		HS		HS	HS
1963	PSN	CW	PSN		PSN	PSN					HS	
1964	PSN	CW					HS		HS		HS	
1965		CW	PSN				HS	HS	HS			
1966		TH/CW	PSN				BNW/HS		HS			
1967		CW					HS					
1968		CW/OWW			PSN							
1969		OWW		OWW	PSN	PSS						
1970			IX	TH/OWW/ PSN	PSN/ RSN	PSS	IX	OWW/ IX	IX	IX		IX
1971			IX	CW/OWW	PSS	PSS						
1972			CW/OWW	CW/OWW	PSS					IX		
1973			Misc	Misc	PSS		Misc	Misc				
1974			Misc	Misc	PSS	BL						
1975			Misc	Misc	PSS	BL						
1976			Misc	Misc	PSS	BL						
1977						BL						
1978						BL						

Definitions:

Colors in table are used to highlight each waste type

BL — B Plant strontium processing wastes and misc. wastes

CW — Coating waste from Plutonium Uranium Extraction (PUREX) or Reduction-Oxidation (REDOX) Plants

HS — 201-C Hot Semiworks waste

IX — Cesium denuded waste from ion exchange process in B Plant

Misc — Sources may include research waste from Battelle Northwest (i.e., BNW) which is now Pacific Northwest National Laboratory, reactor decontamination waste, etc.

OWW — Organic Wash Waste from PUREX Plant

PSN — PUREX high-level waste (HLW) supernate

PSS — PUREX Sludge Supernate derived from washing PUREX HLW sludges in 244-AR Vault or 241-A and 241-AX tanks

RSN — REDOX HLW Supernate

TFeCN — Ferrocyanide waste from 244-CR vault treatment of Tributyl Phosphate waste

TH — Thorium process waste from PUREX Plant

2.4.1.2 200-Series Tanks. The operating history of the 200-series tanks is detailed in RPP-15408, *Origin of Wastes in C-200 Series Single-Shell Tanks*, and briefly summarized here.

In September 1947, construction activities were completed to permit utilization of the 200-series tanks for storage of metal waste from the 221-B Bismuth Phosphate Separations plant (HW-7795-DEL, *Hanford Works Monthly Report September 1947*, page 26). Prior to this date, these tanks were empty. Tanks 241-C-201 (C-201) through 241-C-204 (C-204) began to receive metal waste from the 221-B Plant in November 1947 (HW-8267-DEL, page 29) with these tanks reported as filled in January 1948 (HW-8931-DEL, *Hanford Works Monthly Report January, 1948*, pages 27 and 28, and RPP-15408). In 1951 and 1952, jet pump pits and concrete-encased transfer pipelines to the 241-CR-151 master diversion box were installed on tanks C-201 through C-204 for retrieval of metal waste from these tanks. From December 1953 through February 1955, the metal waste supernate and sludges present in tanks C-201 through C-204 were intermittently retrieved and transferred to 244-CR vault and eventually to the 241-WR vault. Tanks 241-C-203 (C-203) and C-204 received cold uranium (i.e., uranium that had not been irradiated in a reactor) waste from the 202-A PUREX Plant startup testing in November 1955. The cold uranium waste was removed from tanks C-203 and C-204 in December 1955 and discharged to the 216-A-19 ditch (HW-40763, *Separations Section Radiation Monitoring Subsection Monthly Progress Report December, 1955*, page 6). Tanks C-201 through C-204 were then used from May 1955 through October 1956 to receive and store waste originating from research and development activities conducted at the 201-C Hot Semiworks facility in the 200 East Area of the Hanford Site. The cold uranium waste was removed from tanks C-203 and C-204 before transfers of Hot Semiworks waste into these tanks was conducted.

Tanks C-201 through C-204 were not used to receive waste after being filled with waste from the Hot Semiworks. The liquid in tanks C-201, 241-C-202 (C-202), and C-204 was transferred to SST C-104 in 1970. The liquid in tank C-203 was transferred to SSTs C-104 and C-109 in 1970. Residual liquids were subsequently transferred from these tanks into tank C-106 in 1980.

2.4.2 Components of Waste Management Area C

The components included in WMA C are listed in Table 2-6. This list is extracted from Addendum 1 of RPP-13774, *Single-Shell Tank System Closure Plan*, which incorporates units listed on the RCRA Part A, Form 3, Rev. 8 permit application (DOE W-28/RL-88-21, *Dangerous Waste Permit Application, Form 3*), in addition to RCRA Past Practice (RPP), CERCLA Past Practice (CPP), and miscellaneous storage tank units. The list was modified to correct errors in the dates for the construction of some components as well as their description and was verified using essential drawing H-14-104175, *Waste Transfer Piping Diagram 200 East Area*. While most WMA C components are physically located within the C Farm fenceline (also the WMA C boundary), some components extend beyond the fenceline (e.g., pipelines and groundwater) or are located outside the fenceline (e.g., 241-C-154 diversion box).

Table 2-6. Waste Management Area C Components (7 sheets)

Single-Shell Tanks			
Tank 241-	**Constructed**	**Removed from Service**	**Constructed Operating Capacity L (gal)**
C-101	1943–1944	1970	2,000,000 (530,000)
C-102	1943–1944	1976	2,000,000 (530,000)
C-103	1943–1944	1979	2,000,000 (530,000)
C-104	1943–1944	1980	2,000,000 (530,000)
C-105	1943–1944	1979	2,000,000 (530,000)
C-106	1943–1944	1979	2,000,000 (530,000)
C-107	1943–1944	1978	2,000,000 (530,000)
C-108	1943–1944	1976	2,000,000 (530,000)
C-109	1943–1944	1976	2,000,000 (530,000)
C-110	1943–1944	1976	2,000,000 (530,000)
C-111	1943–1944	1978	2,000,000 (530,000)
C-112	1943–1944	1976	2,000,000 (530,000)
C-201	1943–1944	1977	210,000 (55,000)
C-202	1943–1944	1977	210,000 (55,000)
C-203	1943–1944	1977	210,000 (55,000)
C-204	1943–1944	1977	210,000 (55,000)
Diversion boxes			
Unit 241-	**Constructed**	**Removed from Service**	**Description**
C-151	1944	1985	Interconnected 241-C-152, -153, and CR-151 diversion boxes
C-152	1944	1985	Interconnected 241-B-154 and -153 and C Farm, associated with 241-C-301 catch tank
C-153	1944	1985	Interconnected 241-C-151 and -152 diversion boxes
C-154	1965-66	1985	Interconnected B Plant to Building 201-C Hot Semiworks. Box located at Hot Semiworks (H-2-32887, *Promethium Transfer Line Diversion Box Plan, Sections & Det's*)
C-252	1944	1985	Interconnected 241-C-151 diversion box and C Farm
CR-151	1952	1985	Interconnected 244-CR vault and C Farm
CR-152	1942	1985	Interconnected 244-CR vault and C Farm
CR-153	1942	1985	Interconnected 244-CR vault and C Farm
244-CR Vault (contains four tanks)			
Tank 244-	**Constructed**	**Removed from Service**	**Description**
CR-011	1951-1952	1988	Transfer of waste solutions from processes and decontamination operations.
CR-001	1951-1952	1988	
CR-002	1951-1952	1988	
CR-003	1951-1952	1988	

Table 2-6. Waste Management Area C Components (7 sheets)

Miscellaneous Tanks	
Facility Number	**Description**
241-C-301	Catch tank; 36,000-gal capacity 20-ft radius by 20.25-ft tall reinforced-concrete interior painted with two coats of Amercoat Paint (INDC-356-VOL3, *Construction Hanford Engineer Works U.S. Contract Number W-7412-ENG-1 Du Pont Project 9536 History of the Project Volume III*, page 923 and W-72903, *Hanford Engineer Works – Bl'd. #241-TUB 20'-0" Catch Tank Arrangement and Concrete*)
CR-003-TK/SMP	**Tank/Sump**
Miscellaneous Structures	
Facility Number	**Description**
241-C-801	Cesium loadout facility
Valve Pit/Boxes	
Facility Number	**Description**
241-C	Valve pit located at 9-o'clock position adjacent to tank C-103
Unknown	Valve box located at 6-o'clock position south of tank C-112
Unknown	Valve box located at 6-o'clock position south of tank C-111
Unknown	Valve box located adjacent to C-801 building
Tank Pits	
Facility Number[1]	**Description**
241-C-01A	Pump pit
241-C-01B	Heel pit
241-C-01C	Sluice pit
241-C-02A	Pump pit
241-C-02B	Heel pit
241-C-02C	Sluice pit
241-C-03A	Pump pit
241-C-03B	Heel pit
241-C-03C	Sluice pit
241-C-04A	Pump pit
241-C-04B	Heel pit
241-C-04C	Sluice pit
241-C-05A	Pump pit
241-C-05B	Heel pit
241-C-05C	Sluice pit
241-C-06A	Pump pit
241-C-06B	Heel pit
241-C-06C	Sluice pit

[1] The pump pits, heel pits, and sluice pits are sometimes labeled as 241-CR-XX-YYY in documentation.

Table 2-6. Waste Management Area C Components (7 sheets)

Tank Pits		
Facility Number[2]	**Description**	
241-C-07	No pit, covered saltwell caisson pump pit	
241-C-08	No pit, covered saltwell caisson pump pit	
241-C-09	No pit, covered saltwell caisson pump pit	
241-C-110	No pit, covered saltwell caisson pump pit	
241-C-111	No pit, covered saltwell caisson pump pit	
241-C-112	No pit, covered saltwell caisson pump pit	
Tank Pits		
Facility Number	**Description**	
241-C-201	Jet pump pit	
241-C-201	Condenser pit	
241-C-202	Jet pump pit	
241-C-202	condenser pit	
241-C-203	Jet pump pit	
241-C-203	Condenser pit	
241-C-204	Jet pump pit	
241-C-204	Condenser pit	
Transfer Lines[3]		
Line Number	**Connecting Facilities**	
4012	241-CR-153-U4A	241-AX-151 D, E, F, and G-Cell
4013	241-AX-151 D, E, F, and G-Cell	241-CR-152-U3A
8002	241-C-103-03A-U1	241-CR-152-L13
8006	241-C-102-02A-U1	241-CR-152-L12
8010	241-C-101-01A-U1	241-CR-152-L11
8012	241-CR-152-U9,-U11,-U12	241-CR-151-U4
8014	241-C-103-03C-U1	241-CR-152-L10
8017	241-C-102-02C-U1	241-CR-152-L7
8020	241-C-101-01C-U1	241-CR-152-L9
8025	241-CR-152-U10	241-CR-151-U11
8031	241-C-101-01A-U3	241-CR-152-L14
8032	241-C-103-03A-U2	241-CR-152-U6
8035	241-C-103-03C-U2	241-CR-152-U5
8037	241-C-102-02A-U3	241-CR-152-L15
8038	241-C-102-02A-U2	241-CR-152-U4
8041	241-C-102-02C-U2	241-CR-152-U3

[2] The pump pits, heel pits, and sluice pits are sometimes labeled as 241-CR-XX-YYY in documentation.
[3] Does not include temporary hose-in-hose transfer pipelines.

Table 2-6. Waste Management Area C Components (7 sheets)

Transfer Lines (continued)		
Line Number	**Connecting Facilities**	
8044	241-C-101-01A-U2	241-CR-152-U2
8047	241-C-101-01C-U2	241-CR-152-U1
8053	241-C-101-01C-U6	3-in. drain from 241-CR-152
8056	241-C-103-03B-U2	Connects to line 8002
8063	241-C-102-02B-U2	Connects to line 8006
8070	241-C-101-01B-U1	Connects to line 8010
8107	241-CR-152-L8	V844/241-CR-151-L8
8114	241-C-101-01B-U3	Capped nearby heel pump pit 241-C-101-01B formerly to C-103
8121	241-C-102-02C-U3	Former saltwell pumping line
8202	241-C-106-06A-U1	241-CR-153-L13
8206	241-C-105-05A-U1	241-CR-153-L12
8210	241-C-104-04A-U1	241-CR-153-L11
8212	241-CR-151-U3	241-CR-153-U9, U11, U12
8214	241-C-106-06C-U1	241-CR-153-L10
8217	241-C-105-05C-U1	241-CR-153-L7
8220	241-C-104-04C-U1	241-CR-153-L9
8225	241-CR-153-U10	241-CR-151-U10
8231	241-C-104-04A-U3	241-CR-153-L14
8232	241-C-106-06A-U2	241-CR-153-U6
8235	241-C-106-06C-U2	241-CR-153-U5
8237	241-C-105-05A-U3	241-CR-153-L15
8238	241-C-105-05A-U2	241-CR-153-U4
8241	241-C-105-05C-U2	241-CR-153-U3
8244	241-C-104-04A-U2	241-CR-153-U2
8247	241-C-104-04C-U2	241-CR-153-U1
8256	241-C-106-06B-U2	Connects to line 8235
8263	241-C-105-05B-U2	Connects to line 8206
8270	241-C-104-04B-U2	Connects to line 8210
8552	241-C-201,-202,-203,-204-U1	241-CR-151-U2
8555	241-CR-151-U5	241-C-201,-202,-203,-204-U2 and U-3
8601	241-CR-151-L1	244-CR-Tank-001
8603	244-CR-Tank-003	244-CR-Tank-001-U2
8609	244-CR-Tank-002-U2	244-CR-Tank-011
8613	244-CR-Tank-003-U2	244-CR-Tank-011
8616	241-CR-151-L5	244-CR-Tank-011-U1

Table 2-6. Waste Management Area C Components (7 sheets)

Transfer Lines (continued)		
Line Number	**Connecting Facilities**	
8622	241-CR-151-L3	244-CR-Tank 001-U3
8624	241-CR-152-U8	241-CR-151-U7
8625	241-CR-153-U8	241-CR-151-U6
8630	241-CR-152-L1,-2,-3,-4,-5,-6	241-CR-151-U9
8631	241-CR-153- L1,-2,-3,-4,-5,-6	241-CR-151-U8
8644	241-CR-151-U12,-U13,-U15	241-CR-151-U12,-U13,-U15
8647	241-CR-151-L4	244-CR-Tank-003-U1
8648	241-CR-151-L6	244-CR-Tank-002-U1
8656	241-AX-151 connects to header for E thru G Cells	244-CR-Tank-003
8900	201-C Hot Semiworks Valve Box	244-CR-Tank-003-U10
8901/8649/V108/V837	221-B	244-CR-Tank-003-U11
8636/V105	241-CR-151-U1	241-C-151-L6
8653/8618	241-ER-151-L9	241-CR-151-U14
A4013	241-CR-152-U3A	241-AX-151-Washdown Connects to Header for E thru G Cells
Drain Line	241-C-102-02B-U3	241-C-Valve Pit-L1
Drain Line	241-C-103	241-C-Valve Pit
8253 Drain Line	241-C-104-04C-U6	241-CR-153
Drain Line	241-C-104-04B-U3	241-C-Valve Pit-L2
Drain Line	Cut and capped nearby 241-C-107-U1	241-C-Valve Pit-L3
Drain Line	Cut and capped nearby 241-C-108 Saltwell Pump Pit	Capped by 241-C-Valve Pit
Drain Line	Cut and capped nearby 241-C-109 Saltwell Pump Pit	Capped by 241-C-Valve Pit
Drain	241-C-110 Saltwell Pump Pit-U1	241-C-Valve Pit-L4
Drain	241-C-112 Saltwell Pump Pit-U1	241-C-Valve Pit-L5
Drain Line	244-CR-Tank-002	241-CR-151
Drain-301	241-C-106-06C-U8	Metal Filter Drain
Drain-302	241-C-106-06C-U9	Process Building Floor Drain
Drain	241-C-106-06A-U8	SL-100 encasement
SL-100	241-C-106-06A-U9	241-AY-102-02A
SN-200	241-C-106-06C-U6	241-AY-102-02A
Drain	241-C-106-06C-U7	SN-200 encasement
PAS-244	241-ER-153-9	244-CR-Tank-003-U13

Table 2-6. Waste Management Area C Components (7 sheets)

Transfer Lines (continued)		
Line Number	**Connecting Facilities**	
SN-275	241-C-VP-U1,-U2,-U3,-U4,-U5,-U6	244-CR-Tank-003-U15
Cascade line	241-C-101-N5	241-C-102-B
Cascade line	241-C-102-A	241-C-103-B
Cascade line	241-C-104-A	241-C-105-B
Cascade line	241-C-105-A	241-C-106-B
Cascade line	241-C-107-A	241-C-108-B
Cascade line	241-C-108-A	241-C-109-B
Cascade line	241-C-110-A	241-C-111-N2
Cascade line	241-C-111-N1	241-C-112-B
Unknown	241-C-103-03B-U1	241-C-Valve Pit-L6
Unknown	241-C-104-04B-U3	241-C-Valve Pit-L2
Unknown	241-C-105-05B-U3	Capped by 241-C Valve Pit
Unknown	244-CR-Tank-002	244-CR-Tank-001-U1
V050	241-A-152-L7	241-C-104-R2
V051	241-A-152-L8	241-C-104-R2
V100	241-C-151-L1	241-C-153-U9
V1000	241-CR-152-U1A	244-CR-Tank-003-U14
V1001	241-CR-152-U4A	241-CR-153-U3A
V1002	241-CR-152-U6A	241-CR-153-U1A
V101	241-C-151-L2	241-C-104-04A-U4
V102	241-C-101-N3	241-C-151-L4
V103	241-C-105-N1	241-C-151-L3
V104	241-C-101-N4	241-C-151-L5
V105/8636	241-C-151-L6	241-CR-151-U1
V107	241-C-252-U4	241-C-151-L8
V108/812	241-C-151-U1	244-AR-Tank-002-T9
V109	241-C-151-U2	241-A-101-01A-U2
V110	241-C-151-U3	244-CR-Tank-003-U12
V113	241-C-151-U6	241-AX-101-01A
V113	241-C-151-U6	241-AX-103-03A-1
V-114 Drain Line	241-C-153, 241-C-152 and 241-C-151	241-C-301Catch Tank
V115	241-C-105-05A-U8	241-C-152-L1
V118	241-C-152-L4	241-C-153-U6
V119	241-C-152-L5	241-C-153-U5
V120	241-C-152-L6	241-C-153-U4
V121	241-C-152-L7	Capped

Table 2-6. Waste Management Area C Components (7 sheets)

Transfer Lines (continued)		
Line Number	**Connecting Facilities**	
V122	241-C-105-05A-U4	241-C-152-L8
V130	241-B-154-L8	241-C-152-U4
V136	241-C-153-L1	None identified
V137	241-C-111-N6	241-C-153-L2
V138	241-C-110-C3	241-C-153-L3
V139	241-C-110-C2	241-C-153-L4
V140	241-C-110-C1	241-C-153-L5
V141	241-C-153-L6	Capped
V142	241-C-153-L7	Capped
V143	241-C-107-C3	241-C-153-L8
V144	241-C-107-C2	241-C-153-L9
V145	241-C-107-C1	241-C-153-L10
V147	241-C-153-L12	None identified
V148	241-C-104-N3	241-C-153-L13
V149	241-C-104-N2	241-C-153-L14
V150	241-C-104-N1	241-C-153-L15
V-155 Drain Line	241-C-252	241-C-301Catch Tank
V156	241-C-201-N4	241-C-252-L1
V157	241-C-201-N3	241-C-252-L2
V158	241-C-202-N4	241-C-252-L3
V159	241-C-202-N3	241-C-252-L4
V160	241-C-203-N4	241-C-252-L5
V161	241-C-203-N3	241-C-252-L6
V162	241-C-204-N4	241-C-252-L7
V163	241-C-204-N3	241-C-252-L8
V172	241-C-252-U1	Formerly connected to valve boxes and 241-C-104-R6, 241-C-107-R6, 241-C-108-R6, 241-C-109-R5, 241-C-110-R6, 241-C-111-R6 and 241-C-112-R5
V175	241-C-252-U5	201-C-Hot Semiworks Valve Box
V210/V111	241-B-154-L10	241-C-151-U4
V228	241-CR-153-U6A	241-ER-153-7
V843	241-CR-151-L9	241-C-102-R2
V844	241-CR-151-L8	241-C-102-R2

2.4.3 Process Operations

The waste storage activities in WMA C are discussed in Section 2.4.1. Process operations conducted in WMA C include metal waste retrieval (Section 2.4.3.1), ferrocyanide treatment of

tanks wastes (Section 2.4.3.2), strontium/rare earth (Sr/RE) fission products processing (Section 2.4.3.3), PUREX acidified sludge (PAS) processing (Section 2.4.3.4), 241-A Tank Farm Process Condensate (TFPC) treatment testing (Section 2.4.3.5), and cesium and technetium recovery in the 241-C-801 Cask Loading Building (Section 2.4.3.6). The 244-CR vault played a pivotal role in all of these process operations except for loading casks in the 241-C-801 Cask Loading Building. In addition, the 244-CR vault was used to collect the supernate and interstitial liquids removed during interim stabilization of tanks in the C Farm (RPP-6029, *244-CR Vault Interim Stabilization Project Plan*) as well as supernate and sludge removal from tank 241-CX-70 (SD-WM-TI-302, Section 4.3). These wastes were transferred from 244-CR vault tanks to double-shell tanks (DST).

2.4.3.1 Metal Waste Retrieval. The 244-CR vault, diversion boxes 241-CR-151, 241-CR-152, and 241-CR-153, concrete-encased pipelines, and concrete pits atop tanks C-101 through C-106 (heel jet, pump, and sluicing pits) were constructed from 1951 to 1952 in WMA C. These WMA C facilities were part of other facilities constructed in tanks farms 241-U, 241-T (T Farm), 241-TX, 241-B, 241-BX, and 241-BY, as well as major modifications of the 221-U Plant, that were used to retrieve and process metal wastes to recover uranium (HW-19140). The pits atop of the tanks connect via concrete-encased underground pipelines to the 241-CR-152 and 241-CR-153 cascade diversion boxes, which have underground piping connections to the 241-CR-151 master diversion box (see Section 2.4.2). The 241-CR-151 master diversion box has concrete-encased underground pipelines connecting to the 244-CR vault (see Section 2.4.2).

The 244-CR vault contains a sludge accumulation tank (TK-CR-001), two sludge dissolution tanks (TK-CR-002 and TK-CR-003), and a process pump tank (TK-CR-011). An aboveground nitric acid tank (TK-CR-004) was used to add nitric acid to tanks TK-CR-002 and TK-CR-003 for acidifying sludge. Tank TK-CR-004 was relocated into the 271-CR annex building in 1963 (see Section 2.4.3.5). The 244-CR vault was originally equipped with an air supply and exhaust system that included a glass wool filter, exhaust fan, and stack (291-CR). A control house, building 271-CR, was also constructed to contain instrumentation, motor control centers, air compressors, ventilation, and operations and administrative facilities for operation of the 244-CR vault and metal waste retrieval equipment.

Metal waste sluicing in the C Farm started in October 1952 and completed in April 1955. Supernate was first removed from the tank to be sluiced using a transfer pump. The metal waste supernate was transferred to tank TK-CR-001 in 244-CR vault and then to the 241-WR vault to expose the sludge in the tank to be sluiced. Metal waste supernate was then transferred from tank TK-CR-001 back through two sluice nozzles that were installed in the tank being sluiced. The transfer pump was used to transfer the sludge slurry back to tank TK-CR-001. All waste transfers used the installed underground pipelines and the three diversion boxes, 241-CR-151, 241-CR-152, and 241-CR-153.

When sufficient sludge accumulated in the sludge accumulation tank (TK-CR-001), the sluicing was halted. Accumulated slurry was transferred from tank TK-CR-001 to one of the two sludge dissolution tanks (TK-CR-002 and TK-CR-003) in the 244-CR vault for dissolution with nitric acid. Sluicing could then be resumed to TK-CR-001 until the C Farm tank was emptied or sluicing operations were no longer able to effectively remove sludge. Then, a heel jet pump

(installed in the heel jet pit) was used to remove the residual metal waste slurry from the tank to TK-CR-001. A periscope optical system was used to inspect tanks to verify sufficient metal waste sludge had been removed. Sluicing operations were repeated if the periscope inspection revealed significant sludge present in the tank.

The dissolved sludge was transferred from tanks TK-CR-002 and TK-CR-003 to process pump tank TK-CR-011. From TK-CR-011, the acidified waste was transferred through an underground stainless-steel pipeline connecting to the 241-CR-151, 241-ER-151, and 241-UX-154 diversion boxes to the 241-WR vault in 200-West Area. The acidified waste was then transferred from the 241-WR vault into the 221-U TBP Plant for uranium recovery. Nitric acid recovered at the 221-U TBP Plant was transferred back to the 244-CR vault through a separate underground stainless steel pipeline connecting to the aforementioned diversion boxes. The recovered nitric acid solution was received into TK-CR-004 located above ground at the 244-CR vault and was used for acidification of subsequent sludge batches.

The retrieval and processing of metal waste from the C-200-series tanks was similar to the 100-series tanks with the exception of the retrieval equipment. From December 1953 through February 1955, the metal waste supernate and sludges present in tanks C-201 through C-204 was intermittently retrieved and transferred to 244-CR vault. A jet pump and a sluicer were installed in each of the C-200-series tanks for removal of the stored metal waste supernate and sludge. Metal waste supernate was used to activate this jet and transfer supernate and sludge from each of the C-200-series tanks to a sludge accumulation tank in the 244-CR vault. Once the sludge was exposed in the C-200-series tank, the sluicer was activated using supernate from the slurry accumulation tank in the 244-CR vault. Processing of the metal waste slurry in the 244-CR vault was the same as for the metal waste slurries retrieved from the 100-series tanks.

2.4.3.2 Ferrocyanide Treatment of Tank Wastes. The 244-CR vault, which was previously used for metal waste recovery, was reused for precipitation of ^{137}Cs, ^{90}Sr, and ^{60}Co from TBP wastes. A new chemical make-up facility, the 241-C-601 building, was constructed adjacent to the 241-CR-271 control room building. Underground transfer piping to the 244-CR vault and necessary jumpers in diversion boxes also were installed (HW-34487, *Scavenging of Stored TBP Waste*). The 241-C-601 building has since been removed from WMA C. Inside the 241-C-601 building were chemical storage tanks for sodium hydroxide, nickel sulfate, sodium ferrocyanide, and calcium nitrate (HW-38223, *Project CG-603 – 4X Program Design Criteria for Calcium Nitrate Addition Facilities for the Scavenging of Stored TBP Wastes*). Strontium nitrate was sometimes substituted for calcium nitrate (HW-38955-REV, *"In-Farm Scavenging" Operating Procedure and Control Data*). The reaction of nickel sulfate and potassium ferrocyanide at pH ~9 with the TBP wastes in the 244-CR vault resulted in the precipitation of cesium nickel ferrocyanide. The addition of calcium nitrate (or strontium nitrate) to the TBP wastes resulted in the precipitation of ^{90}Sr. Later, sodium sulfide was also added to some waste batches in the 244-CR vault to promote ^{60}Co precipitation (WHC-MR-0089, *Status of TBP Scavenged Waste August 1955 to October 1957*, and WHC-MR-0110, *Cribbing of Scavenged Waste 200 West Area*).

Ferrocyanide precipitation processing in the 244-CR vault is reported to have started on November 9, 1955 (HW-38955-REV), and completed in January 1958. The ferrocyanide treated TBP waste, referred to as TFeCN waste, was transferred from 244-CR vault to tanks C-108,

C-109, C-111, and C-112 for settling of the precipitates before discharge to the 216-BC trenches and cribs.

2.4.3.3 Strontium/Rare Earth Fission Products Processing. The 244-CR vault, the head-end section of the 202-A PUREX Plant, and the 201-C Strontium Semiworks building were used in 1961 through 1963 to recover ^{90}Sr from HLW solutions (HW-66297, *Strontium-90 – Recovery and Lag Storage Interim Program*, and HW-72666, *Hot Semiworks Strontium-90 Recovery Program*). Beginning in August 1963, B Plant was used in conjunction with the former three facilities to separate ^{90}Sr and rare earth fission products (^{144}Ce and ^{147}Pm) from HLW solutions. The Sr/RE processing activities were conducted from August 1963 through February 1967 (RPP-16015, *Origin of Wastes in Single-Shell Tanks 241-B-110 and 241-B-111*). None of the SSTs in C Farm received wastes from the Sr/RE processing conducted in PUREX and B Plants. However, tanks C-107, C-108, C-109, C-111, and C-112 did receive waste from the Sr/RE purification processing conducted in the 201-C Strontium Semiworks building (see Section 2.3.1.1).

The PUREX facility generated a first cycle raffinate solution from the solvent extraction reprocessing of irradiated reactor fuel (i.e., HLW). The first cycle raffinate solution was highly acidic and contained most of the fission products (e.g., $^{89/90}$Sr, ^{144}Ce, ^{147}Pm, and ^{137}Cs) that were separated from the uranium and plutonium during the reprocessing of irradiated reactor fuel. The acidity of the first cycle raffinate solution was reduced by addition of sugar and digestion at elevated temperature to decompose the nitric acid solution. In a section of the PUREX facility known as the head-end, first cycle raffinate solution was reacted with sodium sulfate and lead nitrate to precipitate strontium and rare earth (i.e., cerium and promethium) fission products (HW-63051, *The Recovery of Fission Product Rare Earth Sulfates from PUREX 1WW*, and HW-69534, *Laboratory Development of a Carrier – Precipitation Process for the Recovery of Strontium from PUREX Wastes*). Lead co-precipitated with strontium and increased the amount of strontium precipitated from the first cycle raffinate solution. The resulting strontium and rare earth precipitate was centrifuged and washed to separate the supernate, which contained soluble fission products such as ^{137}Cs, ^{95}Zr-Nb, and ^{106}Ru-Rh. The supernate containing the soluble fission products (e.g., ^{137}Cs, ^{95}Zr-Nb, and ^{106}Ru-Rh) was neutralized and transferred to underground storage tanks. The strontium and rare earth precipitate was metathesized to soluble carbonates by addition of sodium carbonate. The strontium and rare earth carbonate precipitates were then dissolved in nitric acid and transferred to B Plant via 244-CR vault for further processing.

In B Plant, the strontium nitrate/rare earth nitrate solutions were processed to form separate solutions containing strontium and rare earths (RPP-16015). The strontium nitrate/rare earth nitrate solution was reacted with oxalic acid to precipitate the rare earths along with lead, leaving strontium in solution. The precipitate was centrifuged to separate the strontium solution from the rare earth precipitate. The strontium solution was stored in B Plant and transferred periodically to the 201-C Strontium Semiworks building via the 244-CR vault for purification. The rare earth precipitate was dissolved in nitric acid and stored in B Plant for further processing.

Lead was removed from the rare earth solution by adding sodium hydroxide solution to form soluble plumbite and insoluble rare earth hydroxide precipitates (HW-81373, *Removal of Lead from B-Plant Cerium and Rare Earth Fraction*; RL-SEP-197, *Chemical Processing Department*

Monthly Report December 1964, page G-2, and HAN-90907, *Monthly Status and Progress Report for February 1965,* page 21). The plumbite was separated from the rare earth hydroxide precipitate by centrifugation and discarded to the SSTs. The rare earth hydroxide precipitate was washed with sodium hydroxide solution to remove soluble lead and the wash solution was also discarded to the SSTs. The rare earth hydroxide precipitate was dissolved in nitric acid, stored in B Plant, and eventually transferred to the 201-C Strontium Semiworks building via 244-CR vault for purification.

Processing of strontium and rare earth solutions within B Plant continued until June 1966 (HAN-95105-DEL, *Monthly Status and Progress Report June, 1966*, page 15). Separations of strontium and rare earths from the first cycle raffinate solution continued to be conducted in the head-end section of the PUREX facility through February 8, 1967 (HAN-96805-DEL, *Monthly Status and Progress Report February 1967*, page AIII-4). The strontium and rare earth solution was transferred from PUREX to the 244-CR vault for storage from July 1966 through February 1967 while equipment modifications were conducted at B Plant.

2.4.3.4 Plutonium Eranium Extraction Acidified Sludge Processing. The sludges stored in A and AX Farms contained high concentrations of ^{90}Sr that required removal to reduce the heat load in these tanks. The sludges in these tanks were sluiced from 1968 through 1978 (SD-WM-TI-302, Section 3), with the sludge collected in the 244-AR vault. The ^{90}Sr-bearing sludge was washed to remove soluble salts and ^{137}Cs, then dissolved in nitric acid in the 244-AR vault. The dissolved sludge, designated as PAS solution, was transferred to the 244-CR vault. From the 244-CR vault, the PAS solution was transferred to B Plant for centrifugation and ^{90}Sr processing using solvent extraction (ARH-CD-691, *Strontium Recovery from PUREX Acidified Sludge*).

2.4.3.5 241-A Tank Farm Process Condensate Treatment Testing. A micro-pilot plant was installed in the 271-CR building and was operated from January 1960 through April 1963 to evaluate activated carbon and IX materials for separating organics and fission products from the TFPC. The micro-pilot plant was shut down in April 1963 and replaced by an engineering-scale pilot plant that was constructed from 1962 through September 1963 in an annex building adjacent to the 271-CR building. The engineering-scale pilot-plant in the 271-CR annex was operated from September 1963 through March 1965 and included a steam stripper, a vertical leaf filter, an electrodialysis unit and a thin bed ion exchanger (Letter 7G420-MEJ-06-007, "Waste Discharged to the 216-C-8 Crib").

Floor and process drains in the 271-CR and 271-CR annex buildings connected to an underground vitrified clay pipeline that discharged to the 216-C-8 French drain. Letter 7G420-MEJ-06-007 summarizes the analyses of the TFPC waste stream located in reference documents as well as the various tests conducted in the 271-CR and 271-CR annex buildings. Although process records are incomplete, a minimum of 31,780 gal of treated TFPC was discharged to the French drain 216-C-8 from January 1960 through March 1965.

2.4.3.6 241-C-801 Cask Loading Building. In 1962, building 241-C-801 was constructed to enable recovery of ^{137}Cs from PUREX HLW solutions. The 241-C-801 building was used from 1963 through 1968 to load cesium and occasionally technetium onto casks containing IX

material [Letter 7G400-03-SMM-003, "Shipments of Cesium-137 and Strontium-90 from the Hanford Site (1961 through 1977)"].

A cask would be staged in the 241-C-801 building and connected to waste transfer piping at a shielded enclosure within the 241-C-801 building. Tank waste (PUREX HLW 1956-1962 [P1] and 1963-1967 [P2] waste types) was transferred from tank C-103 through underground piping to a valve pit located inside building 241-C-801. The tank waste would then flow into the cask, the target radionuclide would be absorbed by the ion exchange material (Decalso®[4]), and then waste would flow back to tank C-102.

The 201-C Strontium Semiworks building was also used in conjunction with the C-801 cask station to demonstrate the separation of ^{99}Tc from alkaline HLW solutions. Approximately 1 kg of ^{99}Tc was separated from HLW that was stored in C Farm SSTs in October 1963 (HW-79377 C, *Chemical Laboratory Monthly Report – October 1963*, page C-7; and HW-79480, *Chemical Processing Department Monthly Report for October, 1963*, page G-2). The HLW solution was passed through a shielded cask in the 241-C-801 building that contained Decalso® ion exchange material to separate cesium. The effluent solution from the cesium cask was then passed through a separate shielded cask in the 241-C-801 building that contained IRA-401®[5] ion exchange material, which adsorbed technetium from the waste solution. The Strontium Semiworks received the cask that was loaded with technetium in November 1963 and eluted and concentrated the technetium, which was then loaded into a smaller cask for transfer to the Hanford Laboratories located in the 300 Area (HW-79768, *Chemical Processing Department Monthly Report for November, 1963*, page G-2). A second campaign to recover an additional 1 kg of ^{99}Tc from HLW stored in C Farm was conducted in August through September 1964 in the same manner as the first campaign (HW-83876, *Chemical Processing Department Monthly Report for August, 1964*, page B-2 and HW-84354, *Chemical Processing Department Monthly Report September 1964*, page B-1).

The cask loading area within the 241-C-801 building has a drain line connecting to the valve pit. The valve pit and cask loading area have separate drain lines connecting to a drywell located outside of the tank farm fence (drawings H-2-4573, *Engineering Flow Diagram, C-Farm Cesium Loadout Facility*, and H-2-4565, *Plot Plan – Roads Drawing Schedule, Cesium Loadout Facility*). This drywell is located ~23 m (75 ft) north of the 241-C-801 building, outside the tank farm fence (DOE/RL-88-30, *Hanford Site Waste Management Units Report*, Rev. 20, page 1158). No record was located that provides information on the volume and types of wastes potentially discharged to this drywell. An unknown amount of PUREX P1 and P2 waste types along with decontamination solutions may have been discharged to this drywell as a result of operations conducted at the 241-C-801 building.

2.4.4 Unplanned Releases

Fourteen UPRs have occurred within or adjacent to WMA C. The following brief descriptions of the UPRs are summarized from the Waste Information Data System (WIDS) General Summary

[4] Decalso® is a synthetic, sodium aluminosilicate gel manufactured by the Permutit Company, New York.

[5] IRA-401® is a styrene, di-butyl benzene ion exchange bead manufactured by the Rohm and Haas Company, Philadelphia, Pennsylvania.

Reports (DOE/RL-88-30) and represent the best information available on the nature and extent of releases. There is substantial uncertainty in the volume and content of UPRs from components within the WMA C. The UPR sites will be addressed as potentially contributing sources to the soil component and will be part of the soil component investigation and cleanup.

a. UPR-200-E-16 is a surface spill that resulted from a leak in an overground transfer pipeline between tanks C-105 and C-108. The surface spill associated with this release is located ~18 m (60 ft) northeast of tank C-105 and occurred in 1959. The spilled liquid was classified as coating waste from the PUREX process and was an estimated 50 gal.

b. UPR-200-E-27 is located just east of the 244-CR vault and extends east beyond the tank farm fenceline. DOE/RL-92-04 indicates the surface contamination was deposited in 1960, but does not identify the source(s) of the contamination. However, the November 1960 monthly report for the Tank Farm Contractor states the particulate contamination was due to work in C Farm diversion boxes and 244-CR vault (HW-67459, *Chemical Processing Department Monthly Report for November, 1960*, pages B-2 and B-3). Since the UN-200-E-27 release consisted of airborne particulate contamination, the impact was limited to the ground surface.

c. UPR-200-E-68 is wind-borne surface contamination spread from the 241-C-151 diversion box. The release occurred in 1985 and was subsequently decontaminated to background radiation levels or covered with clean soil for later decontamination (the source document is inconclusive). Sometime after the release, the 241-C-151 diversion box was opened, flushed, and sprayed with Turco Fabrifilm[6] to physically fix contamination to the structure surface.

d. UPR-200-E-72 occurred in 1985 and is located south of WMA C near the 216-C-8 crib. The source of the contamination was buried contaminated waste. The waste posed little release potential because the contamination was fixed in place with Turco Fabrifilm. The source of the contamination was determined to be from the burial of previously undocumented contaminated material. The area was surrounded with a chain and posted as a Surface Contamination Area; however, the site is no longer marked or posted. No information regarding the buried material was given in the WIDS report; it is assumed that the contamination extends to the depth of the buried material, but the aerial extent and depth are not known. The volume of contamination was not specified.

e. UPR-200-E-81 is located northeast of the 244 CR vault near the 241-CR-151 diversion box. It occurred as a result of a leak in an underground transfer pipeline in October 1969. The estimated 36,000 gal of waste leaked from the pipeline consisted of PUREX coating waste. The site was covered with 0.5 m (18 in.) of backfill and clean gravel.

f. UPR-200-E-82 occurred in December 1969. The source was determined to be the feed line running between tank C-105 and the 221-B building. The leak was discovered near the 241-C-152 diversion box. The liquid release, an estimated 2,600 gal, flowed from the vicinity of the 241-C-152 diversion box to the northeast, downgrade, until it pooled into

[6] Turco Fabrifilm is a registered trademark of Turco Products, Westminster, California.

an area measuring ~0.46 m^2 (5 ft^2) outside the WMA C fence. The contaminated site was covered with 2 ft of dirt in 1969 (RPP-RPT-29191, *Supplemental Information Hanford Tank Waste Leaks*, pages 128-129). The WIDS report states that additional decontamination of the area was performed in 1985. A gunite cap was subsequently installed on the soil surface above this leak location.

g. UPR-200-E-86 is a spill that resulted from a leak in a pipeline used to transfer waste from the 244-AR vault to WMA C. The depth of the leaking pipeline was ~2 m (8 ft) below ground surface (bgs). The release occurred in March 1971 near the southwest corner of WMA C, outside the fence. The spill consisted of 25,000 Ci of ^{137}Cs in an estimated 17,385 gal of waste (RHO-CD-673, *Handbook 200 Areas Waste Sites*). The soils surrounding the pipeline were sampled, and it was determined the contamination had not penetrated below 6 m (20 ft). The contamination plume volume was estimated at 37 m^3 (1,300 ft^3). The surface of the release site has been stabilized with "shotcrete." The release site is demarcated with concrete AC-540 marker posts and signs indicating "Underground Radioactive Material." A gunite cap was subsequently installed on the soil surface above this leak location.

h. UPR-200-E-91 is located ~30 m (100 ft) from the northeast side of the tank farm. It resulted from surface contamination that migrated from WMA C. The date of the occurrence, its areal extent, and the nature of the contamination are not specified. DOE/RL-92-04 states that the contaminated soil was removed, and the area was released from radiological controls.

i. UPR-200-E-99 is surface contamination that resulted from numerous piping changes associated with the 244-CR vault. It is located south of 7th Street, directly south of the 244-CR vault, and was established as a release site in 1980, although the actual occurrence date is unknown. A radiological survey conducted in support of herbicide applications in 1981 found no detectable contamination in the release area. As a result of the radiological survey, surface contamination postings were removed on March 5, 1981, and the area was released from the radiation zone designation.

j. UPR-200-E-100 is a surface spill of unknown volume and constituents that occurred in 1986. It is located about 60 m (197 ft) east of WMA C and surrounds the 244-A lift station.

k. UPR-200-E-107 is a surface spill located north of the 244-CR vault inside WMA C. DOE/RL-92-04 states that a spill occurred on November 26, 1952, when a pump discharged an estimated 5 gal of liquid to the ground surface during a pump installation. The spilled waste was TBP waste from 221-U building. Decontamination of the ground and equipment was reported to have been immediately undertaken. "Due to the magnitude of the ground contamination, it was decided to excavate a hole and blade the contamination earth into the hole" (RPP-RPT-29191 page 103).

l. UPR-200-E-118 is located in the northeast portion of the tank farm and extends north up to about 300 m (1,000 ft) beyond the fenceline. It was the result of an airborne release

from tank C-107 that occurred in April 1957. The highest exposure rate was estimated at 50 mrem/hour at the ground surface (DOE/RL-92-04).

m. UPR-200-E-136 is a release in 1969 of 64,345 to 90,840 L (17,000 to 24,000 gal) of waste from tank C-101. The quantity and type of waste released from tank C-101 is uncertain (RPP-ENV-33418).

n. UPR-200-E-137 occurred when, as stated in WIDS, "water entered tank C-203, migrated through the saltcake, and either became entrained in the saltcake or leaked out of the tank." The leak was 1,514 L (400 gal) of PUREX HLW. The waste in tank C-203 was subsequently determined to be sludge and was retrieved to a DST in 2006.

In addition to the documented UPRs, there are other events that potentially have resulted in the UPR of wastes within WMA C. Potential sources of additional unplanned waste releases in WMA C include waste losses through spare inlet nozzles or cascade lines and additional pipeline leaks not previously reported in WIDS. These potentially new UPRs were identified through review of the operational history for C Farm (RPP-ENV-33418) and are summarized in the following.

The SSTs in WMA C are equipped with horizontal inlet nozzles. Process waste transfer pipelines were inserted through the inlet nozzles and protruded into the tanks. As discussed in RPP-ENV-33418, a loose seal was installed around the process waste transfer pipeline at the nozzle. The 100-series tanks are also arranged in four cascades of three tanks each. After filling the first tank in the cascade, waste then flows to the second and once filled, the waste flows to the third and final tank in the cascade.

a. Tank waste may have been discharged from the tank inlet nozzles if the waste elevation in the tank exceeded the elevation of the inlet nozzles. Cascade lines which lie below the spare inlets in elevation are also submerged when the waste level exceeds the spare inlet level. The cascade lines consist of a 4-in. schedule 80 pipe welded to the steel liners in the SSTs. The 4-in. pipe is encased inside an 8-in. schedule 80 pipe when traversing between SSTs, but the outer pipe is not sealed to the inner pipe and waste leakage could occur if the inner pipe is breached. When the waste exceeds the operating capacity of the tank, it would appear the waste must find an outlet over the top of the tank liner, breach a weak spot in the cascade line (perhaps where it exits or enters the tank liner), or breach the spare inlet lines. Dates and waste types present in WMA C tanks that filled with waste above the elevation of the spare inlet nozzles are summarized in Table 2-7.

b. Additional pipeline failures that may have resulted in the loss of tank waste within the C Farm are summarized in Table 2-8. Insufficient information was available to estimate the volume of tank waste potentially discharged to the soil from the spare inlet nozzles or newly identified pipeline failures.

Table 2-7. Potential Waste Losses Through Spare Inlets on Waste Management Area C Tanks

Tank	Date	Waste Type Present in Tank
C-101	June 1965–December 1967	Received waste from CR vault. Tank contains CR vault waste (28 kgal), PUREX high-level waste (HLW) (P2) (452 kgal), and 1961-1972 coating waste (CWP2) (94 kgal).
C-103	October 1953–March 1957	Tributyl phosphate (TBP) waste
C-103	June 1961–December 1961	PUREX CWP2
C-104	August 1958	PUREX 1956-1960 coating waste (CWP1)
C-104	June 1965–March 1966	After receiving 15,000 gal of unknown waste type (likely PUREX CWP2 based on RL-SEP-332-DEL, page B-2) from 244-CR vault, the tank was filled above the spare inlets. Majority of waste in tank is PUREX CWP2.
C-105	Pre-October 1967	Waste type unknown; soil contamination found beneath spare inlet nozzles during excavation in October 1967.
C-106	November 1951	Water added to bismuth phosphate metal waste (MW2)
C-106	December 1965–March 1966	PUREX P2 HLW supernate
C-109	June 1961–December 1961	PUREX CWP2
C-109	June 1965–March 1968	Tank received 19,000 gal from 201-C Sr Semiworks (HS). Tank contains 112,000 gal of evaporator bottoms (BT-SltCk), 300,000 gal of PUREX CWP2, and 142,000 gal of Sr Semiworks waste (HS).
C-111	May 1957	TBP waste
C-111	September 1957	Scavenged 242-B BT-SltCk waste (i.e., concentrated 1C/CW and TBP wastes).
C-201	December 1955–January 1956 June 1961–June 1963	201-C Hot Semiworks waste from PUREX flowsheet tests (Note: This is not waste type HS).
C-202	January 1957–March 1957 June 1957–October 1958 June 1961–December 1963	201-C Hot Semiworks waste from PUREX flowsheet tests (Note: This is not waste type HS). Last waste transferred into tank was 201-C building flush solutions.
C-204	March 1968–March 1970	201-C Hot Semiworks waste from PUREX flowsheet tests (Note: This is not waste type HS) and 201-C building flush solutions.

1C/CW = first cycle decontamination waste mixed with cladding removal waste
PUREX = Plutonium Uranium Extraction (plant)

Reference: RL-SEP-332-DEL, *Chemical Processing Department Monthly Report for February, 1965*.

Table 2-8. Potential Pipeline Failures Not Previously Reported in DOE/RL-88-30 (2 sheets)

Date	Waste Type	Event Description from RPP-ENV-33418
6-1964	HS - 201C Strontium Semiworks Waste	"The underground process line from the 252-C diversion box to 112 tank, C Tank farm, failed. The failed pipeline was isolated. Jumpers were fabricated and installed to establish a new process route." The failed pipeline is line V172.
11-1964	Cesium Depleted PUREX HLW Supernate (P1)	Installation was completed on an alternative effluent return route from the C-801 (801-C) Cesium Loadout Building to Tank 103-C. See drawing H-2-4574, *Process & Service Piping Tanks to Loadout Station* for details of this piping. A three-way ball valve was inserted in the C-801 (801-C) effluent return line to SST C-102 to enable routing waste to SST C-103 or C-102.
2-1965	PUREX CWP2	"On February 18, 1965, the 244-CR Vault was found flooded up to approximately the level of the tank tops. Immediate steps were taken to reduce the liquid level by jetting the solution to the 011 Tank. Partial cause of the flooding is attributed to a failure in the coating waste line which enters the 151-CR diversion box. Drainage from this diversion box collects in the 002-CR vault sump. Water from a sampler flush line and drainage from rain and snow contributed to the liquid level in the vault. To date, the 001, 002, and 003 sumps have been emptied, and the 011 sump is being emptied, to the 011 Tank. This liquid is being pumped from the 011 Tank to Tank 103-A in the 241-A Tank Farm. In trying to establish a coating waste routing from the PUREX Plant to the 241-C Tank Farm a leak was also discovered in the underground line adjacent to the 152-A Diversion Box. Because of the two apparent leaks in this line it has been abandoned as being unusable."
3-1965	PUREX CWP2	"A liquid level rise in Tank 103-C, the cesium feed tank, was apparently caused by a failed line in the encasement between the 152-CR diversion box and Tank 102-C which permitted coating waste from the PUREX Plant to leak into the encasement and drain to Tanks 101-C, 102-C, and 103-C via the tank pump pits. Coating waste has been routed through a spare line to Tank 102-C and no further leaks have been detected. The coating waste solution accumulated in Tank 103-C did not significantly affect cesium loading capability as a cask was loaded normally following the incident." Note: Pipeline 8041 inside a concrete encasement was used to route the PUREX CW to SST C-102 (see drawing H-2-44501, sheet 92). This encasement traverses from diversion box 241-CR-152 along the west side of SSTs C-101, C-102, and C-103. In order for the PUREX CW to drain into SSTs C-101, C-102, and C-103, the encasement containing the failed transfer pipeline must have partially filled with waste. The integrity of this encasement is unknown and may have leaked waste to the soil. Drawing H-2-2338, sheet 45 indicates pipeline 8041 is out of service. Pipeline 8041 connects from nozzle U-3 in the 241-CR-152 diversion box and nozzle U-2 in pit 02C atop SST C-102.
5-1966	PUREX CWP2	"A leak in the PUREX coating waste route (152-CR diversion box) was detected by an abnormal liquid level increase of the 002CR vault sump. The leaking flexible jumper in the 152CR diversion box was replaced." Note: Diversion box 241-CR-152 and 244-CR Vault sump are concrete structures with painted surfaces. It is uncertain whether leaked waste was contained inside diversion box 241-CR-152 and 244-CR Vault sump.

Table 2-8. Potential Pipeline Failures Not Previously Reported in DOE/RL-88-30 (2 sheets)

Date	Waste Type	Event Description from RPP-ENV-33418
Pre-1988	PUREX P2 supernate	Pipeline V-103 - "Earlier investigations of the extremely high levels of contamination found between Tanks 104-C and 105-C (Environmental Protection Deviation Report 87-10). The following observations were documented at the time and were the bases for the conclusion that both tanks were sound: The fill line V-103 was stated to have been abandoned at an earlier date due to pipeline leakage, and the activity noted in DW 30-03-02 could have been due to migration of pre-existing contamination that was first seen in the exploratory scans. This line was part of the old PUREX supernate (PSN) transfer route from Tank 241-AX-101. The material was thermally hot, and water injection was required to maintain a temperature below 60°C. The cause of failure was believed to have been due to thermal shock induced by the intermittent transfers. In-tank photographs failed to show any evidence that either tank was unsound. However, the Tank 241-C-105 photos indicated that the tank had been filled to a level above that of the cascade and sidefill pipelines. The possibility of leakage through the wall penetration seals was discussed. The liquid levels in Tank 241-C-105 and -104 remained at a high level for almost six months after the first exploratory well scans, and the observed activities, including that in DW 30-03-02, had remained stable throughout, whereas seepage from either tank would normally have been seen as steadily increasing radiation at the 35 to 41 feet farm excavation depth. The activity at this depth however has diminished in all wells since 1974."
Unknown	Unknown	Line V112 is identified as a leaker adjacent to diversion box 241-C-151. The date and amount of waste leaked from this pipeline is unknown.

HLW = high-level waste PUREX = Plutonium Uranium Extraction (plant) SST = single-shell tank

Waste types:
CW = Cladding waste, aluminum clad fuel
CWP2 = PUREX CW (1961-1972)
P1 = PUREX HLW (1956-1962)
P2 = PUREX HLW (1963-1967)

References:
DOE/RL-88-30, *Hanford Site Waste Management Units Report*, Rev. 20.
Internal memo 13331-88-088, "Environmental Protection Deviation Report 87-10, Radiation Level Increase In Drywell 30-03-09."
H-2-2338, *Diversion Box 241-CR-152 Nozzle Information*.
H-2-44501, *Area Map 200 East "A" Plant Facilities*.
RPP-ENV-33418, *Hanford C-Farm Leak Assessments Report: 241-C-101, 241-C-110, 241-C-111, 241-C-105, and Unplanned Waste Releases*.

3. WASTE MANAGEMENT AREA C SITE CHARACTERIZATION EFFORTS

This chapter provides a summary evaluation of sources and contaminant distribution in the vadose zone and groundwater underlying WMA C. It also identifies potential corrective action objectives and requirements. The information on known and suspected contamination is presented in Section 3.1 of RPP-14430 and in RPP-35484. Additional data to support improved understanding of the nature and extent of contamination at WMA C will be collected during the field investigation described in this work plan.

Limited characterization of the soils was completed during the Phase 1 RCRA corrective action process from 2004 to 2007. The characterization effort focused on sites with the highest observed ^{137}Cs contamination (on the order of 10^7-10^8 pCi/g). This approach was taken because high inventory levels of mobile contaminants (e.g., ^{99}Tc and nitrate) are invariably associated with high ^{137}Cs content. The results of the Phase 1 characterization efforts are documented in RPP-35484. Additional field characterization activities have been undertaken since the publication of RPP-35484. These activities are described in RPP-35169, *Near Term Data Quality Objectives for Vadose Zone Characterization Waste Management Area C*, and Appendix D of RPP-PLAN-35341, *Work Plan for Near-Surface Vadose Zone Characterization Utilizing the Hydraulic Hammer/Direct Push Technology for 35 Direct Pushes in FY08*. The near-term DQO supports characterization efforts that have been conducted at UPR-86 and UPR-81 at WMA C.

This chapter contains information that could be used for portions of the RCRA TSD closure plans, including the nature and extent of contamination, facility description, and current RCRA interim status groundwater monitoring requirements.

3.1 KNOWN AND SUSPECTED CONTAMINATION

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 of contamination at a site caused by a given event or activity. A summary of available WMA C data regarding source, sediments, and groundwater contamination is presented in the following subsections and RPP-ENV-33418 and RPP-35484.

When considering the data in Sections 3.1.1 and 3.1.2, 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 ^{137}Cs is 30.2 years, approximately the time between 1968 and 1998. Thus, ^{137}Cs 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 WMA C are dependent on nuclear and chemical aspects of the processes that generated the waste. The inventory of chemicals and radionuclides lost to the vadose zone in WMA C is a function of the waste types stored in the tanks and other facilities over their

decades of use. Because of its long operational history, C Farm received waste generated by all of the major processes as discussed in Section 2.4.3. Best estimates of specific sources for each leak event are provided in RPP-ENV-33418.

Sources of releases include fluid discharges, tank waste through tank leaks, ancillary equipment leaks, and failures (e.g., diversion boxes, transfer and cascade pipelines). These releases impacted the sediments. These releases are discussed in detail in RPP-ENV-33418.

Based on reassessment of tank waste loss events in C Farm, tank C-101 has a loss estimate of 20,000 gal. Tank C-105 has an estimated leak loss range from 40 to 2,000 gal. The tank C-105 leak was targeted in the Phase 1 characterization efforts because of the presence of high ^{137}Cs (>10,000,000 piCi/g) in drywell 30-05-07. Tank C-110 waste loss appears to be the result of a tank overflow through spare inlet nozzles and is less than 2,000 gal. Waste loss from tank C-111 indicates that the liquid level decrease can be attributed to evaporation. Available information on specific leak events is provided in RPP-ENV-33418.

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. RPP-ENV-33418 provides information that 11 pipelines in WMA C are known or are suspected to have failed (Table 2-8). In addition, tanks C-101, C-103, C-104, C-105, C-106, C-109, C-201, C-202, and C-204 have potential waste losses from spare inlets (Table 2-7). An effort to investigate these tanks related to spare inlet losses are being conducted under the near-term field sampling activities (RPP-PLAN-35341 Appendix D).

It should be noted that there are other support facilities and other operations within and adjacent to the tank farm that may have been sources for contamination in the groundwater. Several of these facilities are listed below.

a. A pit for steam cleaning heavy equipment was dug during 1954 northeast of tank C-103 (241-CR Steam Cleaning Pit). The pit has been covered but is not delimited above ground in any way other than being within the C Farm fence (HW-60807, *Unconfined Underground Radioactive Waste and Contamination in the 200 Areas, 1959*). Thus, its exact location is unknown.

b. The cask loading area within the C-801 building has a drain line connecting to the valve pit. The valve pit and cask loading area have separate drain lines connecting to a drywell located outside of the tank farm fence (drawings H-2-4573 and H-2-4565). This drywell is located ~23 m (75 ft) north of the C-801 building, outside the tank farm fence (DOE/RL-88-30, Rev. 20, page 1158). No record was located providing information on the volume and types of wastes potentially discharged to this drywell. An unknown amount of PUREX P1 and P2 waste types along with decontamination solutions may

have been discharged to this drywell as a result of operations conducted at the C-801 building.

c. A 300-ft × 800-ft burial ground, known as dry waste garden #12, went into service in 1956, located 500 ft north of the north corner of the C Farm. It received boxed waste from the PUREX Plant containing both plutonium and mixed fission products. One trench was filled, while two are open as of 1959 (HW-60807).

d. A construction burial ground was completed in 1958. It is a plot 150 ft × 500 ft located 2,000 ft north of 241-C at the northwest edge of the burning pit. It was used to handle equipment from 293-A construction and the temporary PUREX canyon ventilation barricade used for the new crane addition (HW-60807).

3.1.2 Releases to Soils

Fourteen UPRs have occurred in WMA C that were recorded (see Section 2.4.4). Of these releases, only UPR-200-E-82 was investigated as part of the Phase 1 characterization effort. UPR-200-E-82 is a pipeline leak of 2,600 gal containing 4.34 Ci/gal of ^{137}Cs. It was chosen for Phase 1 characterization due to the presence of soil samples containing 550,000,000 pCi/g of ^{137}Cs (ARH-1945, *B Plant Ion Exchange Feed Line Leak*). Section 2.4.4 discusses these UPR sites that have impacted the soils.

Twelve UPRs are known or thought to have occurred within or adjacent to WMA C within the designated DQO boundary. These UPR sites are of the highest priority for characterization as expressed by Ecology. There is uncertainty in the nature and extent of UPRs from components within WMA C. Estimates of contaminant release volumes, inventories, and locations for some UPRs are included in the WIDS. There are several sites mentioned in the source documents and WIDS that do not provide direct indication of some of their locations, making confirmation sampling of the waste sites more difficult.

Consolidated UPRs (i.e., within the WMA C DQO boundary) and collectively documented in Appendix B of HFFACO (Ecology et al. 1989) under the operable unit for WMA C (200-PO-3) include the following:

UPR-200-E-16	UPR-200-E-72	UPR-200-E-86	UPR-200-E-118
UPR-200-E-27	UPR-200-E-81	UPR-200-E-91	UPR-200-E-136
UPR-200-E-68	UPR-200-E-82	UPR-200-E-107	UPR-200-E-137

Section 2.4.4 provides a complete discussion of these 12 consolidated UPR sites. Section 2.4.4 has additional UPRs associated in the vicinity of WMA C that are outside the designated DQO boundary. Two of the UPRs are associated with tank leaks [i.e., UPR-200-E-136 (tank C-101) and UPR-200-E-137 (tank C-203)]. An additional two UPRs are outside the designated DQO boundary (UPR-200-E-200-99 and UPR-200-E-100) but are addressed in Section 2.4.4.

In addition, various operations in the tank farm may have contributed to releases to the soils. Floor and process drains in the 271-CR and 271-CR annex buildings connected to an underground vitrified clay pipeline that discharged to the 216-C-8 crib.

Letter 7G420-MEJ-06-007 summarizes the analyses of the TFPC waste stream from reference documents as well as the various tests conducted in the 271-CR and 271-CR annex buildings. Although process records are incomplete, a minimum of 31,780 gal of treated TFPC was discharged to the crib 216-C-8 from January 1960 through March 1965. Potential leaks from pipelines within C Farm may have also impacted the soils as described in Section 2.4.4. Approximately 10 miles of pipelines exist inside the WMA C fenceline boundary. One of these lines is a candidate for additional investigation under 200-IS-1 (DOE/RL-2002-14, *Tanks/Lines/Pits/Boxes/Septic Tank and Drain Fields Waste Group Operable Unit RI/FS Work Plan and RCRA TSD Unit Sampling Plan; Includes: 200-IS-1 and 200-ST-1 Operable Units*).

As discussed in Section 2.4.3.6, the C-801 cask loading building had process piping going to it as well as a return line. An additional return line was also completed, providing an alternative effluent return route from the C-801 cesium load-out building to tank C-103 in November 1964. See drawing H-2-4574, *Process & Service Piping Tanks to Loadout Station* for details of this piping. A three-way ball valve was inserted in the C-801 effluent return line to tank C-102 to enable routing waste to tanks C-103 or C-102. The process waste stream being treated was a cesium-depleted PUREX HLW supernate (P1). After the ^{137}Cs was removed, 60% of the ^{99}Tc was then removed before returning the waste stream to the tanks. No records were found to explain the need for a second return line, but its construction may indicate concerns about the integrity of the initial return line and possible waste losses. Section 2.4.3.6 provides more detail, and the line replacement is discussed in Table 2-8.

For tank C-101 and its 20,000-gal leak volume as discussed in Section 3.1.1, soil contamination was also present. In 1970, several new drywells (30-01-01, 30-01-06, 30-01-09, and 30-01-12) were installed around tank C-101. Drywells 30-01-01 and 30-01-12 were installed in March 1970. Drywell 30-01-06 was installed in January 1970. Drywell 30-01-09 was installed in April 1970.

During the drilling of the fourth drywell on March 17, 1970, 5,000-10,000 c/m contamination was encountered at the 38-ft level and drilling was terminated (ARH-1526-1, *Chemical Processing Division Daily Production Reports January, 1970 through March, 1970*, page 130). Drilling of the fourth drywell was resumed on March 18, 1970, and 5,000 to 10,000 c/m contamination was encountered between the 42- and 48-ft level, but after 48 ft, no contamination was seen (ARH-1526-1, page 132). Drilling of the fourth drywell around tank C-101 was reported as being completed on March 24, 1970 (ARH-1526-1, page 138). Contamination was not reported as being encountered during the drilling of other wells around tank C-101. It is not clear which drywell is referred to as the "fourth" in ARH-1526-1. Since this is the last drywell installed around tank C-101 in 1970, it is thought that the "fourth" drywell is in reference to drywell 30-01-09. According to RHO-CD-896, *Review of Classification of the Nine Hanford Single-Shell "Questionable Integrity" Tanks*, page 46, drywell number 30-01-09 was found to have contamination between the 29- and 36-ft levels when first monitored, which is consistent with the "fourth" drywell being 30-01-09.

3.2 NATURE AND EXTENT OF CONTAMINATION DETERMINED FROM PHASE 1 INVESTIGATIONS

An understanding of the nature and extent of subsurface contamination in the vadose zone in WMA C is needed to determine where additional characterization efforts are required beyond Phase 1 and the characterization activities addressed in RPP-35169. For the Phase 1 characterization effort, before the field investigation was conducted, preliminary conceptual models of the subsurface contamination were developed (RPP-14430) that were based on historical tank farm operations records (RPP-7494, *Historical Vadose Zone Contamination from the A, AX, and C Tank Farm Operations*), geology and hydrology (RPP-14430), and gross gamma and spectral gamma logging data (e.g., RPP-8321, *Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-C Tank Farm-200 East Area*; GJ-HAN-92, *Vadose Zone Characterization Project at the Hanford Tank Farms: Tank Summary Data Report for Tank C-110*; GJO-98-39-TAR/GJO-HAN-18, *Hanford Tank Farms Vadose Zone: C Tank Farm Report*; GJO-98-39-TARA/GJO-HAN-18, *Hanford Tank Farms Vadose Zone: Addendum to the C Tank Farm Report*). For a review of subsurface contamination in the groundwater, see PNNL-13024, PNNL-16436, and DOE/RL-2008-01 with updates in the annual Hanford Site Groundwater Monitoring reports through FY 2007.

The following discussions concerning the nature of contamination at specific areas within WMA C are organized to first address those sites for which characterization activities were conducted as part of the Phase 1 field investigation. These sites include the potential leak from tank C-105 and the pipeline leak to the west of C Farm near diversion box 241-C-152 (UPR-200-E-82). Additional sites that are known to have contamination are discussed to provide as comprehensive a description of contamination within WMA C as possible. The discussions for other sites are largely based on historical information and are, therefore, less detailed.

At borehole C4297 near tank C-105, soil samples were taken at different depths and analyzed for radionuclide and chemical content, and hydrogeologic characteristics. The data from these sites are summarized in this section, with additional soils characterization data provided in RPP-35484; PNNL-15503, *Characterization of Vadose Zone Sediments Below the C Tank Farm: Borehole C4297 and RCRA Borehole 299-E27-22*; and DOE/ORP-2008-01, *RCRA Facility Investigation Report for Hanford Single-Shell Tank Waste Management Areas*.

At UPR-200-E-82, soil samples were taken from different direct pushes at different depths, and similar analyses were conducted. These data are summarized below with more detailed discussions of these data provided in PNNL-15617, *Characterization of Vadose Zone Sediments from C Waste Management Area: Investigation of the C-152 Transfer Line Leak*. Characterization of the UPR-200-E-82 site was selected preferentially over two other UPRs, UPR-200-E-86 and UPR-200-E-81, for the initial characterization effort because of higher reported ^{137}Cs contamination (ARH-1945) and more easily interpreted characterization data. From this perspective, additional characterization was considered more likely to significantly improve the understanding of waste distribution in the vadose zone. The other two UPRs (UPR-200-E-86 and UPR-200-E-81) were also pipeline leaks associated with waste transfer facilities west of C Farm. Under the near-term DQO (RPP-35169), the releases from UPR-200-E-81 and UPR-200-E-86 are presently being investigated.

After completion of initial plans for WMA C and initiation of field activities, a preliminary surface geophysical exploration (SGE) using a high-resolution resistivity (HRR) technique was implemented at WMA C (RPP-RPT-31558, *Surface Geophysical Exploration of C Tank Farm at the Hanford Site*). Although not part of the original characterization plan, this technique has been used at other waste sites in the 200 Areas (PNNL-14948, *Plume Delineation in the BC Cribs and Trenches Area*; RPP-RPT-28955, *Surface Geophysical Exploration of T Tank Farm at the Hanford Site*; RPP-RPT-30976, *Surface Geophysical Exploration of S Tank Farm at the Hanford Site*; RPP-RPT-31557, *Surface Geophysical Exploration of U Tank Farm at the Hanford Site*) and showed enough promise to be used at other locations such as WMA C. The objective of the preliminary investigation was to collect and analyze an initial set of resistivity data to identify low-resistivity regions that could be correlated to soil inventory records. The resistivity data was used to aid in selection of locations for conventional sampling and analysis for this work plan. Section 3.2.1.2 provides more information on the SGE deployment and results. Results from these field activities, coupled with evaluation of historical processing records and previous characterization data, have led to a better understanding of the nature and extent of subsurface contamination in WMA C, as described in Section 3.2.1.

3.2.1 Vadose Zone

The major investigation finds from the Phase 1 characterization activities are summarized as follows.

a. Chemical analyses of sediments retrieved from borehole C4297 near tank C-105 showed several features characteristic of tank waste vadose zone contamination. These included high ^{99}Tc and nitrate concentrations between 135 and 160 ft bgs and an altered zone just below the tank bottom between 45 and 60 ft bgs with elevated pH values (8 to 9.3) and high sodium content (32 to 131 µg/g). Please see Section 3.2.1.1 and RPP-35484 for further information.

b. A shallower contaminated zone, within borehole C4297 sediments, contained elevated ^{137}Cs and ^{154}Eu concentrations at ~13 ft bgs, and a ^{60}Co contamination zone between 40 and 60 ft bgs. This contamination is attributed to loss of waste from one or more transfer lines.

c. Direct push sediment sample data around UPR-200-E-82 showed maximum ^{99}Tc and nitrate concentrations at the deepest sampling location, ~80 ft bgs, and underneath the estimated leak location. These data suggest that the leak fluids and mobile contaminants have penetrated at least 80 ft bgs and are likely present at greater depths. Recent high ^{99}Tc concentrations at nearby monitoring wells (299-E27-23, 299-E27-4, 299-E27-13, 299-E27-21, and 299-E27-14) may indicate that some fraction of this waste has entered the unconfined aquifer.

d. Surface geophysical exploration in WMA C showed one large anomalous resistivity zone centered around tank C-104 and a smaller zone between tanks C-108 and C-109. The sources of these anomalies are not well understood nor are the depth intervals at which they occur.

3.2.1.1 Sampling Results. Borehole C4297 was drilled near the source of the tank C-105 leak near the southwest portion of tank C-105 and close to drywell 30-05-07, where high ^{137}Cs (>10^7 pCi/g) concentrations were measured at and below tank bottom depth as summarized in Section 3.2.1 indicating that tank waste contamination is present through the zones discussed. The C4297 borehole laboratory data indicates the following.

a. An elevated pH zone, 8 to 9.3, between 40 and 52 ft bgs.

b. Elevated water leachable anion concentrations of nitrate, carbonate, sulfate, chloride, and fluoride occur at discrete depth intervals. Elevated fluoride (1 to 2 µg/g) and carbonate (44 to 158 µg/g) occur just below the backfill from 40 to 52 ft bgs for fluoride and from 40 to 60 ft bgs for carbonate, generally coincident with the high pH zone. Conversely, the highest concentrations of nitrate, sulfate, and chloride are deeper in the vadose zone. Chloride concentrations (3 to 21 µg/g) are highest between 135 and 196 ft bgs, nitrate concentrations (11 and 20 µg/g) are highest between 133 and 195 ft bgs, and sulfate concentrations (52 to 133 µg/g) are highest between 133 and 161 ft bgs.

c. Variable water leachable concentrations of cations (sodium, calcium, magnesium, and strontium) occur at discrete depth intervals. Sodium concentrations are elevated (32 to 131 µg/g) between 40 and 60 ft bgs, coincident with the high pH zone. A secondary zone of slightly elevated sodium concentrations (20 to 24 µg/g) occurs in the backfill between 12 and 40 ft bgs. Calcium, magnesium, and strontium are clearly concentrated (25 to 30, 8 to 11, and 0.12 to 0.14 µg/g, respectively) between 133 and 137 ft bgs. Conversely, these cations are depleted (< 2, < 0.5, and < 0.004 µg/g, respectively) in the high sodium concentration zone between 40 and 60 ft bgs (see Figure 3-1).

d. Water leachable concentrations of trace constituents (^{99}Tc, uranium, and molybdenum) are present at distinguishable concentrations with depth (see Figure 3-2). Technetium-99 is present between 40 and 159 ft bgs, and concentrations are bimodal with depth. Highest concentrations (0.4 to 8.4 pCi/g) occur from 133 to 154 ft bgs, with less elevated concentrations (0.14 to 2.6 pCi/g) between 40 and 66 ft bgs. Elevated uranium concentrations (0.007 to 0.01 µg/g) occur between 40 and 60 ft bgs, coincident with the high pH zone. Molybdenum is elevated (0.01 to 0.1 µg/g) between 55 and 65 ft bgs.

e. Gamma energy analysis for gamma-emitting radionuclides indicated ^{137}Cs activity (between 3 and 32 pCi/g) near the surface (2 to 12 ft bgs) and ^{60}Co (between 0.1 and 0.5 pCi/g) at greater depth (41 to 66 ft bgs).

Characterization data pertinent to the tank waste release from pipeline V122 (UPR-200-E-82) west of the C Farm in 1969 are summarized in this section. The types of available data include sediment sample analyses from 20 vertical direct push probeholes surrounding the UPR-200-E-82 site, a gunite cap covering the pipe leak, and six slanted direct push probeholes that were directed underneath the cap from peripheral locations. Integration of this information leads to the following key observations.

Figure 3-1. Distribution of pH and Major Anions and Cations in Borehole C4297 Sediments

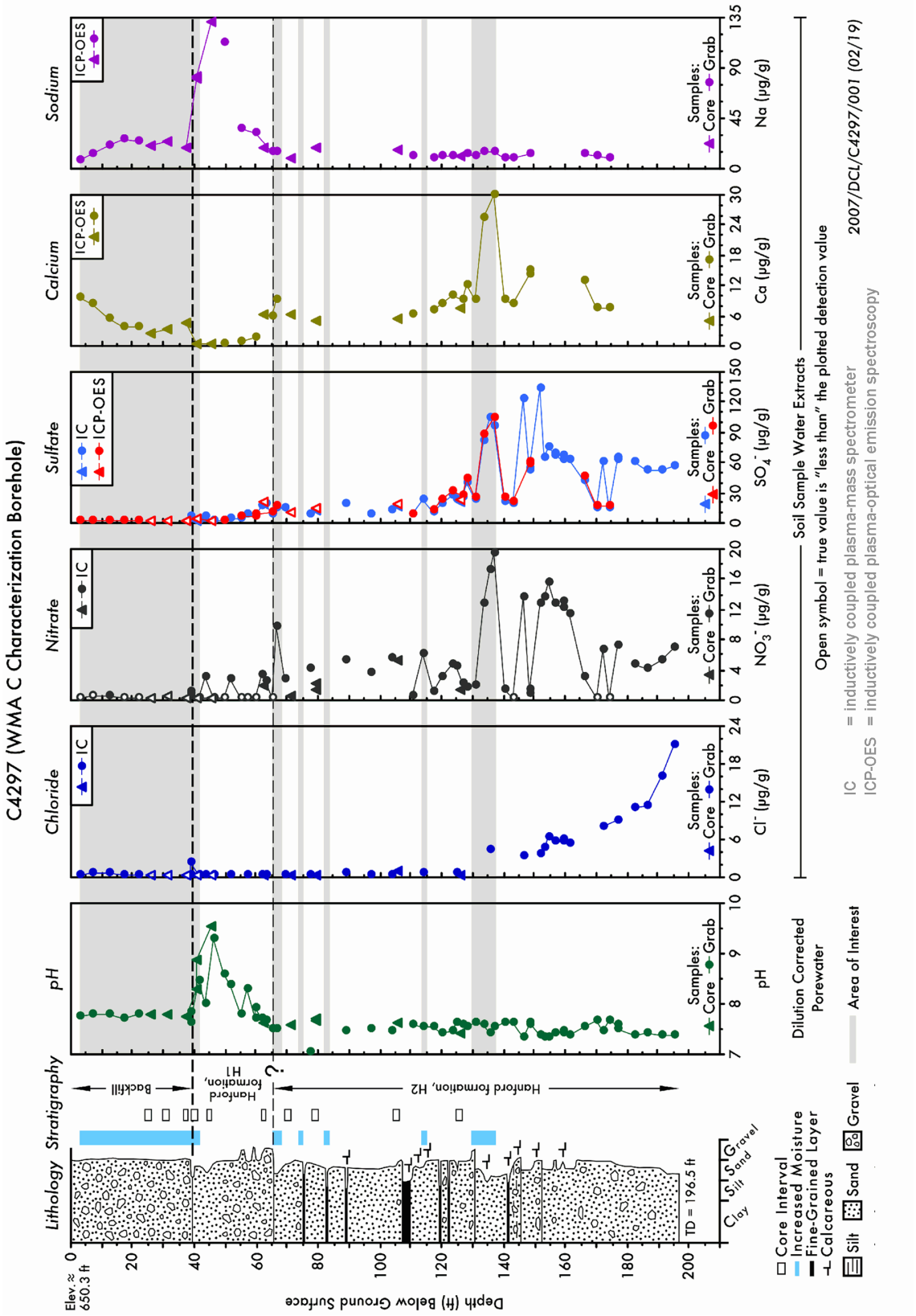
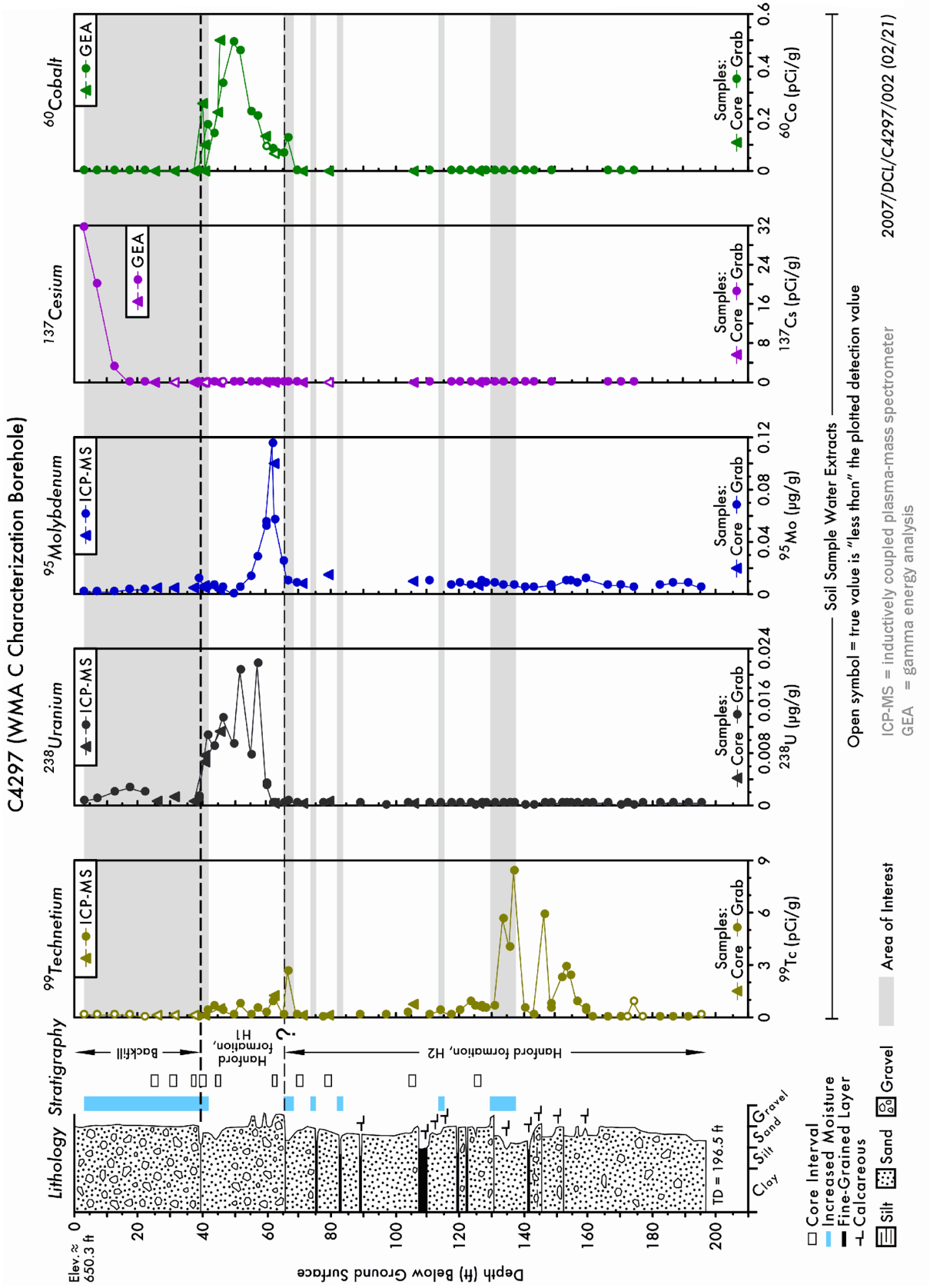


Figure 3-2. Distribution of Trace Mobile Constituents in Borehole C4297 Sediments



Water extracts from recovered vadose zone sediment samples are routinely high in nitrate and sodium with respect to water extracts from ambient sediments collected at a site not contacted by tank waste (water extract data from the H2 Hanford formation sediments collected at borehole 299-E33-338 south of the B Farm are used for comparison). In numerous instances, pH values are also more alkaline. These observations indicate that essentially the entire area investigated by these direct push probes has been contacted by alkaline and enriched nitrate and sodium fluids.

Water extracts of sediments from vertical probehole data show two distinct near-surface areas (10 to 20 ft bgs) contaminated by ^{99}Tc (up to 3.3 pCi/g dry sediment) and Hanford-processed uranium (up to 0.77 µg/g dry sediment). These areas are just to the southwest and northeast of the UPR-200-E-82 site leak location and may indicate the lateral extent of the leak. Water extract data show varying degrees of alkalinity and enrichment in sodium and nitrate.

Slant probehole data closest to the UPR-200-E-82 site leak location and sampled at the greatest depth (approximately 80 ft bgs) show maximum and coincident water extractable ^{99}Tc (10 to 30 pCi/g dry sediment) and nitrate (10 to 20 µg/g dry sediment).

From the information presented in RPP-35484, it is concluded that the UPR-200-E-82 site tank waste fluids have migrated to at least 80 ft bgs since the leak event in 1969. Conversely, estimates of the lateral extent of the leaked fluid are less certain. The more contaminated zones to the southwest and northeast of the breached pipeline location are consistent with lateral spreading of that leak but may also be an indication of separate leak events. Both of these locations are close to diversion boxes and associated extensive pipeline infrastructure typical of diversion boxes. Given the ubiquitous sodium and nitrate enrichment in water extracts from sediments throughout the sampled area, multiple losses of waste fluids are plausible.

At the tank C-108/C109 anomaly, neither of the drywells within the anomaly footprint contain significant levels of gamma-emitting contamination. The closest indication of a source term is at drywell 30-08-02, where ^{137}Cs and ^{154}Eu peak at ~20 ft bgs, suggesting another transfer line leak. Examination of more recent geophysical logging shows at least four episodes of contamination in this drywell: one prior to 1976, between 1989 and 1997, between 1997 and 2002, and between 2002 and 2006. In each episode, ^{60}Co appears to have started at ~40 ft bgs and moved downward to ~80 ft bgs. Whether this leak is related to the apparent anomaly just to the west is unclear. Soil chemistry data from borehole C4297 can be used to estimate major aqueous species.

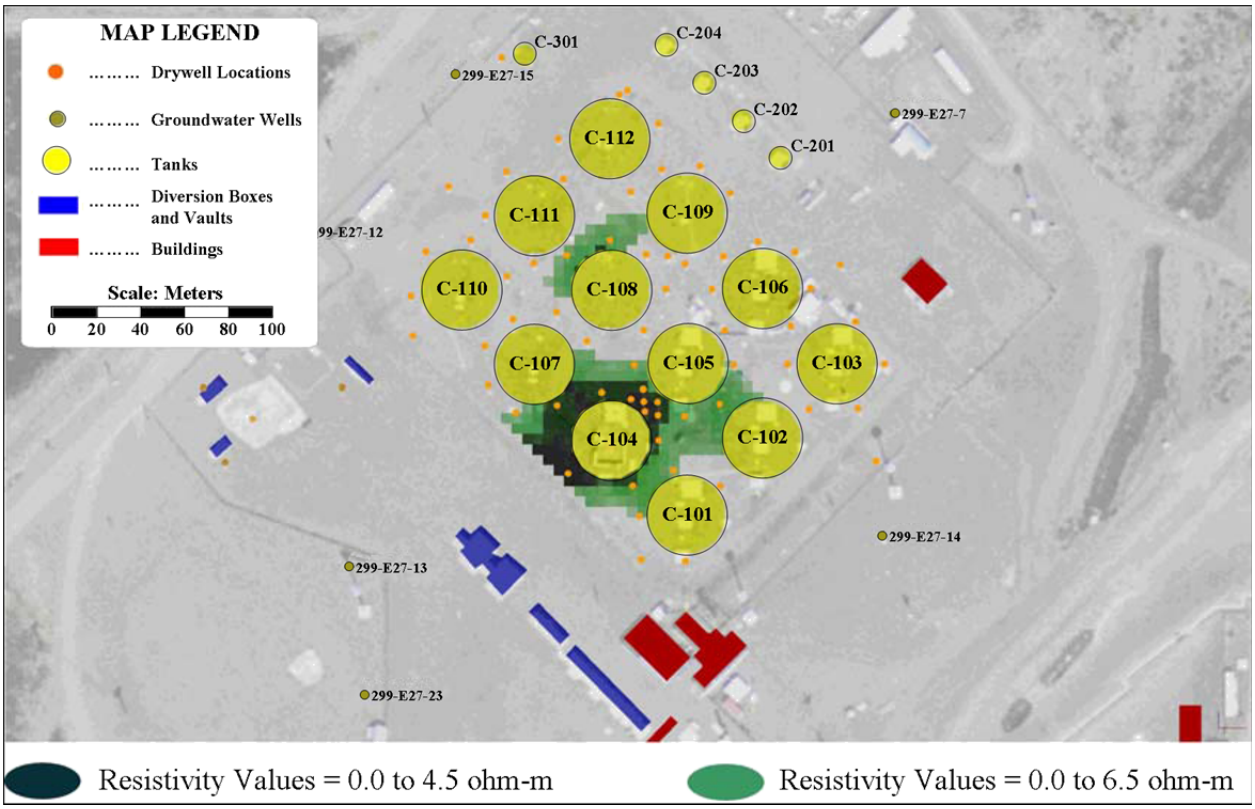
3.2.1.2 Preliminary Surface Geophysical Exploration Results. In August 2005, a reconnaissance-level geophysical survey of C Farm was made using electrical resistivity techniques (RPP-RPT-31558). The usefulness of this technique was predicated on the concept that the intrinsic ability of vadose zone soils to conduct electric current can be changed with the addition of high salt waste fluids. If so, measurable contrasts in conductivity (or the inverse property resistivity) between contaminated versus uncontaminated soils can occur. In particular, increases in nitrate and sodium content in contaminated soil are hypothesized to facilitate soil conductivity properties, thereby lowering measured resistivity values. By passing electric current through large volumes of soil using numerous transmission pathways, a qualitative,

three-dimensional picture of waste distribution may be derived. The additional advantage of this method is that large volumes of soil can be tested fairly easily in this manner.

The preliminary geophysical investigation was performed by collecting resistivity data using 69 drywells within the tank farm and with a set of eight monitoring boreholes (e.g., groundwater wells), one buried electrode installed in the west end of the tank farm, and four surface electrode arrays outside of the farm. The four surface electrode arrays were run parallel to the tank farm fenceline. Only the well-to-well electrode readings provided resistivity data having the capability to identify and delineate contaminant plume features within and around tank farms.

Areas of low resistivity are shown in Figure 3-3 for the C Farm. Areas with low resistivity are most likely associated with increased soil and/or inorganic salt concentration provided by waste solutions contacting vadose zone soil. Specific areas of low-resistivity values within the C Farm are a region near tanks C-101, C-102, C-104, C-105, and C-107, along with a smaller low-resistivity zone near tank C-108.

Figure 3-3. Well-to-Well Surface Geophysical Exploration Results for Drywells Only

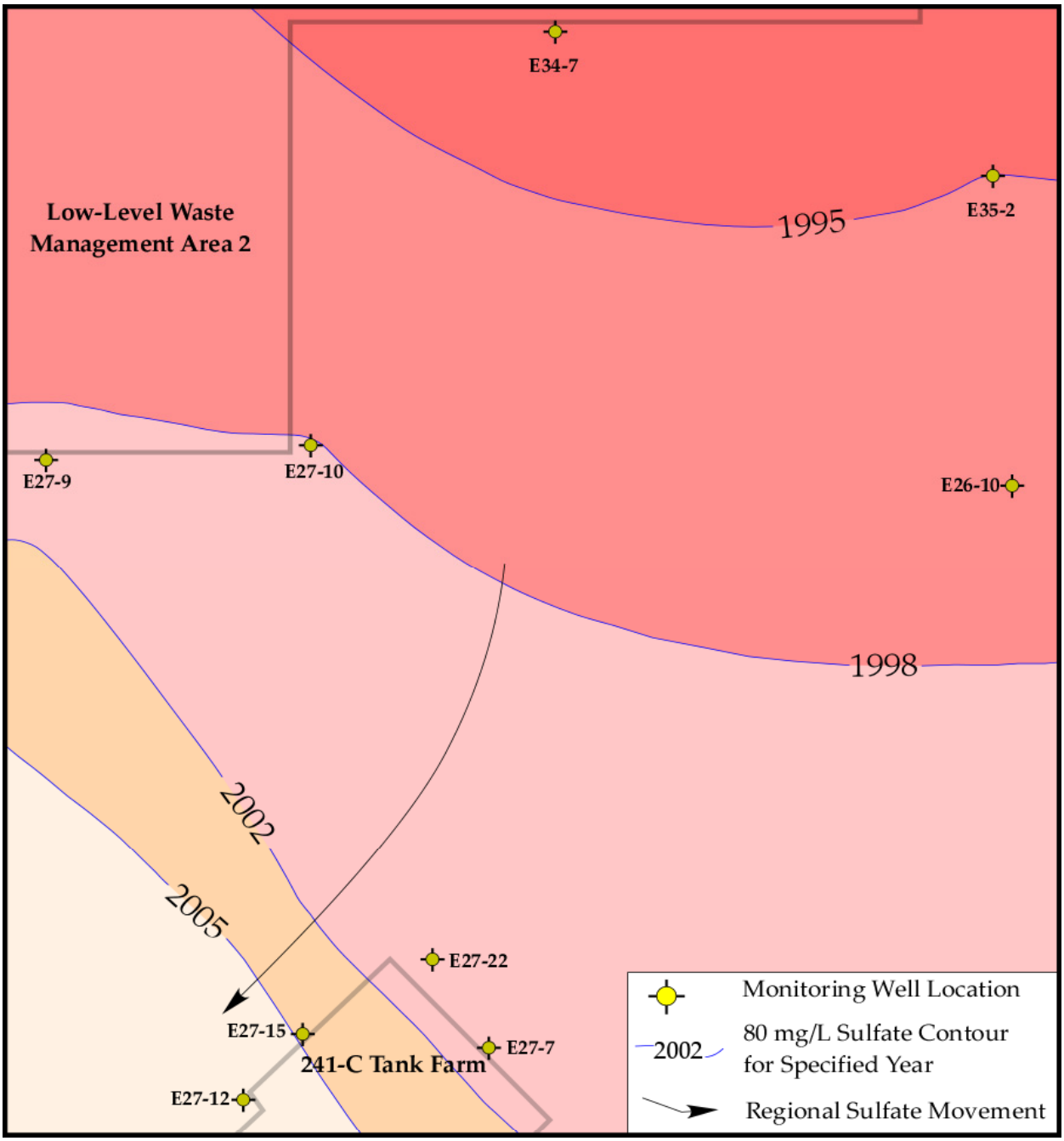


3.2.2 Groundwater

The primary contaminants observed at this site are sulfate, ^{99}Tc, and nitrate. Also, there are elevated chloride concentrations and low levels of cyanide at some wells. Sulfate concentrations are influenced by high levels of regional sulfate contamination migrating into the area from the northeast as the aquifer recedes towards a pre-Hanford water table (Figure 3-4). A time series of

the 80 mg/L contour illustrates the movement of sulfate into and across WMA C to the southwest. The source of the sulfate associated with the draining aquifer is being investigated under the BP5 RI/FS under CERCLA. This mapping also confirms the southwest flow direction across the site.

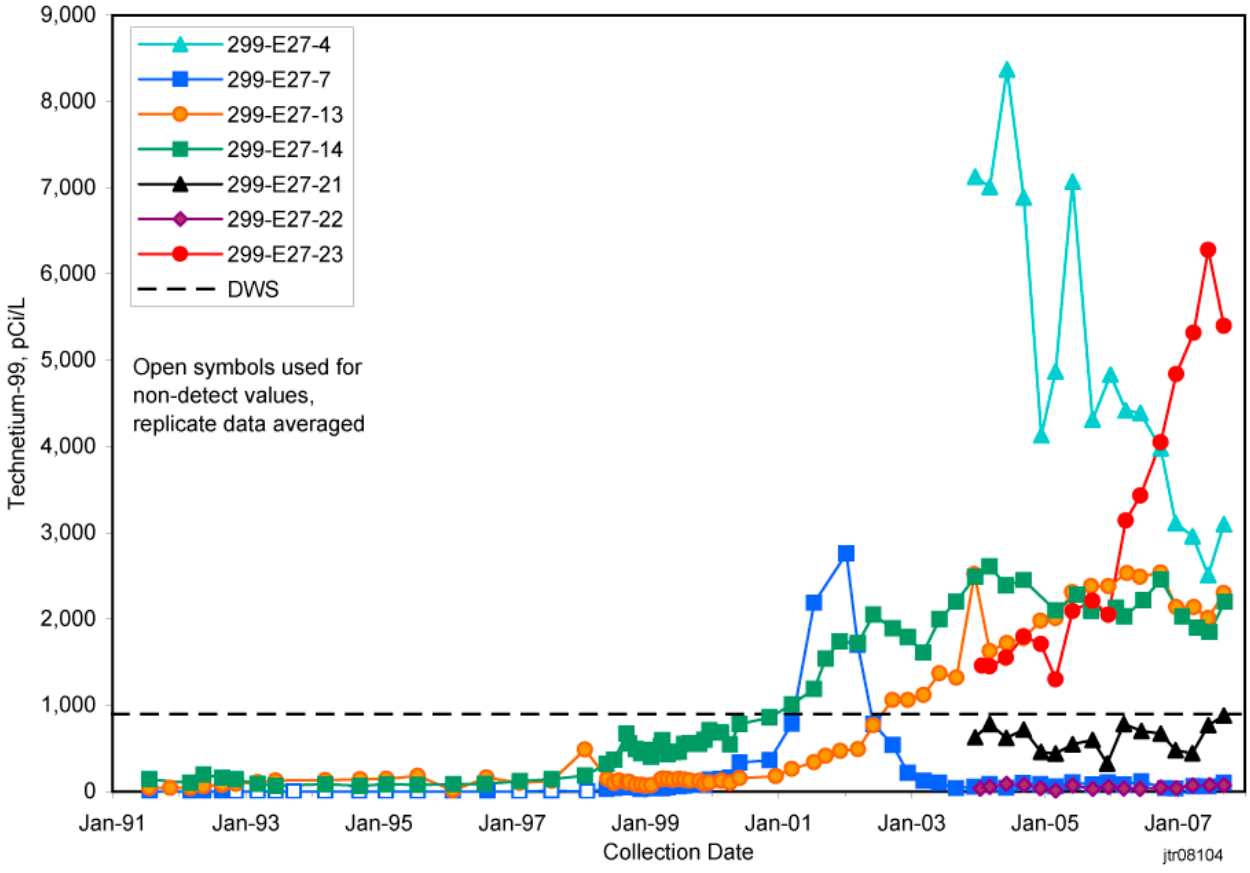
Figure 3-4. Time Series Contours Illustrating the Regional Control of Sulfate from High Values Associated with the Receding Aquifer Along the Basalt Subcrop



Note: Movement of sulfate contours over time confirms southwest flow at WMA C.

At WMA C, nitrate, ^{99}Tc, and sulfate have been the most significant contaminants found in underlying groundwater. In addition, low levels of cyanide have been observed in the groundwater in some wells. Nitrate concentrations have generally increased in all monitoring wells. Maximum ^{99}Tc concentrations (~8,400 pCi/L) occurred in June 2004 in monitoring well 299-E27-4 near the southwest corner of WMA C. Technetium-99 concentration levels have declined since then to 2,510 pCi/L in 2007. In several monitoring wells to the east and southeast of groundwater monitoring well 299-E27-4 (299-E27-13, 299-E-27-14, and 299-E27-23), ^{99}Tc concentrations have generally increased since the late 1990s, and all of these monitoring wells currently have concentrations near or in excess of 2,000 pCi/L (Figure 3-5). This suggests a tank waste source near monitoring well 299-E27-4 and the ongoing development of a plume toward the east beneath WMA C. Transfer line losses of PUREX waste (UPR-200-E-82 in 1969 and UPR-200-E-86 in 1971) occurred very near to monitoring well 299-E27-4 (southwest of well E27-12 shown in Figure 3-4 and Figure 2-5) and because of their proximity, either are plausible sources of the contamination seen in that well. If one or both of these releases are sources of current groundwater contamination, additional high volume discharges seem necessary to have caused the current contamination. That is, the estimated volumes lost during the leak events (2,600 and about 17,400 gal from UPR-200-E-82 and UPR-200-E-86, respectively). DOE/RL-2008-01 suggests that the trends of nitrate to ^{99}Tc concentration ratios for each well (299-E27-13, 299-E27-4, and 299-E27-23) may be three different sources for groundwater contamination on the southwest side of WMA C.

Figure 3-5. Recent Technetium-99 Concentrations in Samples from Groundwater Monitoring Wells in Waste Management Area C



The other occurrence of high ^{99}Tc at WMA C occurred in upgradient monitoring well 299-E27-7 in January 2002, when a relatively sharp peak value of 2,760 pCi/L was measured. This high ^{99}Tc spike dropped rapidly within several months. At this time period, regional sulfate contamination began migrating into the area from the northwest. It is not known if these observations are related. However, DOE/RL-2008-01 suggests ^{99}Tc contamination observed in FY 2002 at groundwater monitoring well 299-E27-7 is currently affecting the groundwater quality in well 299-E27-23 based on overlapping trends of nitrate to ^{99}Tc concentration ratios for each well.

The last contaminant of interest is cyanide. Cyanide-contaminated waste was a byproduct of the uranium recovery process completed in the early 1950s to separate uranium from metal waste generated by the bismuth phosphate process. This process was TBP-based and was known as TBP waste. Because the TBP waste volume exceeded tank storage capacity, intentional discharges to the subsurface were needed. The main impediment to subsurface discharge was extremely high concentrations of fission products, particularly ^{137}Cs, in TBP waste. To scavenge ^{137}Cs from TBP waste, a ferrocyanide-based separation process was used. Numerous facilities at C Farm were used for this process. These included tanks that stored TBP and scavenged TBP waste, the 244-CR vault where scavenging took place, and various diversion boxes and pipes through which waste was transferred. Thus, tank farm operations occurred that could have lost cyanide-contaminated waste to the subsurface. Although WMA C facilities were used in the ^{137}Cs separations processes, the intentional discharges to the subsurface ^{137}Cs did not take place at or nearby to WMA C.

The largest and most consistent cyanide concentrations in monitoring wells around WMA C occur at upgradient monitoring well 299-E27-7 on the northeast side of WMA C. Unequivocal cyanide concentrations were first measured in October 1999 and reached a maximum value of about 45 µg/L in September 2004. The latest measurement in June 2007 was 3.8 µg/L (Figure 3-6). Cyanide has also been measured sporadically at all other WMA C monitoring wells to the north, west, and south of monitoring well 299-E27-7. In these locations cyanide concentrations have ranged from non-detected to 18 µg/L.

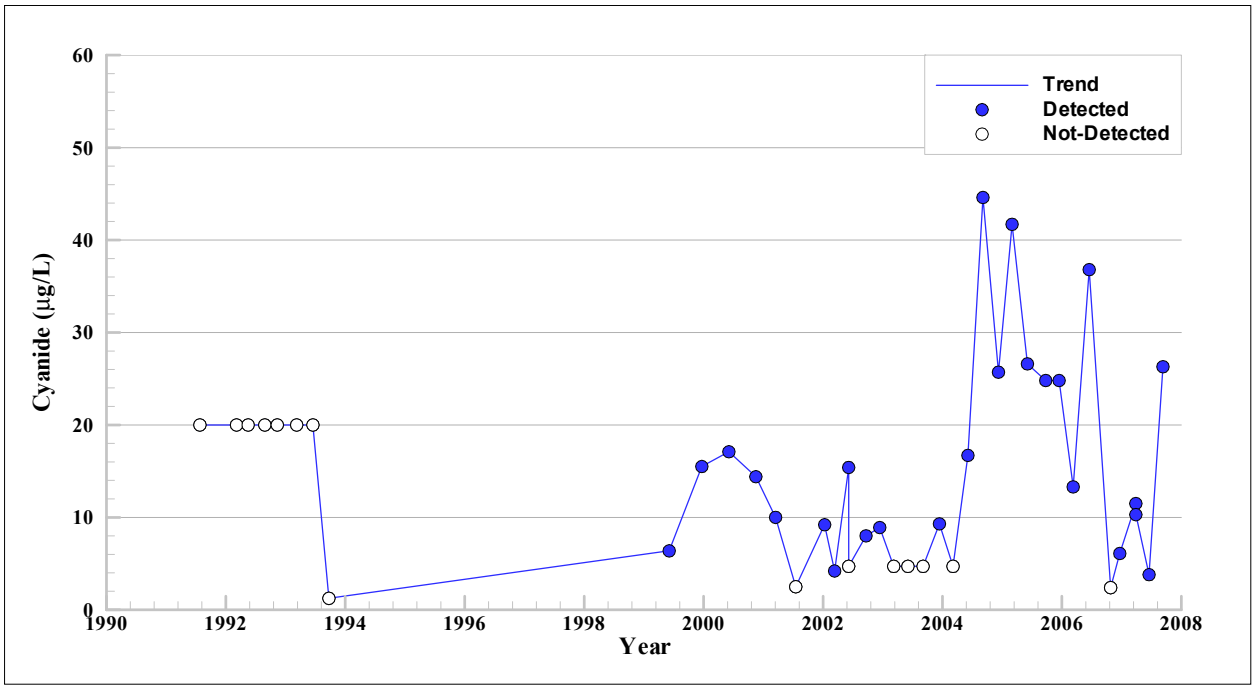
Currently, no particular leak event from this operation period is known that could have been the precursor to the current groundwater contamination. One point of entry into the unconfined aquifer appears to be near the 299-E27-7 location. Therefore, groundwater has been impacted by some waste releases in WMA C (RPP-35484 and DOE/RL-2008-01). However, evaluations of groundwater contamination and remediation are not in the scope of this Phase 2 work plan. Investigating groundwater contamination under WMA C is part of the 200-BP-5 groundwater operable unit RI/FS conducted by DOE-RL (DOE/RL-2007-18, *Remedial Investigation/ Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*).

3.2.3 Three-Dimensional Physical Representation of Waste Management Area C

For this work plan, a three-dimensional computer representation of WMA C using the data collected to date was prepared. Figure 3-7 is one view from a three-dimensional representation of WMA C. The complete three-dimensional model was imported into an Adobe® Portable

Document Format[8] (PDF) that allows any user with Adobe Reader to use Adobe's three-dimensional tool to manipulate the model (e.g., rotate, zoom, pan, add layers, etc.).

Figure 3-6. Cyanide Concentrations at Groundwater Monitoring Well 299-E27-7



The model includes the following:

a. WMA C fenceline, nearby roads, and the DQO boundary.

b. Topographic information: major contour lines (every 2.5 m) are shown in blue, and minor contour lines in light green.

c. Major geologic units; click on the colors in the stratigraphic legend to add and remove layers; contour lines are also provided for the top of each stratigraphic unit.

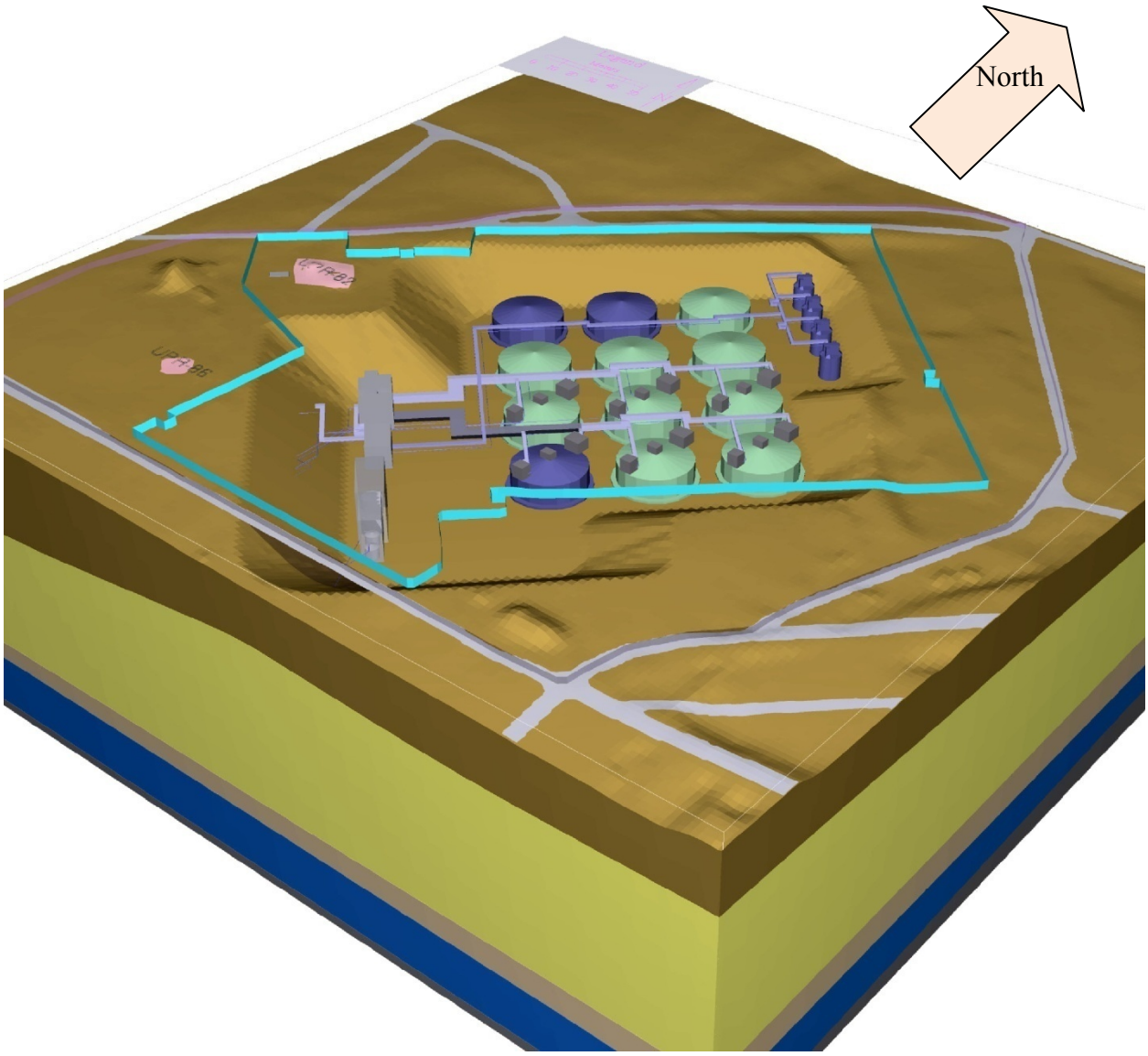
d. Infrastructure: SSTs (100-series, 200-series), CR vaults, most but not all diversion boxes, and major pipelines.

e. Contaminant concentrations for ^{137}Cs, ^{60}Co, nitrate, and ^{99}Tc. Cesium-137 and ^{60}Co measurements were collected as part of the spectral gamma logging efforts of the late 1990s (GJ-HAN-92, GJO-98-39-TAR/GJO-HAN-18, GJO-98-39-TARA/GJO-HAN-18), while the nitrate and ^{99}Tc were measured from samples taken as part of the Phase 1 characterization activities.

f. A set of predetermined views.

[8] Adobe® Portable Document Format is a registered trademark of Adobe Systems Incorporated, San Jose, California.

Figure 3-7. Three-Dimensional Computer Representation of Waste Management Area C



The model along with instructions for manipulating the model is included in Appendix C.

3.3 CONCEPTUAL MODELS

The National Research Council in *Conceptual Models of Flow and Transport in the Fractured Vadose Zone* (National Research Council 2001) defines a conceptual model as "… an evolving hypothesis identifying the important features, processes, and events controlling fluid flow and contaminant transport of consequence at a specific field site in the context of a recognized problem." Furthermore, Dr. Eileen Poerter (Colorado School of Mines), while giving the 2006 Darcy Lecture for the National Groundwater Association, recommended using "multiple working hypotheses" (alternative conceptual models) when studying complex geohydrologic systems. This section provides an overview of the alternative conceptual models supporting the

DQO process for the Phase 2 characterization data needed for the WMA C CMS. As more data are collected during the Phase 2 characterization activities, these conceptual models will be updated and revised as necessary.

With regard to the unintentional discharge of waste from SST farm infrastructure into the subsurface at various WMAs on the Central Plateau, the nature and extent of contaminant release and subsequent migration have been conceptualized in terms of the source term properties (e.g., contaminant inventory and release mechanisms), the driving forces that move contaminants (e.g., recharge rates) and the properties of the medium through which contaminants move (e.g., subsurface stratigraphy). The following discussion emphasizes the variability of key factors over time (e.g., the local water flux controlling contaminant migration can vary by orders of magnitude when considering the leak event, operational recharge events, and long-term recharge through an engineered cover). Similarly, some critical factors may differ depending on the location (e.g., variability in operational fluid discharges at one WMA versus another that contact and move contaminants in the subsurface).

3.3.1 Alternative 1: Phase 1 Conceptual Model

This model is documented in Chapter 16 and Appendix A of DOE/ORP-2008-01 and was derived from process records, gross gamma logging information collected from the 1960s through the 1990s,[9] spectral gamma data collected in the late 1990s to early 2000s,[10] and the data collected during the Phase 1 characterization efforts conducted from 2000 to 2007.[11] One of the primary goals of the Phase 1 characterization effort was to understand the relationship of the inventory of contaminants (that adversely impact groundwater) observed in the vadose zone to the concentrations of those contaminants in the groundwater. To accomplish this, the Phase 1 characterization effort collected soil samples at major leaks within a WMA with known high ^{137}Cs concentrations (10,000,000 pCi/g) in the nearby soils to find depth of the mobile contaminants (e.g., ^{99}Tc, nitrate) based on the relationship between ^{137}Cs and ^{99}Tc in the fission process (i.e., if high ^{137}Cs is present, then ^{99}Tc should also be present, but deeper because ^{99}Tc does not adsorb onto the soil).

The complete Phase 1 conceptual model is described in DOE/ORP-2008-01, Appendix A. Rather than evaluating individual leaks sequentially, the summary discussion in Appendix A is oriented toward comparisons of similar information related to several leak events where possible, particularly the larger leaks that are more completely characterized. The purpose of these comparisons is to emphasize and describe those key characteristics and processes that are common to all leak events and therefore are indicative of systematic behavior. At the same time,

[9] See reports on analysis of historical gross gamma data (HNF-3136, HNF-3531, HNF-3532, HNF-3831, HNF-4220, HNF-5433, RPP-6088, RPP-6353, RPP-7729, RPP-8321, RPP-8820, RPP-8821).

[10] See DOE's Grand Junction Office reports and Associated Addendum: Vadose Zone Characterization Project at the Hanford Tank Farms: DOE/ID/12584-268, DOE/ID/12584-268A, GJO-96-2-TAR, GJO-96-2-TARA, GJO-97-13-TAR, GJO-97-13-TARA, GJO-97-14-TAR, GJO-97-14-TARA, GJO-97-1-TAR, GJO-97-1-TARA, GJO-97-30-TAR, GJO-97-30-TARA, GJO-97-31-TAR, GJO-97-31-TARA, GJO-98-39-TAR, GJO-98-39-TARA, GJO-98-40-TAR, GJO-98-40-TARA, GJO-98-64-TAR, GJO-98-64-TARA, GJO-99-101-TAR, GJO-99-101-TARA, GJO-99-113-TAR, GJO-99-113-TARA.

[11] See Field Investigation Reports (RPP-7884, RPP-10098, RPP-23752, DOE/ORP-2008-01 Appendixes L and M, RPP-35484 and RPP-35485).

it is important to keep in mind that each tank waste release site is unique in some way and that site-specific factors not emphasized in this general discussion may provide significant impacts to contaminant behavior in the subsurface. These factors, which must be determined from site-specific evaluation, may result in more refined or alternative conceptual models that are most appropriate for a given site.

At a summary level, the following key characteristics and processes in Sections 3.3.1.1 through 3.3.1.4 are concluded to be the primary components of the conceptual model and common to all major tank leak events.

3.3.1.1 Initial Leak Period.

a. Unintentional discharges of tank waste were events that occurred because waste transfer pipelines and storage tanks were compromised and allowed waste releases to the subsurface. The primary degrading waste storage conditions of tanks were overheating and overfilling.

b. Following release into the vadose zone, waste fluids increased ambient moisture content and perturbed the local geochemical conditions at the point of entry and beyond. Natural physical and chemical processes sometime after the leak event began to eliminate these perturbations.

c. Waste fluids were distributed rapidly over limited areas of the vadose zone until ambient moisture contents were essentially restored. Key characteristics and processes were unsaturated flow and lateral migration that resulted from hydrogeologic controls. Consequently, waste contacted an expanded vadose zone volume compared to the initial volume of the released waste.

d. Chemical reactions between tank waste fluid and the vadose zone soil-water system occurred as waste fluids were distributed in the vadose zone. Key characteristics and processes were moderation of the high local elevated pH conditions typical of tank waste fluids and sorption/precipitation/desorption of reactive contaminants onto soil surfaces. In some cases, tank waste chemistry altered the reactivity of specific contaminants relative to their behavior under ambient conditions [notably, for waste with high sodium content (tank 241-SX-108), ^{137}Cs mobility was temporarily enhanced]. By the time ambient moisture content was essentially reestablished, contaminants were variably distributed in the vadose zone volume contacted by tank waste, depending on their reactivity. Maximum distribution occurred for nonreactive constituents (e.g., ^{106}Ru, ^{99}Tc, and nitrate).

3.3.1.2 Current Conditions.

a. Following the initial waste fluid release and distribution into the vadose zone, lateral and vertical waste migration continued, but controlling physical and chemical processes changed in some respects. Migration was driven by local recharge conditions that were dictated by the permeability of the gravel/sand fill that covers the SST system in the tank

farm. Chemical reactions continued that were primarily controlled by the ambient environment.

b. To date, observable migration has occurred only for nonreactive to slightly reactive contaminants (mostly nitrate and ^{99}Tc and to a lesser extent ^{60}Co, chromium, and uranium, where present). The exception to this observation is at the tank 241-SX-108 leak where enhanced ^{137}Cs mobility occurred due to the presence of high sodium concentrations in the tank waste (RPP-10098, *Field Investigation Report for Waste Management Area B-BX-BY*). Under these conditions, sodium sorbs preferential on soil phase sorption sites.

c. Under natural recharge conditions through a gravel cover, vertical migration rates of 1 to 3 ft/year in the Hanford formation of the vadose zone for ^{60}Co have been observed at a few drywells in WMAs C and B-BX-BY, most notably at drywells 22-03-09, 22-06-05 (HNF-3532, *Analysis of Historical Gross Gamma Logging Data from BY Tank Farm*) and 30-08-02 (RPP-8321).

d. A total of 11 characterization boreholes were installed during the Phase 1 characterization activities. Technetium-99 was found approximately between 85 ft bgs and 150 bgs for the 200 West WMAs and 130 to 170 ft bgs for the 200 East WMAs (DOE/ORP-2008-01). Drilling depths ranged from 115 ft bgs in 241-TX Tank Farm to 264 ft bgs in B Farm and were sufficient to reach and in some cases pass through a maximum concentration zone where ^{99}Tc concentrations at the deepest location were one or more orders of magnitude below the highest recorded values in the borehole. Based on these analyses, the bulk of the inventory for ^{99}Tc is inferred to still reside in the vadose zone, ~70 to 150 ft above the unconfined aquifer. However, mobile tank waste contaminants (e.g., ^{99}Tc, NO_3) have impacted groundwater as indicated by groundwater monitoring well analysis.

e. The lower CCU is present in the 200 West Area but not in the 200 East Area.

3.3.1.3 Future Conditions.

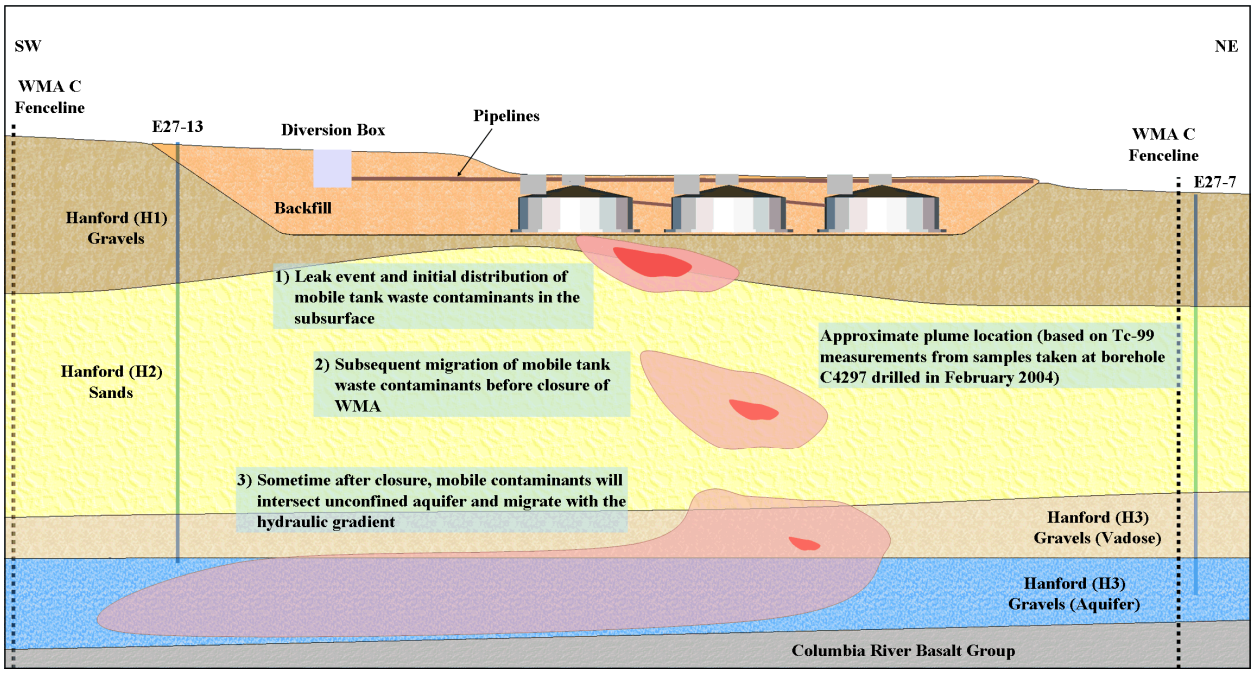
a. Future migration rates are expected to diminish if an engineered barrier is installed. If installed, an engineered barrier is expected to reduce recharge rates from ~100 mm/y to much less than 1.0 mm/yr for some time (PNNL-14744). This rate may experience an eventual small increase with barrier degradation. Ambient chemical conditions will be maintained and only highly mobile or slightly retarded contaminants (K_d <0.6 mL/g) will reach the unconfined aquifer in a period of several thousand years. For those mobile contaminants currently in the shallow vadose zone, significant increases in travel time and reductions in peak groundwater concentrations relative to current conditions are projected.

b. For those contaminants deeper in the vadose zone, the engineered barrier is less effective, and if no remedial actions take place, the inventory of nonreactive contaminants in the vadose zone will continue to migrate to the unconfined aquifer causing the ground concentrations to rise and to peak over the maximum contaminant level (MCL) sometime

in the future (RPP-7884, *Field Investigation Report for Waste Management Area S-SX*; RPP-10098; RPP-23752, *Field Investigation Report for Waste Management Areas T and TX-TY*; DOE/ORP-2005-01).

These general periods are shown as different plume locations in Figure 3-8. The depicted plumes can be considered as the distribution of highly mobile contaminants that always migrate with the waste fluid. The data and analytical results collected during Phase 1 characterization indicate the bulk of the contaminant inventory remains in the vadose zone.

Figure 3-8. Alternative 1: Phase 1 Conceptual Model



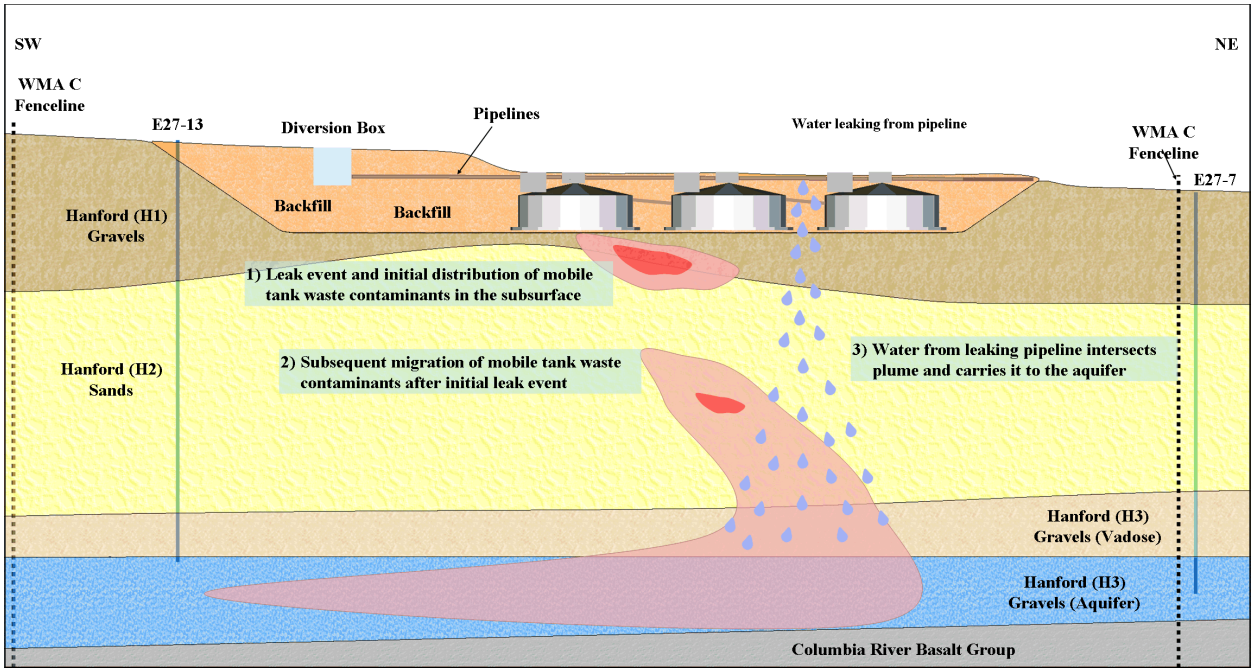
3.3.1.4 Importance of Water as a Driving Force. Despite the measurement of the highest levels of nonreactive to slightly reactive contaminants (^{99}Tc, chromium, nitrate, and cyanide) in the vadose zone ~70 to 120 ft above the water table, groundwater monitoring data from wells near WMA fencelines indicate that some tank waste has reached the aquifer in discrete locations, notably on the southern side of the SX Farm, the east side of 241-S Tank Farm, the northeastern corner of the T Farm, and east of BX Farm and south of C Farm. These sites are noted for high ^{99}Tc concentrations (above the MCL of 900 pCi/L) in nearby groundwater monitoring wells and high uranium concentrations (above the MCL of 30 µg/L) at BX Farm as well. If these contaminants were initially present in leaked tank waste, the conceptual model described above must be expanded to include these observations.

Examination of site-specific conditions at the WMAs suggests a mechanism that explains these observations. This mechanism is enhanced recharge of raw water or waste water by one or more of the following: (1) localized unintentional releases from leaking pipelines, (2) flooding of the

tank farm due to rapid snow melting, and/or (3) intentional releases from nearby cribs, trenches, and ditches. The following are specific examples of known enhanced recharge within the WMAs:

a. At the southeast corner of SX Farm, a several-year period of steady water loss from an operating raw water pipeline (pipes are not routinely monitored at all and normal construction specifications allow minimal leakage rates) in the early 1990s was indicated by sustained growth of a tree at that location. Also, during field characterization, the moisture content in sediments retrieved from a nearby borehole was anomalously high, suggesting recent additions of water to the vadose zone locally (RPP-7884). Enhanced recharge (RPP-7884, Appendix E and Attachment E3; DOE/ORP-2005-01) through a vadose zone area previously contaminated by tank waste would accelerate the migration rate of mobile contaminants in the vadose zone and in several instances has apparently driven these contaminants completely through the vadose zone and into the nearby unconfined aquifer (see Figure 3-9).

Figure 3-9. Expanded Phase 1 Conceptual Model Accounting for Artificial Recharge due to Pipeline Leak



b. Water losses of several gallons per minute for several years above a vadose zone contaminated by tank waste could result in effective recharge rates well above average recharge rates from precipitation of about 100 mm (4 in.) per year. For example, if a pipe joint leak occurs at the rate of 0.5 gpm, the yearly volume output is 262,800 gal. If this fluid volume migrates through a flux plane of 100 m^2, the equivalent annual volume discharge from ambient recharge of 100 mm/yr would be 2,642 gal. Thus, the leak recharge rate is effectively 100 times the ambient recharge rate. This differential can quickly increase with higher leak rates and/or distribution over smaller flux planes.

c. At T Farm, there was a large snow melt event in February 1979, which created temporary ponding over the farm followed by rapid infiltration into the subsurface. At that time, the drywells were not grouted to 90 ft and could have provided preferential pathways for vertical migration to that depth (RPP-23752). Flooding events probably occurred at other tank farms in the past during site operations. In 2001 and 2002, interim measures were conducted to mitigate flooding on tank farms.

d. Large intentional discharges of raw water or waste water occurred in cribs, trenches, and ditches close to WMAs B-BX-BY and U. Waste Management Area B-BX-BY is bounded on the west and north by cribs that have received ~30,000,000 gal of liquid effluent. At this location, a perched water table is observed ~220 to 240 ft bgs. If tank waste as it travels through the vadose zone encounters a perched water table, the perched water table will impact when and where contaminants from the vadose zone will enter the unconfined aquifer. At WMA U, the 216-U-14 trench is located to the east, while 216-Z-20 trench is located to the west. Approximately 346,000,000 gal of water were discharged to these trenches during their operational lifetime. Perching occurred on top of the CCU and elevated moisture content was observed in the vadose zone at WMA U (DOE/ORP-2008-01, Appendix M; RPP-35485, *Field Investigation Report for Waste Management Area U*). Intentional discharges to cribs, ditches, and trenches ceased in the mid-1990s.

It is inferred from these observations that when enhanced recharge encounters preexisting tank waste in the vadose zone, this preexisting tank waste can be transported to the unconfined aquifer. Because of the detrimental impact of enhanced recharge in the tank farms, a series of interim corrective actions (Section 3.5) have been implemented to prevent enhanced recharge.

3.3.2 Alternative 2: Movement of Contaminants Down Stratigraphic Dip Conceptual Model

Dr. Stan Sobczyk has provided an updated depiction of the 2007 conceptual model (see Figure 3-10). Dr. Sobczyk bases this conceptual model on the following.

a. Tank and/or pipelines leak.

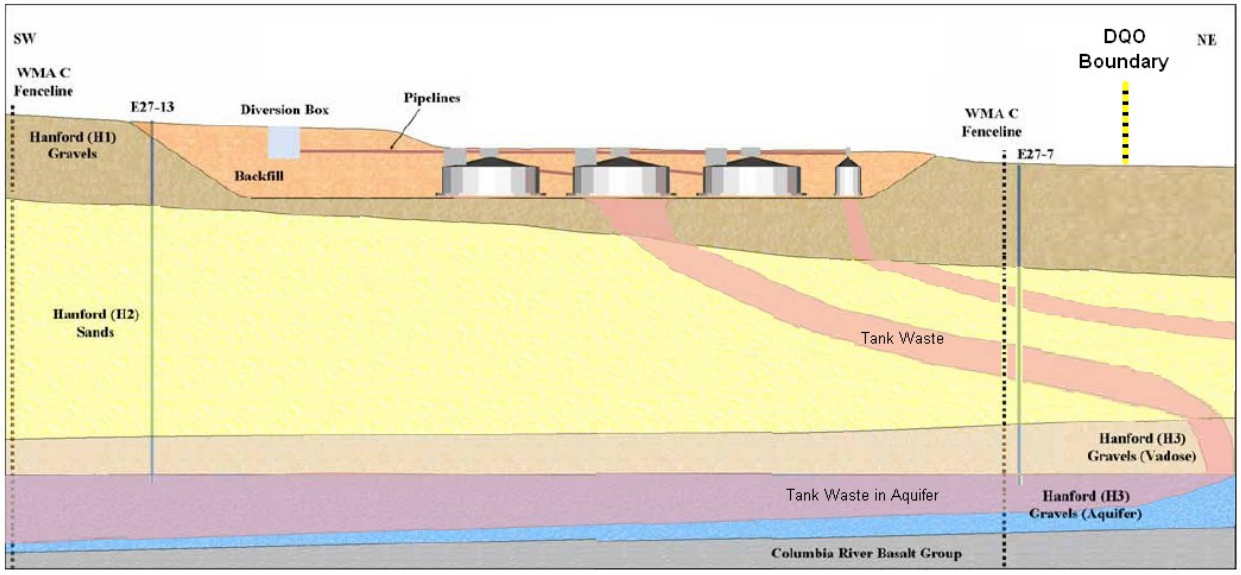
b. Tank waste migrates primarily vertically through backfill and H1 gravels.

c. Tank waste and moisture migrates primarily laterally through the H2 sands following stratigraphic dip.

d. Tank waste migrates primarily vertically through the coarser material in the lower H2 and H3 gravels until it reaches groundwater.

e. Tank waste is denser than groundwater and sinks in the aquifer as it is transported to the southwest under the tank farm.

Figure 3-10. Alternative 2: Movement of Contaminants down Stratigraphic Dip Conceptual Model



Dr. Sobczyk has suggested a similar conceptual model for the release from tank 241-BX-102 (BX-102) for the movement of uranium from the tank BX-102 overfill event. The conceptual model provided by Dr. Sobczyk is being used in the DQO process for the Phase 2 characterization efforts at WMA C, which will include sampling to assess this conceptual model as discussed in Section 4.4.2.

3.3.3 Alternative 3: Preferential Pathways Conceptual Model

Preferential pathways have been hypothesized as a method of moving contaminants through the vadose zone. These are typically small-scale features with physical properties that can enhance the movement of contaminants vertically downward through the vadose zone. The ones cited most frequently at Hanford are poorly constructed wells and/or clastic dikes. Of these two features, the poorly constructed well would likely be associated with larger void spaces and therefore allow a greater migration rate.

Poorly constructed wells might allow the contaminant to move vertically downward between the casing and the surrounding media. However, at tank farms, the depth of almost all drywells within the tank farms is 100 ft bgs, while groundwater is 230 to 300 ft bgs. Therefore, it is unlikely that a poorly constructed drywell within a tank farm is providing a preferential pathway all the way to groundwater. On the other hand, in some locations nearby groundwater monitoring wells extend to the aquifer and could have provided a sufficient pathway for aquifer contamination. This may have occurred in WMA B-BX-BY where some ^{99}Tc and uranium from the tank BX-102 leak may have reached the unconfined aquifer.

Clastic dikes are common structures that occur in many geologic units in the Pasco Basin and vicinity (BHI-01103, *Clastic Injection Dikes of the Pasco Basin and Vicinity – Geologic Atlas* Series). Clastic dikes are tabular and tapered intrusive bodies that are composed of continental

clastic sediments. BHI-01103 contains a photograph (Figure 9-44 on page 9-55) of irrigation on top of a clastic dike. In this photograph, water can be seen moving down the clastic dike until it reached the bottom of the dike, at which point, water began spreading laterally and vertically. This photograph illustrates the potential for clastic dikes to become preferential pathways. However, it should be noted that BHI-01103 in describing this clastic dike noted the following:

- *The highest observed hydraulic infiltration within an infilling unit was in a random occurrence dike network located in Lind Coulee east of Warden, Washington (32 km north of the Pasco Basin).*

- *The rate of moisture movement was not measured, but water could be observed moving down the dike at rates estimated at least 10 times the rates observed in other dikes in this study. The clastic dike acted as a conduit to transmit soil moisture downward through a preferential pathway to the base of the dike before spreading out into the host sediments.*

- *The very high moisture velocity in the infilling unit that was observed is due to the unconsolidated, well-sorted nature of the sediments.* ***The characteristics of this infilling unit are unique compared to infilling units observed in the Pasco Basin and vicinity****.*

Clastic dikes have been noted in the vicinity of all tank farms. However, due to the small-scale nature of these features, it is not possible to address this conceptual model in the DQO process for Phase 2 characterization, but movement down a hypothetical clastic dike can be captured in the CMS assessment of groundwater impacts. The likelihood of effectively locating, retrieving, and analyzing clastic dike materials is too small to successfully execute a dedicated characterization effort. Instead, modeling analyses must be relied on to evaluate the significance of this conceptual model as a mechanism for enhancing contaminant migration through the vadose zone. Figure 9-44, page 9-55 of BHI-01103 was used to develop a conceptualization of contaminant movement down a clastic dike (Figure 3-11).

3.3.4 Alternative 4: Unknown Leak Event Conceptual Model

Another possibility that could occur within a tank farm is a waste pipeline leak that did not manifest itself at the surface. The transport of contaminants from a new source, such as an unknown leak event, would follow one of the previous transport models.

Each WMA contains miles of pipeline; it is plausible that one or more of these pipelines leaked without any knowledge of such a leak. These leaks, if they occurred, could lead to large volumes (i.e., >30,000 gal) of waste discharged over a period of years resulting in localized volumes of soil with elevated levels of tank waste contaminants. Figure 3-12 shows this conceptualization.

If it can be demonstrated that SGE can discriminate subsurface anomalies in the tank farm environment, it may be possible to target specific areas that may be representative of this model. A final determination of the application of SGE to help locate unknown leaks will be made following the confirmation testing around UPR-81, UPR-82, and UPR-86.

Figure 3-11. Alternative 3: Preferential Pathways (Clastic Dikes) Conceptual Model

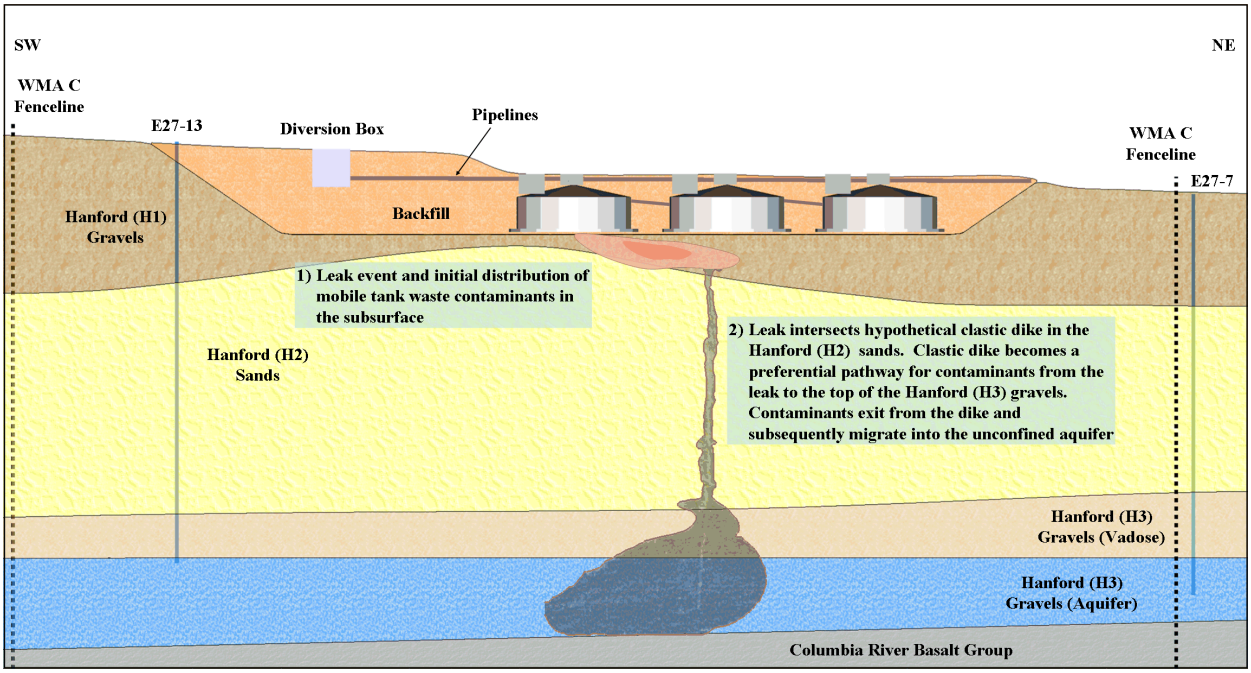
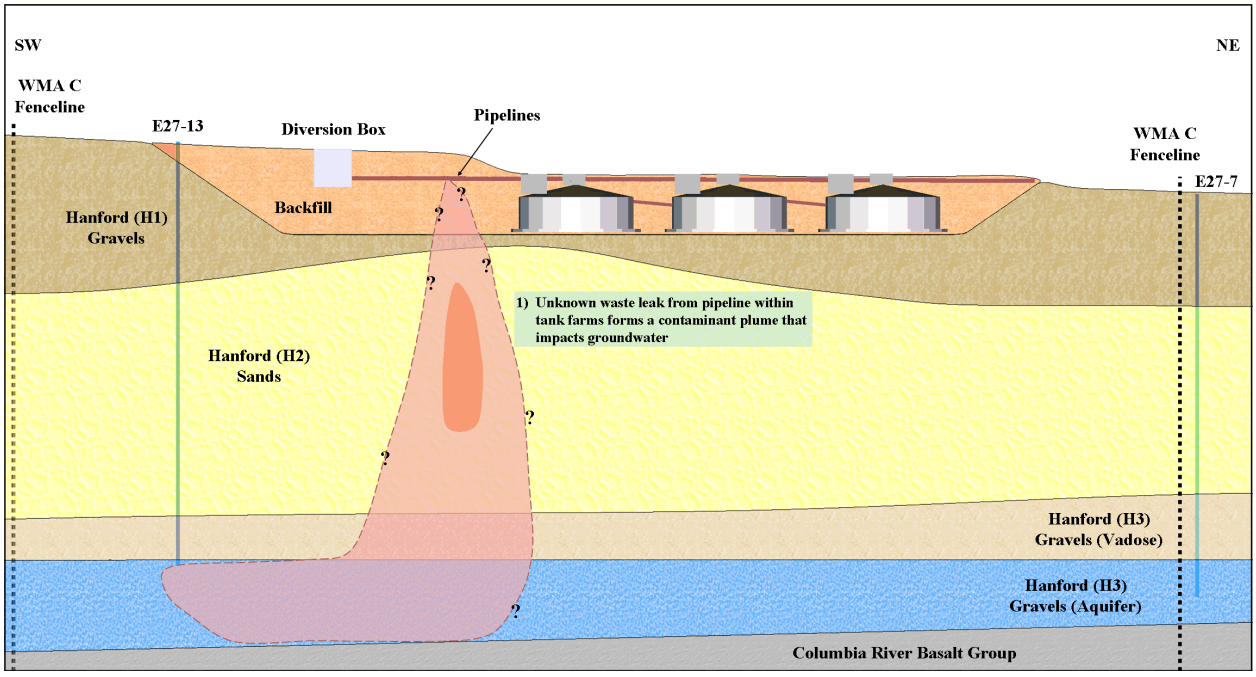


Figure 3-12. Alternative 4: Unknown Leak Event Conceptual Model



3.3.5 Application of Conceptual Models to Waste Management Area C

The generalized conceptual models for tank farm releases and migration through the vadose zone can be further refined for WMA C based on known and suspected releases. These models can be organized into five source term/location configurations:

a. Interior portions of the tank farm including the C-100-series tanks and associated infrastructure.

b. C-200-series tanks and associated infrastructure.

c. Pipelines and diversion boxes in the western portion of the tank farm.

d. Pipelines and drains located outside of the tank farm.

e. Airborne contaminated surface sites outside of the tank farm.

3.3.5.1 Conceptual Model for Interior Portions of 241-C Tank Farm. The conceptual model for UPRs within the interior portion of C Farm includes consideration of the generalized conceptualization for alternative conceptual models 1, 2, and 4 and is based on information from characterization borehole C4297 located between tanks C-104 and C-105. This borehole was drilled to a depth of 196 ft bgs with ^{99}Tc being reported to a depth of 160 ft bgs. At this location, the bulk of the ^{99}Tc inventory has not yet reached groundwater, because ^{99}Tc was not detected below 160 ft. These data do not indicate that the tank C-105 leak caused this contamination as a likely source of high ^{99}Tc concentration levels in the nearby unconfined aquifer. However, since no other sources of the high ^{99}Tc levels outside of WMA C are readily inferred, at least one groundwater contamination source within or adjacent to WMA C must be considered, necessitating further characterization near the tanks. Other events at WMA C are potential sources for contamination of the groundwater. These events (e.g., tank leaks, overfilling tanks, and pipeline leaks) can be either known (tank C-101 overfill) events or unknown events.

The Phase 1 conceptual model and alternative conceptual models 1 and 3 capture the concept that the migration of contaminants may have had a stronger lateral migration and has reached groundwater. In addition, the possibility exists that within the interior of the tank farm of the 100-series tanks there is one or more unknown releases (model 4) that have occurred and migrated to at least 175 ft bgs and possibly to groundwater.

3.3.5.2 Conceptual Model for C-200-Series Tanks. This conceptual model is based on alternative conceptual models 1 and 2. This model is also based on the information associated with UPR-200-E-137 for tank C-203, which indicates that over a period of 2 to 3 years, precipitation apparently entered this tank and then leaked out in 1984. The volume of the leak has been estimated at 400 gal (HNF-EP-0182, *Waste Tank Summary Report for Month Ending December 31, 2011*) containing PUREX waste with the uranium and plutonium still present (RPP-15408). In addition, documents indicate that the C-200-series tanks may have been overfilled leading to a release through the spare inlet ports. This conceptual model assumes the potential that all four C-200 tanks may have released waste but in relatively small volumes;

waste migration is attenuated by the small volume released, and it is expected that evidence of a leak would be detected below the tanks and that the waste has not yet migrated to groundwater.

3.3.5.3 Conceptual Model for 244-CR Vault, Pipelines, and Diversion Boxes in 241-C Tank Farm. This conceptual model for releases at these locations includes consideration of alternative conceptual models 1, 2, and 4; and is also based on information associated with UPR-82, UPR-86, UPR-81, and documented flooding of the 244-CR vault. This western portion of the C Farm conceptual model represents contaminant releases occurring in the upper regions of the vadose zone from pipeline leaks and documented flooding. In addition, the conceptual model for UPR-82 and UPR-86 includes consideration of contaminant migration being attenuated by the placement of gunite piles over these sites. As part of the Phase 1 characterization effort, a number of vertical and slant probeholes were drilled at UPR-82. The vertical probeholes were drilled to a depth of 30 ft bgs around the outer edges of the gunite pile over this pipeline leak, while the deepest slant probehole was drilled to a depth of 80 ft bgs directly under this location. Technetium-99 was found at this depth. Since the probehole did not penetrate through the ^{99}Tc contamination, further characterization at this location is warranted with the goal of penetrating through the ^{99}Tc contamination. Furthermore, a number of probeholes will be used to collect samples at UPR-81, near the CR vaults.

3.3.5.4 Conceptual Model for Near Surface, Shallow Releases Associated with 241-C Tank Farm. The conceptual model for these includes consideration alternative models 1, 2, and 4. This model is also based on information associated with the 216-C-8 French drain, 241-C-801 valve drain, UPR-72, and associated pipelines and drains.

Although process records are incomplete, a minimum of 31,780 gal of treated 241-A TFPC was discharged to the 216-C-8 French drain from January 1960 through March 1965 (Letter 7G420-MEJ-06-007). At the cesium loadout facility (241-C-801 building) located in the northeastern corner of WMA C, cesium and technetium were loaded onto casks containing ion exchange resin. The origin of the waste was from tank C-104 and consisted of PUREX P1 and P2 tank waste. The valve pit connected to the loadout facility had a drain line connected to a drywell drain outside of the tank farm fence. While no records have been located that provide information on volumes or types of waste that were potentially discharged to the drain from the valve pit, the potential for discharges to have occurred exists. UPR-72 is assumed to be buried radioactive material.

This conceptual model represents planned release sites that are known or suspected to have contributed to vadose zone contamination. Migration of contaminants could vary from little or no migration or to a depth of 160 ft or more. The potential for these releases to have reached groundwater is unknown because of the uncertainty in the volumes released and other influencing factors.

3.3.5.5 Conceptual Model of Contaminated Surface Sites Associated with 241-C Tank Farm. The conceptual model for these sites describes surface contamination. This model is based on information associated with UPR-200-E-16, UPR-200-E-27, UPR-200-E-68, UPR-91, UPR-107, UPR-115, and UPR-118. All represent surface contamination from airborne releases of small volumes, and the contamination is expected to be at or near the ground surface (<15 ft).

a. UPR-200-E-16 is a surface spill that resulted from a leak in an overground transfer pipeline between tanks C-105 and C-108. The surface spill associated with this release is located ~18 m (60 ft) northeast of tank C-105 and occurred in 1959. The spilled liquid was classified as coating waste from the PUREX process and was an estimated 50 gal.

b. UPR-200-E-27 is located just east of the 244-CR vault and extends east beyond the tank farm fenceline. DOE/RL-92-04 indicates the surface contamination was deposited in 1960, but does not identify the source(s) of the contamination. However, the November 1960 monthly report for the Tank Farm Contractor states the particulate contamination was due to work in C Farm diversion boxes and 244-CR vault (HW-67459, pages B-2 and B-3). Since the UN-200-E-27 release consisted of airborne particulate contamination, the impact was limited to the ground surface.

c. UPR-200-E-68 is wind-borne surface contamination spread from the 241-C-151 diversion box. The release occurred in 1985 and was subsequently decontaminated to background radiation levels or covered with clean soil for later decontamination (the source document is inconclusive). Sometime after the release, the 241-C-151 diversion box was opened, flushed, and sprayed with Turco Fabrifilm[12] to physically fix contamination to the structure surface.

d. UPR-91 is located ~100 ft from the northeast side of the tank farm and resulted from surface contamination that migrated from WMA C. The contaminated area was scraped and contaminated material removed (DOE/RL-92-04).

e. UPR-107 is a surface spill located north of the 244-CR vault, inside WMA C. DOE/RL-92-04 states that a spill occurred on November 26, 1952, when a pump discharged an estimated 5 gal of liquid to the ground surface during a pump installation.

f. UPR-115 is located east of C Farm, south of 8th Street, across an unnamed gravel road. Routine radiological surveys confirm radiological contamination in this area. No surveys can be found to provide information about the radiological conditions inside the posted area. Very little is known about this posted area. In 1980, a larger area of posted contamination was located in the same vicinity. The contaminated soil from UPR-200-E-91 was removed in 1981. It is difficult to determine if the two sites are related. In June 2004, 200-E-115 was stabilized with gravel and posted as an Underground Radioactive Material Area.

[12] Turco Fabrifilm is a registered trademark of Turco Products, Westminster, California.

g. UPR-200-E-118 is located in the northeast portion of the tank farm and extends north up to ~300 m (1,000 ft) beyond the fenceline. It was the result of an airborne release from tank C-107 that occurred in April 1957.

3.4 PERFORMANCE ASSESSMENT

The Phase 2 master work plan provides the process for performance assessments in the RCRA corrective action process. This process is governed by HFFACO, Appendix I, Section 2.5 (Ecology et al. 1989) which states that the performance assessment must address the requirements in RCRA, HWMA, *Clean Water Act of 1972* (CWA), *Safe Drinking Water Act of 1974* (SDWA), and CERCLA, as well as the *Atomic Energy Act of 1954*.

To meet RCRA, HWMA, CWA, SDWA, and CERCLA requirements, the performance assessment evaluates the impacts associated with contaminants in the soils based on reasonable maximum exposure[13] from possible future land use options (e.g., residential, industrial) for groundwater and direct contact exposure pathways, as well as ecological risk receptors. Furthermore, it provides estimates of media cleanup standards (OSWER Directive 9902.3-2A) for scenarios where risks exceed performance objectives and will be used for evaluating CMAs.

Atomic Energy Act of 1954 requirements are met through DOE O 435.1, *Radioactive Waste Management*, which requires the dose to representative members of the public for (1) all exposure pathways and (2) air pathway be evaluated along with release of radon from the facility (DOE M 435.1-1, *Radioactive Waste Management Manual*, Chap IV, Sections P 1A – 1C).

It is expected that the WMA C performance assessment will be divided into two major sections: impacts to human health and impacts to the ecological environment. A summary of the approach for calculating impacts to human health is provided in Section 3.4.1. This is a summary because the methods and assumptions that will be used in WMA C performance assessment will be determined through the ongoing performance assessment working sessions started with Ecology, NRC, EPA, Tribal Nations, and interested stakeholders that began in February 2009 after issuance of Revision 0 of this document in December 2008. These agreements will take into account, as appropriate, the assumptions and methodologies used by Tank Closure and Waste Management Environmental Impact Statement. The methodology and approach for calculating ecological risk is provided in Section 3.4.2 and may be modified through the ongoing process started with Ecology, NRC, EPA, Tribal Nations, and interested stakeholders to develop the scope, methods and assumptions of the performance assessment through a series of working sessions.

The ecological risk approach follows guidance given in WAC 173-340-7490, "Terrestrial Ecological Evaluation Procedures" and DOE-STD-1153-2002, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*. This approach is provided in Section 3.4.2.

[13] In WAC-173-340-708(3)(b): The reasonable maximum exposure is defined as the highest exposure that is reasonably expected to occur at a site under current and potential future site use.

3.4.1 Estimated Impacts to Human Health

After submittal to Ecology in December 2008 of Revision 0 of this document, a process was developed in February 2009 and is ongoing that addresses performance assessment scope, methods, and assumptions. The ongoing process started with Ecology, NRC, EPA, Tribal Nations, and interested stakeholders to develop the scope (conceptual exposure model, conceptual site model, selection of numerical codes, etc.) of the performance assessment through a series of working sessions or workshops will address various performance assessment attributes.

The schedule for the working sessions is provided in Table 3-1.

Table 3-1. Proposed Schedule of Working Sessions

Num.	Subject	Date
0.	Goal/Process	February 24 – 25, 2009
1.	Residual Inventory	May 5 – 7, 2009
2.	Assessment Context/General Conceptual Model	September 1 – 3, 2009
3.	Soil Inventory	October 27 – 29, 2009
4.	Engineered Systems #1 (waste residuals, surface cap, recharge)	January 26 – 29, 2010
5.	Features, Events and Processes	March 30 – April 1, 2010
6.	Natural System (detailed conceptual model, data)	May 25 – 27, 2010
7.	Engineered Systems #2	July 27 – 29, 2010
8.	Dosimetry (detailed conceptual model, exposure scenarios)	September 28 – 30, 2010
9.	Numeric Codes (as well as topics not covered sufficiently above)	January 25 – 27, 2011
10.	Ecological Risk Assessment	May 17 – 19, 2011
11.	Results from Initial Model Results (contents of Maintenance Plan)	TBD
12.	Results from Final Model Results	TBD

The results from sampling and other characterization activities will be used to update the contaminant distribution models or inventory models as needed and to support the performance assessment. This work plan also will support the CMS decision-making process. This work plan focuses on identifying and gathering the characterization information that will be needed for evaluating the selection of the preferred remedy(ies) from the CMS alternatives. Results of the characterization activities will be used for evaluating risk to potential receptors and for the CMS alternative analyses. Results from sampling conducted under this work plan will support the inventory models used in the performance assessment shown in Table 3-1. These models will support the exposure models to be used in the performance assessment. Because of the multiple requirements by multiple agencies, numerous exposure scenarios will be performed. The major exposure scenarios are listed in respect to the responsible agency. The agencies are listed in alphabetical order.

For DOE/ORP, the following exposure scenarios include:

- All pathway
- Air pathway
- Radon
- Inadvertent Human Intruder.

Note: The all pathway scenario includes groundwater and soil media related to ingestion, dermal contact, and inhalation. These exposure scenarios are based on requirements in DOE O 435.1 and its associated manual and guidance.

For EPA, the *Anticipated* Central Plateau Exposure Scenarios include:

- Rural Resident
- Institutional Control (IC) Caretaker
- Adult Recreational Trespasser
- Youth Recreational Trespasser
- Construction Worker
- Two Tribal Subsistence Lifeways scenarios provided by the Yakama Nation and the Confederated Tribes of the Umatilla Indian Reservation.

These exposure scenarios are based on requirements in various EPA requirement and guidance documents and designed to meet CERCLA requirements under the HFFACO.

For Ecology, exposure scenarios include:

- Unrestricted
- Industrial.

These exposure scenarios are based on requirements in *Model Toxics Control Act* (MTCA) (RCW 70.105D, "Hazardous Waste Cleanup — Model Toxics Control Act") and its implementing requirements in WAC 173-340, "Model Toxics Control Act — Cleanup" and designed to fulfill RCRA requirements under the HFFACO.

3.4.2 Ecological Risk Assessment Approach

Sections 3.4.2.1 through 3.4.2.5 describe the general approach for conducting the ecological risk assessment (ERA) for WMA C. The ERA is an element of the CMS alternatives evaluation process for all of the WMAs associated with the SST farms. Waste Management Area C is the first WMA to undergo implementation of corrective actions under the CMS. Information developed under the ERA process will be used in the development and analysis of CMAs, including the no-action alternative. To maintain consistency across the Hanford Site, the ERA for WMA C will adopt relevant methodology and data that were used in the Central Plateau ecological risk assessment (CPERA). This ecological risk assessment is not tiering off of the CPERA, just adopting consistence methods to maintain consistency.

3.4.2.1 Ecological Risk Assessment Requirements and Guidance. The SST system at WMA C will require cleanup under both the RCRA TSD closure and RCRA corrective action requirements. As part of RCRA corrective action, certain applicable requirements of MTCA cleanup regulations (WAC 173-340) that are incorporated into the WAC 173-303, "Dangerous

Waste Regulations," including WAC 173-340-357, "Quantitative Risk Assessment of Clean-Up Action Alternatives," must be followed. WAC 173-340-357 requires assessment of ecological risk as part of the determination of cleanup levels and remedial action alternatives. The MTCA addresses hazardous chemicals but does not address the radionuclide contaminants which are known to have been released into the environment at WMA C. To address chemical and radiological ecological risks, the WMA ERAs will be performed in accordance with two guidance documents:

a. WAC 173-340-7490, "Terrestrial Ecological Evaluation Procedures"

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

3.4.2.1.1 Washington Administrative Code Terrestrial Ecological Evaluation Procedures. WAC 173-340-7490 prescribes a protocol for evaluating risks to terrestrial receptors from chemical (nonradionuclide) constituents in soil. WAC 173-340-7490 establishes a tiered approach for assessing risk and determining cleanup levels that are protective of terrestrial soil biota, plants, and animals. Tiers are based on exclusions for certain types of sites, simplified ecological evaluations, and site-specific evaluations. Site-specific terrestrial ecological evaluation methodology (WAC 173-340-7493, "Site-Specific Terrestrial Ecological Evaluation Procedures") identifies a variety of methods that may be used to evaluate risks and determine protective cleanup levels for terrestrial organisms. The process also has provisions for allowing certain sites to "exit" from further consideration if specified criteria are met.

3.4.2.1.2 U.S. Department of Energy Graded Approach for Evaluating Radionuclides. The International Atomic Energy Agency (IAEA) has concluded that chronic radiation doses below 0.1 rad/day will not harm terrestrial animal populations, and that chronic dose rates below 1 rad/day are unlikely to have an adverse effect on terrestrial plants or aquatic biota (IAEA, *Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards*). DOE-STD-1153-2002 was developed to address risks of radiation doses to aquatic and terrestrial biota based on the IAEA dose standards. DOE-STD-1153-2002 provides a graded approach to ecological risk evaluation and contains Level 1 biota concentration guides (BCG) for radionuclides in soil, sediment, and water that equal the 0.1 and 1 rad/day threshold dose levels. For exposure to multiple radionuclides, the technical standard uses the sum of the fractions (i.e., sum of the fractional dose contributions from each radionuclide) to calculate the total dose. The Level 1 screening methodology is used primarily to prioritize actions for sites with the greatest potential for generating adverse effects. If the calculated dose is greater than the BCG for a given radionuclide, the initial screening level has been exceeded, indicating that the second step, a site-specific evaluation, should be performed.

The software program RESRAD-BIOTA (Version 1.21, ANL 2006) was developed as the calculation tool that is currently approved, updated, and supported for implementing DOE-STD-1153-2002. The code serves as the DOE's "next generation" biota dose evaluation tool and duplicates the Level 1 screening (i.e., BCGs) and analysis methods contained in DOE-STD-1153-2002. RESRAD-BIOTA is the most current and extensive source of BCGs.

The BCGs, calculation tools, and general methodology for evaluating the risk from radionuclide exposures to ecological receptors will be used for radionuclide evaluation in the WMA C ERA.

3.4.2.2 Summary of Ecological Risk Assessment Approach. The geographical scope of the WMA C ERA will generally be defined as the WMA C proper plus a buffer area with a 100-m width outside of the fenceline (Figure 3-13). This is also known as the "CMS Boundary." The areas inside the WMA C fenceline are currently managed such that there is no viable habitat by using herbicides and pesticides on a regular basis, and fences are placed around the perimeter to keep larger animals out of the WMAs, including WMA C (see Section 2.2). However, adjacent areas outside of the fence offer potential habitat that could support receptor species. Current conditions outside the fenceline may be indicators of future colonizing species and receptors.

The purpose of the WMA C ERA is to

a. Evaluate potential threats to the terrestrial and aquatic environment from releases of hazardous substances (chemicals and radionuclides) associated specifically with WMA C.

b. Determine whether a release of hazardous substances to soil may pose a threat to the terrestrial environment.

c. Characterize existing or potential threats to plants or animals exposed to hazardous substances in soil.

d. Establish site-specific cleanup standards, as applicable.

e. Facilitate selection of a corrective action by developing information necessary to conduct evaluations of CMAs.

Documentation resulting from the ERA for WMA C will ultimately guide development and implementation of corrective measures at WMA C and other SST WMAs.

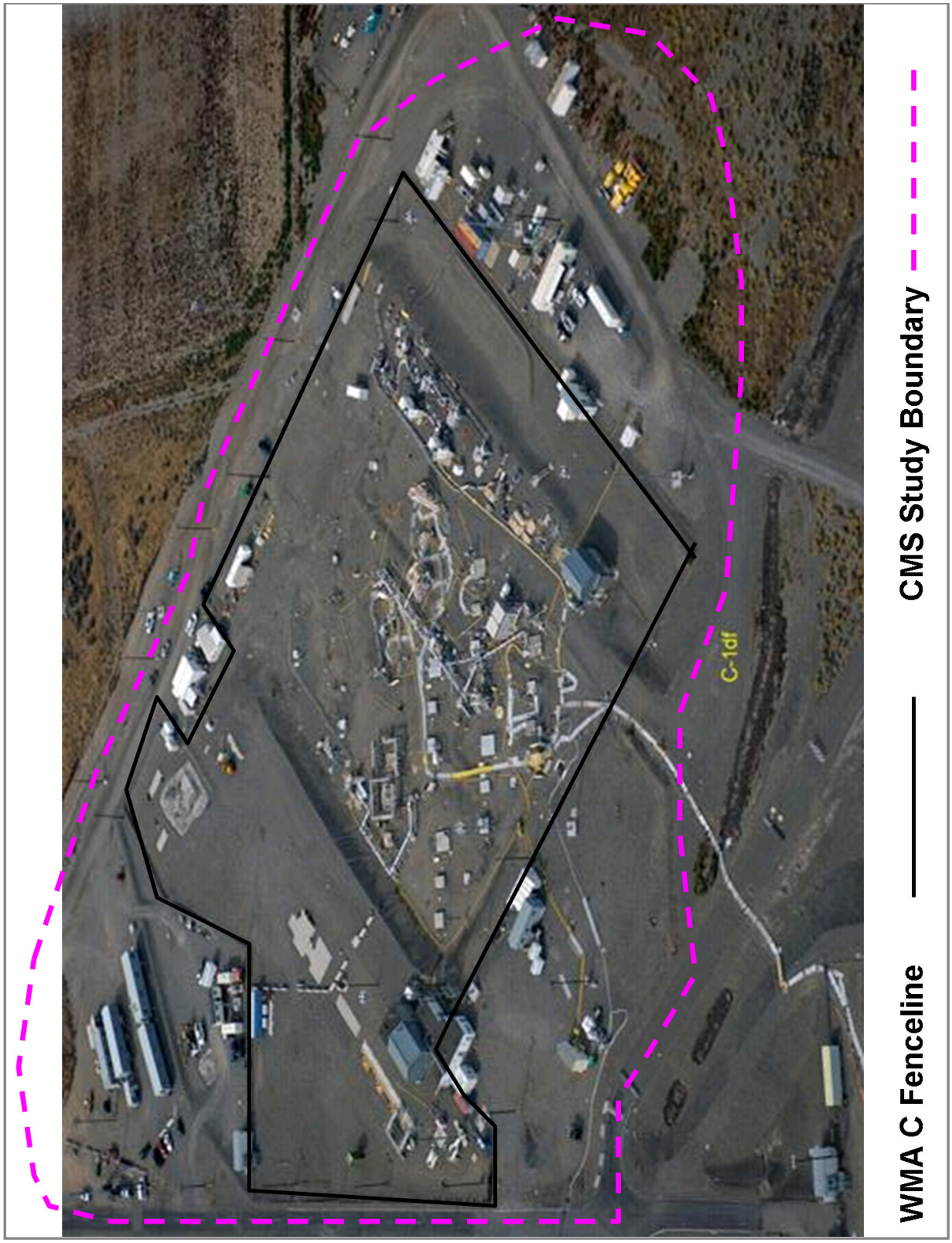
3.4.2.3 Implementation of Ecological Risk Assessment Approach. The ERA approach for WMA C (as well as the other SST WMAs) is guided by WAC 173-340-7490. Specifically, WAC 173-340-7493 will be used.

There are two elements in planning a site-specific terrestrial ecological evaluation. Both elements are performed in consultation with and approval by Ecology. The two elements are the following:

a. Completing the problem formulation step.

b. Selecting one or more methods under WAC 173-340-7493(3) for addressing risks identified in the problem formulation step.

Figure 3-13. Aerial Photograph of Waste Management Area C Facility Boundary (Black). (Geographical extent of the Ecological Risk Assessment will include habitat within 100 m outside of the facility boundary)



3.4.2.3.1 Problem Formulation. Ecological risk assessment problem formulation identifies the chemicals of ecological concern, the exposure pathways, and terrestrial receptors of concern, and includes a toxicological assessment in accordance with WAC 173-340-7493(2)(a)(i) through (iv). Each of these elements of the problem formulation are briefly described in the following. Also included to meet EPA guidance is assessment of aquatic receptors of concern as it relates to WMA C.

Identification of Chemicals of Ecological Concern. WAC 173-340-7493 identifies hazardous substances of concern that should be considered in a site-specific terrestrial ecological evaluation. Metals, pesticides, chlorinated organics, nonchlorinated organics, and petroleum are identified as priority constituents in Table 749-3 of WAC 173-340-900, "Tables." Priority constituents identified in Table 749-3 (WAC 173-340-900) that are expected to be present as a result of a release of tank waste to soil within the 0 to 4.6 m (0 to 15 ft) depth will be evaluated in the ERA.

Based on process knowledge and existing radiological survey or soil characterization data, radionuclides are known to be present within WMA C. DOE-STD-1153-2002 will be used to evaluate compliance with specified limits on radiation dose to populations of terrestrial biota. Specifically, DOE-STD-1153-2002 provides dose evaluation methods that can be used to meet the requirements for protection of biota in DOE O 450.1A, *Environmental Protection Program* and DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, and the dose limits for protection of biota developed or discussed by the National Council on Radiation Protection and Measurements (*Effects of Ionizing Radiation on Aquatic Organisms* [NCRP 1991]) and IAEA (1992).

RPP-23403, *Single-Shell Tank Component Closure Data Quality Objectives* presents a comprehensive list of volatile organic, semivolatile organic, general organic, inorganic, and radionuclide constituents expected in tank waste. RPP-23403 bins tank waste constituents for analysis as either "primary" or "secondary" constituents. Primary constituents are those likely to be present in SSTs that may be analyzed by reliable methods and within the constraints of the DQOs. Secondary constituents are those that are reported using the methods for primary contaminants but not identified specifically as primary constituents. Secondary constituents that require evaluation in the risk assessment may be moved to the primary constituent list. WAC Table 749-3 (WAC 173-340-900) contains soil indicator concentrations for several of the primary and secondary tank waste constituents identified during the SST DQO process (RPP-23403). Nearly all primary and secondary radionuclide constituents identified in RPP-23403 have paired BCGs for the protection of terrestrial and aquatic receptors (DOE-STD-1153-2002, ANL 2006).

Available data on contaminants in the soil will be used to determine which substances in WAC Table 749-3 (WAC 173-340-900) and RESRAD-Biota Level 1 BCGs (ANL 2006) are present in WMA C. The identification process for contaminants of potential ecological concern (COPEC) will consider the likelihood that primary and secondary constituents are sufficiently persistent and accessible within WMA C to cause exposure to terrestrial receptors.

Exposure Pathway Identification. An exposure pathway is the pathway that a hazardous or radioactive substance takes or could take from its source to the exposed organism. The exposure

pathway describes the mechanism by which an individual or population is exposed or has the potential to be exposed to hazardous substances. Each exposure pathway includes an actual or potential source or release from a source, an exposure point, and an exposure route. If the exposure point differs from the source of the hazardous substance, the exposure pathway also includes a transport/exposure medium. Examples of exposure pathways include but are not limited to dermal contact with or ingestion of contaminated soil, uptake of soil contaminants by biota resulting in exposure to a receptor, or secondary transport and exposure via consumption of contaminated prey items.

Understanding the exposure pathways and mechanisms are important for evaluating CMAs. The ERA will identify and document potential pathways from contaminant sources to terrestrial biota within WMA C and adjacent areas.

Terrestrial Receptors of Concern. Terrestrial receptors of concern to be evaluated in the ERA will be representative of the taxonomic groupings identified in WAC 173-340-7493(2)(a)(iii). Receptor groups include soil biota (invertebrates), vascular plants, ground-feeding birds, ground-feeding small mammal predators, and herbivorous small mammals. To strengthen the pathway evaluation, two higher trophic predatory species, the badger and the red-tailed hawk, will be considered in the WMA C ERA.

Aquatic Receptors of Concern. Aquatic receptors of concern will be evaluated through numerical modeling.

Toxicological Assessment. The purpose of the toxicological assessment is to identify significant adverse effects to the receptors of concern that may result from exposure to the chemicals of ecological concern [WAC 173-340-7493(2)(a)(iv)]. The toxicological assessment consists of an ecological effects evaluation using the hazardous substance soil indicator concentrations for primary and secondary SST contaminants established in WAC 173-340-900, Table 749-3, for the protection of plants, soil biota, and wildlife. The ecological effects evaluation for radionuclides in soil will be performed using RESRAD Biota Level 1 BCG values for primary and secondary contaminants provided for the protection of terrestrial plants and wildlife (DOE-STD-1153-2002, ANL 2006).

Soil contamination data for soil depths ranging from 0 to 4.6 m (0 to 15 ft) will be assembled from existing sources such as borehole and vadose zone characterization reports, results from Phase 2 characterization activities, monitoring reports, radiological field survey results, and other available sources for WMA C. Maximum concentrations for each primary and secondary nonradionuclide listed in Table 749-3 (WAC 173-340-900) will be evaluated against its respective published screening values for terrestrial plants, soil biota, and wildlife. Maximum radionuclide concentrations in existing soil data or radiological field survey data will be compared to applicable Level 1 soil BCGs that are provided for protection of radiological effects on terrestrial plants and animals (as reported from RESRAD-BIOTA, Version 1.2.1 [ANL 2006]).

Soil data collected to support the human health risk investigation for WMA C will also be included in the toxicological assessment for terrestrial ecological receptors of concern.

Table 3-2 provides soil indicator concentrations for nonradionuclides published in WAC 173-340-900 (Table 749-3) for the contaminants that have been identified as primary or secondary contaminants in SST DQO (RPP-23403), plus pesticides and petroleum products. Table 3-3 provides BCGs for terrestrial plants and wildlife for radionuclides in soil, as published in DOE-STD-1153-2002 and the current version of its companion software, RESRAD-BIOTA (Version 1.21 [ANL 2006]) for the contaminants identified as primary or secondary contaminants in RPP-23403.

3.4.2.3.2 Risk Evaluation. Following the problem formulation is the risk evaluation step. The purpose of the risk evaluation is to assemble the information necessary to develop cleanup levels and adequately support the selection and evaluation of corrective action alternatives in the CMS. Ecological risk evaluation methods will follow guidance published in WAC 173-340-7493(3).

During the toxicological assessment performed under the problem formulation step, analytical results for soil will be compared to the available soil indicator concentrations presented in Table 749-3 of WAC 173-340-900 and BCGs established in RESRAD-BIOTA (ANL 2006) and DOE-STD-1153-2002. Any analyte that exceeds the published soil indicator concentration for a terrestrial receptor will be identified as a COPEC and the need for corrective action will be established. However, if analytical data do not signify an exceedance of a soil indicator concentration for a given receptor, a combination of additional measures may be taken to further evaluate potential risk.

Soil Indicator Concentrations. For hazardous substances published in Table 749-3 (WAC 173-340-900) where a soil indicator concentration for a given receptor is not assigned, an indicator concentration can be developed in accordance with WAC 173-340-7493(4). Two approaches would be applied: further literature survey and development of a wildlife exposure model.

a. **Literature Survey.** Indicator concentrations for soil biota and plants may be developed by consulting the scientific literature using methods provided by the Oak Ridge National Laboratory (ORNL/TM-13391, *Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants*).

b. **Wildlife Exposure Model.** Indicator concentrations for wildlife would be developed as prescribed in WAC 173-340-7493(3)(c) using wildlife exposure model parameters published in WAC 173-340-900 Tables 749-4 and 749-5.

Tissue Analysis and Dietary Exposure Modeling. Small mammal tissue sampling and analysis is proposed as a supplemental method for evaluating contaminant pathways and risks to wildlife receptors (Appendix B). Small mammals would be collected in available habitat adjacent to the WMA C fenceline where potential overlap may occur between small mammal home range and the occurrence of soil contamination within WMA C.

Results of tissue analyses would be used to evaluate contaminant exposure of small mammals via direct contact or ingestion of soil, as well as serve as inputs to dietary exposure models for upper trophic level receptors (i.e., badger and red-tailed hawk).

Table 3-2. Ecological Indicator Soil Concentrations (mg/kg) for Protection of Terrestrial Biota (2 sheets)
(Benchmarks adapted from WAC 173-340-900 Table 749-3)

Hazardous Substance	Plants[a]	Soil Biota[a]	Wildlife[a]	SST Priority[b]
Metals				
Aluminum (soluble salts)	50			Primary
Antimony	5			Primary
Arsenic III[c]			7	Primary
Arsenic V[c]	10	60	132	Primary
Barium	500		102	Primary
Beryllium	10			Primary
Boron	0.5			Secondary
Bromine[d]	10			
Cadmium	4	20	14	Primary
Chromium (total)	42	42	67	Primary
Cobalt	20			Primary
Copper	100	50	217	Primary
Fluorine[e]	200			
Iodine[f]	4			
Lead	50	500	118	Primary
Lithium	35			Secondary
Manganese	1,100		1,500	Primary
Mercury, inorganic	0.3	0.1	5.5	Primary
Molybdenum	2		7	Secondary
Nickel	30	200	980	Primary
Selenium	1	70	0.3	Primary
Silver	2			Primary
Technetium[f]	0.2			
Thallium	1			Primary
Tin	50			Secondary
Uranium	5			Primary
Vanadium	2			Primary
Zinc	86	200	360	Primary
Pesticides[g]				
Aldrin			0.1	Secondary
Benzene hexachloride (including lindane)			6	Secondary
Chlordane		1	2.7	
DDT/DDD/DDE (total)			0.75	
Dieldrin			0.07	Secondary
Endrin			0.2	Secondary
Hexachlorobenzene			17	

Table 3-2. Ecological Indicator Soil Concentrations (mg/kg) for Protection of Terrestrial Biota (2 sheets)
(Benchmarks adapted from WAC 173-340-900 Table 749-3)

Hazardous Substance	Plants[a]	Soil Biota[a]	Wildlife[a]	SST Priority[b]
Heptachlor/heptachlor epoxide (total)			0.4	
Pentachlorophenol	3	6	4.5	Secondary
Other Chlorinated Organics				
1,2,4-Trichlorobenzene		20		Primary
1,2-Dichloropropane		700		Secondary
1,4-Dichlorobenzene		20		Secondary
2,4,5-Trichlorophenol	4	9		Primary
2,4,6-Trichlorophenol		10		Primary
Chlorobenzene		40		Primary
PCB mixtures (total)[h]	40		**0.65**	Primary
Other Nonchlorinated Organics				
Acenaphthene	20			Primary
Benzo(a)pyrene			12	Secondary
Di-n-butyl phthalate	200			Primary
Nitrobenzene		40		Primary
Phenol	70	30		Secondary
Styrene	300			Secondary
Toluene	200			Primary
Petroleum				
Gasoline range organics		100	5,000 except that the concentration shall not exceed residual saturation at the soil surface	
Diesel range organics		200	6,000 except that the concentration shall not exceed residual saturation at the soil surface	

[a] Blank cells indicate that no value is available for analyte-receptor combination.
[b] Only Primary and Secondary contaminants from the SST DQO (RPP-23403, *Single-Shell Tank Component Closure Data Quality Objectives*) are included in this table except for pesticides and petroleum where all pesticides listed in WAC 173-340-900, "Tables," Table 749-3 are included. Pesticides and petroleum are considered primary analytes for ecological risk. For primary analytes, if detected a numerical value is reported, if not detected, analytes are reported with a less than minimum detection limit (MDL). For secondary organic analytes, if detected a numerical value is reported as an estimate, if not detected, the analytes are not reported. This is the same process used in SST DQO RPP-23403.
[c] Total arsenic is reported [same as SST DQO (RPP-23403)].
[d] Bromine is reported as bromide [same as SST DQO (RPP-23403) where it was classed as secondary].
[e] Fluorine is reported as fluoride [same as SST DQO (RPP-23403) where it was classed as primary].
[f] Included in the radionuclide analysis, radionuclide will be converted from radioactivity to mass using specific activity. Iodine-129 and ^{99}Tc were both classed as primary in SST DQO (RPP-23403).
[g] In addition to the semivolatile organic analysis, EPA Method 8080 (EPA 1994) for pesticides will also be run to meet the reporting requirements for ecological indicator soil concentrations.
[h] Polychlorinated biphenyls (PCB) reported as both arochlor and total PCBs.

Table 3-3. Soil Biota Concentration Guides for Terrestrial Animals and Plants (Adapted from RESRAD-BIOTA Level 1 Terrestrial Evaluation [ANL 2006])

Nuclide	Terrestrial Animal BCG (pCi/g)	Terrestrial Plant BCG (pCi/g)	Single-Shell Tank Priority
Americium-241	3.9E+03	2.2E+04	Primary
Carbon-14	4.8E+03	6.1E+04	Primary
Curium-242	2.1E+03	7.9E+04	Primary
Curium-244	4.1E+03	1.5E+05	Primary
Cobalt-60	6.9E+02	6.1E+03	Primary
Cesium-137	2.1E+01	2.2E+03	Primary
Europium-152	1.5E+03	1.5E+04	Primary
Europium-154	1.3E+03	1.3E+04	Primary
Europium-155	1.6E+04	1.5E+05	Primary
Tritium (H-3)	1.7E+05	1.7E+06	Primary
Iodine-129	5.7E+03	1.7E+05	Primary
Neptunium-237	3.9E+03	8.2E+03	Primary
Plutonium-238	5.3E+03	1.8E+04	Primary
Plutonium-239	6.1E+03	1.3E+04	Primary
Antimony-125	3.5E+03	3.5E+04	Primary
Strontium-90	2.3E+01	3.6E+03	Primary
Technetium-99	4.5E+03	2.2E+04	Primary
Thorium-228	5.3E+02	6.4E+03	Primary
Thorium-230	1.0E+04	1.8E+05	Primary
Thorium-232	1.5E+03	2.4E+04	Primary
Uranium-233	4.8E+03	5.2E+04	Primary
Uranium-234	5.1E+03	5.2E+04	Primary
Uranium-235	2.8E+03	2.7E+04	Primary
Uranium-238	1.6E+03	1.6E+04	Primary

BCG = biota concentration guide
Reference: ANL 2006, *RESRAD-BIOTA for Windows* (Version 1.21).

While tissue analysis is not specifically identified as a means of evaluation in WAC 173-340-7493, the information obtained from such data is valuable for documenting potential for contaminant transport and biotic uptake to higher trophic, predatory species of wildlife.

3.4.2.3.3 Uncertainty Analysis. The WMA ERA will include a qualitative uncertainty analysis to identify specific causes of uncertainties and evaluate their potential impact on the risk estimates. Other considerations of uncertainties, including natural variability, range and uncertainty of potential risks, and methods to reduce uncertainty will also be documented in accordance with WAC 173-340-7493(5).

3.4.2.4 Hanford Site Ecological Risk Assessments and Related Activities. The WMA C ERA is a component of the broadly scoped SST ERA that will be conducted as part of the CMS for the SST farm. The ERAs for tank farms will support closure decisions for the Hanford Site. This section briefly summaries the other assessment and monitoring projects relevant to characterizing ecological risks at the Hanford Site. The following subsections briefly summarize the Central Plateau Ecological Risk Assessment and River Corridor Baseline Risk Assessment which are relevant to characterizing ecological risks at the Hanford Site. In addition to the risk assessments described below, other ecological risk assessments have also been conducted at Hanford (e.g., Columbia River Comprehensive Impact Assessment [DOE/RL-96-16, *Screening Assessment and Requirements for a Comprehensive Assessment, Columbia River Comprehensive Impact Assessment*], the Waste Treatment Plant, 100 Areas, 300 Area, and Pacific Northwest National Laboratory surveys).

3.4.2.4.1 Central Plateau Ecological Risk Assessment. The CPERA evaluates risks to ecological receptors from waste sites in the 200 Area under current conditions. The purpose of the CPERA is to characterize the potential for ecological risk to support waste-site remedy decision making and to fulfill the CERCLA requirements for evaluating baseline ecological risk to the surface and near-surface environment of the Central Plateau. Work conducted for the CPERA was conducted using CERCLA guidance for ecological risk assessment (EPA/540/R-97/006) and included regulator and stakeholder interviews and workshops; identification of contaminants of potential ecological concern and potential ecological risk receptors (DOE/RL-2001-54, *Central Plateau Ecological Evaluation*); and identification of DQOs (WMP-20570, *Central Plateau Terrestrial Ecological Risk Assessment Data Quality Objectives Summary Report – Phase I*; WMP-25493, *Central Plateau Terrestrial Ecological Risk Assessment Data Quality Objectives Summary Report – Phase II*; and WMP-29253, *Central Plateau Terrestrial Ecological Risk Assessment Data Quality Objectives Summary Report – Phase III*); SAPs (DOE/RL-2004-42, *Central Plateau Terrestrial Ecological Sampling and Analysis Plan – Phase I*; DOE/RL-2005-30, *Central Plateau Terrestrial Ecological Sampling and Analysis Plan – Phase II*; and DOE/RL-2006-27, *Central Plateau Terrestrial Ecological Sampling and Analysis Plan – Phase III*) and field characterization activities (D&D-28419, *Ecological Evaluations of Selected Central Plateau Waste Sites; With Addendum – Review of Potential No Action or Institutional Control Waste Sites*).

Specific investigations conducted for the CPERA included collection and analysis of soil, biota, soil gas, and media associated with West Lake. Soils were analyzed for metals, polychlorinated biphenyls (PCB) (including PCB congener analyses), organochlorine pesticides, and radionuclides. Supporting soil measurements (e.g., soil nutrients, pH, total organic carbon, and particle size) also were collected to aid in risk interpretation. Vegetation surveys were performed to evaluate relative abundance, diversity, and measures of habitat quality. Biota collected included ground-dwelling invertebrates, lizards, and small mammals. Each biotic receptor was analyzed for tissue concentrations of contaminants. Lizards and small mammals

also were examined in the field for gross abnormalities. Relative abundance was estimated for invertebrates, lizards, and small mammals. These activities have culminated in extensive information to identify and calculate the potential for risks to the environment from concentrations of Hanford Site contaminants on the Central Plateau (DOE/RL-2007-50, *Central Plateau Ecological Risk Assessment Data Package Report*).

Operable unit decisions for Central Plateau waste sites and groundwater are supported by remedial investigations and feasibility studies. These decisions are supported by the CPERA. The CPERA report (DOE/RL-2007-50) presents the results of the ERA for the Central Plateau waste sites. The groundwater operable unit decisions address remedies for existing groundwater plumes and are intended to ensure that contaminant plumes are contained within the Central Plateau and do not pose a future threat to the River Corridor or Columbia River.

3.4.2.4.2 River Corridor Baseline Risk Assessment. The River Corridor Baseline Risk Assessment (RCBRA) evaluated risks from CERCLA waste sites to human health and the environment (DOE/RL-2007-21, *River Corridor Baseline Risk Assessment*). The RCBRA waste are located in the 100 Area, 300 Area, and portions of the 600 Area. The RCBRA also evaluated adjacent riparian and near-shore environs of the Columbia River. Results of the RCBRA will be used to support development of final Records of Decision in the Hanford Site River Corridor. Remedial actions are currently being performed in contaminated areas of the River Corridor under Interim Action Records of Decision. The ERA component of RCBRA was conducted using EPA/540/R-97/006 and included numerous regulator and public workshops and meetings. The RCBRA involved development of a work plan (DOE/RL-2004-37, *Risk Assessment Work Plan for the 100 Area and 300 Area Component of the RCBRA*), a DQO process report (BHI-01757, *DQO Summary Report for the 100 Area and 300 Area Component of the RCBRA*), and a SAP (DOE/RL-2005-42, *100 Area and 300 Area Component of the RCBRA Sampling and Analysis Plan*). The RCBRA project employed similar sampling strategies and methods to characterize risk in the terrestrial portion of the assessment as the CPERA. Given the similarity of terrestrial site sampling between RCBRA and Central Plateau projects, data from both projects were shared for performing risk analyses.

3.4.2.5 Ecological Risk Assessment Schedule. The schedule showing the following activities for the ecological risk assessment is provided in Chapter 6.

- Compilation of Existing Data
  - Ecological/field Descriptive Information
  - Analytical Data

- Problem Formulation
  - Identification of Chemicals of Ecological Concern
  - Exposure Pathway Identification
  - Terrestrial Receptors of Concern
  - Toxicological Assessment (including benchmark evaluation)

- Risk Evaluation
  - Tissue Analysis and Dietary Exposure Modeling

- Uncertainty Analysis

If no relevant existing data are available for analysis, collection of supplemental samples (soils for human health risk assessment, small mammal tissues for exposure model) would be coordinated with the problem formulation phase of the ERA. If existing data are available to perform initial steps of the ERA through the toxicological assessment, supplemental soil and tissue data may be collected as necessary following problem formulation prior to risk evaluation.

3.5 IDENTIFICATION OF CONTAMINANTS OF CONCERN

The DQO for this work plan (RPP-RPT-38152) used the same approach as RPP-23403 for developing analytical parameters. In this approach, "primary" constituents were identified from the Hanford Facility Dangerous Waste Part A Permit Application, Form 3, Revision 8, for the SST system (DOE W-28/RL-88-21) [Letter 03-ED-009, "Hanford Facility Dangerous Waste Part A Permit Application, Form 3, Revision 8, for the Single-Shell Tank (SST) System"] (Part A); underlying hazardous constituents; Title 10 CFR Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste," subsection 10 CFR 61.55, "Waste Classification;" and identified potential risk contributors. Analytical methods were identified for the primary constituents. In addition to the identified constituents, a number of these methods can also detect many other chemicals or radionuclides. These other or "secondary" analytes will be evaluated and reported using strategies described in RPP-23403.

This approach was adopted in D&D-30262, *Data Quality Objectives Summary Report for the 200-IS-1 Operable Unit Pipelines and Appurtenances* for tank farm pipelines and associated appurtenances and associated UPRs. In addition, WMP-28945, *Data Quality Objective Summary Report in Support of the 200-BP-5 Groundwater Operable Unit Remedial Investigation/Feasibility Study Process* identifies constituents that will be analyzed as part of the groundwater characterization. The analytes from these documents were considered in formulating the analytical parameters for the DQO supporting this work plan.

Extensive lists of sample analysis methods and analytes (chemicals and radionuclides, see Section 4.5 of RPP-RPT-38152) were identified during the DQO. However, not all methods will be performed on every sample. During development of RPP-RPT-38152, strategies were envisioned that would allow for optimization of the analytical work, leading to the availability of more sample volume for constituents of highest concern, and allowing for use of lower detection limits and improved quality control. These optimization strategies are described in Sections 3.5.1 and 3.5.2.

Separate from the optimization strategies described below, the lists of analytes for WMA C soil samples may be modified to reflect changes over time in RPP-23403. The DQO, RPP-RPT-38152, identified sulfide as a soil investigation chemical of potential concern based on sulfide having been identified in RPP-23403 as a constituent associated with tank waste. Sulfide was subsequently removed in a later revision of RPP-23403; therefore, sulfide has also been

eliminated as a soil investigation chemical of potential concern. The removal of sulfide was documented in DOE's letter to Ecology Letter 11-TPD-020, "Organic Analyses Optimization for Waste Management Area (WMA) C," and Ecology's response Letter 11-NWP-053, "Re: Organic Analyses Optimization for Waste Management Area (WMA) C."

3.5.1 Stepped Approach for Evaluating Tank Waste Contaminants of Concern

To optimize the cost-effectiveness of this characterization effort, RPP-RPT-38152 allows the use of a two-step approach to vadose zone sample analysis. This is consistent with previous tank farm characterization efforts conducted in support of the Phase 1 RFI process. There are two key variables in this approach: the concentration of any hazardous substance or radionuclide and the risk created by these constituents. Step 1 assesses if there are chemicals present that are of concern in the context of human health and biotic risk. If the answer is yes, step 2 analyses are undertaken to provide the data to determine the extent of the risk created by the presence of contaminants in the Phase 2 RFI/CMS. If the answer to step 1 is no, then no further sampling at that location would be conducted.

Because the two-step approach has the potential to result in significant cost savings, a detailed description of the approach is retained in this work plan. However, to date the approach has not been used at WMA C. Under the two-step approach, step 1 analyses must be completed and results evaluated before step 2 analyses can be performed. Implementation of this approach would result in missed holding times for step 2 analytes, unless resampling is undertaken. Therefore, the full suite of analyses is performed at the outset to alleviate the risks to data quality (holding times) and cost/schedule (resampling). Nevertheless, the description of the two-step approach is retained in this work plan, in the event that future changes to require sampling and analytical steps can be made that would allow effective implementation of the approach.

Step 1 employs a method-based screening process to determine if the soil has been contaminated with tank waste. A select set of threshold indicator constituents is used in step 1 to indicate the presence of tank waste. Step 1 analytes and methods are a subset of step 2 analytes and methods. If any one of the tank waste indicator thresholds is met, then the full suite of step 2 methods (minus methods already performed in step 1) is performed (see Section 4.0 of RPP-RPT-38152). The criteria for selecting these "threshold indicator constituents" are based on these constituents being historically associated with tank waste, indicative of tank farm constituents released into the environment and driving human health risk, and the most detected constituents in Phase 1 investigations. The Step 1 analytes and their threshold values[14] are as follows.

^{238}U	Detected at or above 1.39 pCi/g.
^{239}Pu	Detected at or above 0.0233 pCi/g.
^{137}Cs	Detected at or above 1.37 pCi/g.
^{90}Sr	Detected at or above 0.262 pCi/g.
NO_3 (as NO_3)	Detected at or above 232 µg/g.

[14] DOE/RL-92-24, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*, Volume I. DOE/RL-96-12, *Hanford Site Background: Part 2, Soil Background for Radionuclides*.

Cr (for Cr+6)	Detected at or above 26.8 µg/g.
^{99}Tc	Detected at the Method Detection Limit.
^{129}I	Detected at the Method Detection Limit.
CN	Detected at the Method Detection Limit.
TBP	Detected at the Method Detection Limit

Uranium-238, ^{239}Pu, ^{137}Cs, ^{90}Sr, NO_3, and Cr are present at low levels in Hanford background soil. The stated thresholds are met only if the contaminants are detected and the detected concentrations are at or above the stated values.

If the 2-step process were implemented as envisioned in RPP-RPT-38152, the following methods would be performed on samples to acquire the above analytes: inductively coupled plasma/mass spectroscopy, alpha energy analysis, inductively coupled plasma spectroscopy, ion chromatography, gamma energy analysis (GEA), separation/beta counting for ^{90}Sr, separation/GEA for ^{129}I, spectrophotometric for cyanide, and semivolatile organic analysis by gas chromatography/mass spectroscopy (GC/MS) for TBP. Cobalt-60 concentration will be obtained by GEA along with ^{137}Cs. Cobalt-60 and ^{99}Tc sample results will be used to assess the relationship of these radionuclides in the soil. The sampling and analysis plan (Appendix A/RPP-PLAN-38777, *Sampling and Analysis Plan for Phase 2 Characterization of Vadose Zone Soil in Waste Management Area C*) provides more detail on the sampling and analysis for this work plan.

3.5.2 Optimizing for Organics and Polychlorinated Biphenyls, Pesticides, and Gasoline and Diesel Range Organics

In RPP-RPT-38152, five direct push locations are identified as candidate sites that have the highest potential for providing data on organic waste releases associated with tank wastes. The five candidate direct push sites are associated with UPR-81 (three locations at Site P) and on the northwest and northeast side of SST C-103 (two locations at Site L).

3.5.2.1 Sources of Organics at Sites L and P. For these two sites, WIDS indicates that the release occurred in the waste transfer line near the 241-CR-151 diversion box on October 15, 1969. The release is associated with the 241-CR-151 diversion box, the 241-C-102 tank and the PUREX 202-A Building. The source of the release was in an underground transfer line from the 202-A Building to the 241-C-102 tank via the 241-CR-151 diversion box. LAUR-93-3605, *Analysis of the History of 241-C Farm* states:

> "An organic layer was noted in C-102 in 1969 and reported (Anderson, T. D. "Organics in 102-C Tank," letter to W. L. Godfrey, October 2, 1969) to be 36 kgal. This organic layer was subsequently transferred to C-103 in a P-10 pumping of C-102 in 1975. There is a recorded transfer of 111 kgal in '75-4, but the level change in C-102 indicated that only 25 kgal was transferred, with another 8 kgal in '78-3, for a total of 33 kgal. Presumably, this combined 33 kgal transfer was largely the organic layer, and would have left 3 kgal in C-102."

The event description in Table 2-8 in this document for row Date = 3-1965 Waste Type = PUREX CWP2 is given below.

> "A liquid level rise in Tank 103-C, the cesium feed tank, was apparently caused by a failed line in the encasement between the 152-CR diversion box and Tank 102-C which permitted coating waste from the PUREX Plant to leak into the encasement and drain to Tanks 101-C, 102-C, and 103-C via the tank Pump pits. Coating waste has been routed through a spare line to Tank 102-C and no further leaks have been detected. The coating waste solution accumulated in Tank 103-C did not significantly affect cesium loading capability as a cask was loaded normally following the incident.
>
> Note: Pipeline 8041 is inside a concrete encasement was used to route the PUREX CW to SST C-102 (see drawing H-2-44501, sheet 92). This encasement traverses from diversion box 241-CR-152 along the west side of SSTs C-101, C- 102, and C- 103. In order for the PUREX CW to drain into SSTs C-101, C-102, and C-103, the encasement containing the failed transfer pipeline must have partially filled with waste. The integrity of this encasement is unknown and may have leaked waste to the soil.
> Drawing H-2-2338, sheet 45 indicates pipeline 8041 is out of service. Pipeline 8041 connects from nozzle U-3 in the 241-CR-152 diversion box and nozzle U-2 in pit 02C atop SST C-102."

Based on this information it would appear that the potential exists that more than one release may have occurred in and around CR-151, CR-152 and C-101/102/103 tanks from 1965 to 1969. While waste is referenced as PUREX coating waste in WIDS or PUREX cladding waste in this document, the presence of organics is documented in tank C-102 during this time frame. While these data are inconclusive that a release of organic contaminated waste occurred, the rationale for selecting sites in the DQO was to identify areas of known or suspected releases having some potential for containing organic contamination. It was felt that sample locations "L" and "P" satisfied these criteria which are located at each end of the encasement.

3.5.2.2 Organics Optimization Rationale. At these five locations at Sites L and P, following the spectral gamma and neutron logging, the entire suite of analytes will be analyzed in the sample zones. Tributyl phosphate will be used as the indicator organic for the occurrence of any organic contamination associated with tank waste. Tributyl phosphate is a known tank waste contaminant because it was used extensively as a solvent in the reprocessing of spent nuclear fuel. Tributyl phosphate was chosen because it has the highest probability of being found. It is the only organic constituent other than acetone and 2-Butanone found above detection limits in all tank residual samples and it is found at higher concentrations 75 to 73,000 µg/g (mg/kg) which is 10 to 100,000 times higher than all other organics including PCB. It was presented during the DQO process that if TBP is not found then it is unlikely that other organic (i.e., volatile organic analysis, semi-volatile organic analysis, diesel range organics/gasoline range organics, PCBs) contaminants related to tank waste would be found. The DQO team agreed to use this compound as an indicator for tank waste organics.

Furthermore, if the data for the organic analytes from the pre-retrieval samples taken at the C-200 tanks is examined, the Best Basis Inventory reports the following organic analytes were found above the MDL in the pre-retrieval samples: Butylbenzylphthalate, 1-Butanol, Acetone,

Aroclor 1254, 2-Butanone, Xylenes (total), Xylene (m & p), Trichloroethene, Xylene (o), Hexone, Methylenechloride, and Toluene. The mean concentrations for Butylbenzylphthalate, 1-Butanol, and Acetone were 66.7 µg/g, 16.8 µg/g, and 1.01 µg/g, respectively. The only PCB above MDL was Aroclor-1254 with a mean concentration of 0.46 µg/g. 2-Butanone had a mean concentration of 0.29 µg/g, with the rest of the non-detected organic analytes having a mean concentration of less than 0.1 µg/g. Tributyl phosphate was found as a tentatively identified compound (TIC) in all of the pre-retrieval samples with the highest concentration found at tank C-204 at greater than 200,000 µg/g. Tributyl phosphate in the post-retrieval samples for these tanks had results ranging from ~5,000 mg/kg (C-201) to ~73,000 mg/kg (C-204).

Other organic compounds found above detection limits in some, but not all tank residuals, are Butylbenzylphthalate (3.27 mg/kg [C-103]), Di-n-butylphthalate (6.11 mg/kg [C-103], 6.08 mg/kg [C-204]), Hexone (2.27E-02 mg/kg [C-202]), and Xylenes (Total) (2.0E-02 mg/kg [C-203]).

If TBP is not detected in any of the samples, then organics will be eliminated from the list of contaminants of potential concern (COPC) and not analyzed for at other locations in WMA C. If TBP is detected in any of the samples, then organics will remain on the list of COPCs and organic compounds will be analyzed for as part of the step 2 suite of analytes following a detection of the step 1 tank waste trigger constituents. Other volatile and semivolatile compounds were rejected as either not being indicators of tank waste or more importantly are common laboratory contaminants. For example, the following compounds are recognized as common laboratory contaminants detected in the analysis for volatile and semivolatile organics:

- Volatiles
  - Methylene chloride
  - Acetone
  - 2-Butanone
  - bis-2 Ethylhexyl Phthalate
  - Diethyl Phthalate
  - Benzyl Phthalate
  - Chloroform (volatile organic compound)

- Semivolatiles
  - Common Phthalate contaminants
  - n-Butyl Phthalate
  - n-Octyl Phthalate.

If observed in samples, the associated blanks will be considered when deciding if these are from contamination associated with a tank release or a laboratory source. This list of contaminants is not all inclusive. However, the list serves to illustrate the potential for false positive results being reported due to laboratory contamination. Identifying common laboratory contaminants and accounting for their influence on how data are interpreted will improve the decision error by reducing the potential for false positives to be interpreted as contaminants being present and the risk that a decision is made to remediate a site that is not contaminated.

Polychlorinated biphenyls are of specific concern to direct contact and ecological risk and will be sampled in the near-surface vadose zone only. Three vadose zone samples will be collected in the region of 0 to 15 ft bgs at the five direct push locations (15 samples) and analyzed for Aroclors and congeners. If PCBs are not detected in any of the samples, then they will be eliminated from the list of COPCs and not analyzed for at other locations in WMA C. If PCBs are detected in any of the samples, then they will remain on the list of COPCs and be analyzed for as part of the step 2 suite of analytes following a detection of the step 1 tank waste trigger constituents. The results from the initial five sample locations will be used to attempt to establish a correlation between PCB Aroclors and congeners that would support future analysis for only PCB Aroclors.

Pesticide application is widespread throughout the tank farms as part of operation and maintenance activities to prevent vegetation from becoming established. Petroleum products were also used, principally as fuels. At these five sites, samples collected from 0 to 14 ft will be evaluated for pesticides and petroleum. If a pesticide or petroleum product is detected at or above its threshold value in any of the five samples, then they will remain on the list of COPCs and will be analyzed for as part of the step 1 suite of screening analytes at subsequent sample locations. If no pesticides or petroleum products are detected at the five sites, they will be dropped from further analysis. The pesticides and petroleum products that will be analyzed are the following:

Aldrin	0.1 mg/kg
Benzene hexachloride (including lindane)	6 mg/kg
Chlordane	1 mg/kg
DDT/DDD/DDE (total)	0.75 mg/kg
Dieldrin	0.07 mg/kg
Endrin	0.2 mg/kg
Hexachlorobenzene	17 mg/kg
Heptachlor/heptachlor epoxide (total)	0.4 mg/kg
Pentachlorophenol	3 mg/kg
TBP	Detected at MDL
Gasoline range organics	100 mg/kg
Diesel range organics	200 mg/kg

Gas chromatography/mass spectroscopy will be used to screen for pesticides to determine if a method-based analysis for pesticides is required. If the GC/MS analysis does not detect any of the pesticides, no further analysis will be conducted. Organic chemicals will be analyzed by the following methods: Gas chromatography/mass spectroscopy for volatile organic compounds (VOC), extraction and GC/MS [or gas chromatography/flame ionization detection (GC/FID)] for semivolatile organic compounds (SVOC), and gas chromatography/electron capture detection (GC/ECD) for PCBs. In addition, a number of samples will be analyzed by high resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS) for PCB congeners.

3.5.2.3 Application of Organics Optimization. Since initiation of Phase 2 WMA C field investigation work, sampling has been completed at the three Site P locations, two Site L locations, and other locations. Analytical results obtained from a total of nine soil investigation locations (including the five at Sites L and P) were evaluated in FY 2011 to determine whether

an opportunity exists to optimize the investigation at the remaining sites. As a result of this evaluation, and as documented in Letters 11-TPD-020 and 11-NWP-053, DOE and Ecology have agreed to optimize the WMA C investigation and focus on constituents of highest concern. The remaining soil samples will be analyzed for a reduced suite of organic analytes. Semi-volatile organics, PCB Aroclors, and pesticides will continue to be analyzed; however, analysis of volatile organics, gasoline and diesel range organics, PCB congeners, ethylene glycol, and monobutyl and dibutyl phosphate is discontinued for the FY 2011 sampling locations.

3.6 INTERIM MEASURES

This section describes the interim measures that have been evaluated and/or implemented as they relate to WMA C. Interim measures are initial response actions that can be taken while characterization activities are under way and while long-term strategies are being developed to reduce the impacts of past releases on groundwater under RCRA. Interim measures do not require comprehensive evaluation in a CMS. Interim measures identified to date for WMA C focus on actions to minimize infiltration and contaminant migration to groundwater. Interim measures have been implemented at WMA C during the past several years.

Corrective measures are response actions that are intended to reduce contaminant migration to groundwater to acceptable regulatory levels. Corrective measures require the balancing of risk, benefits, and costs. In general, corrective measures involve a substantial commitment of resources, require a more thorough evaluation prior to implementation, and are intended to provide a more permanent solution to the long-term threats posed by a contaminant release. Detailed evaluation of the proposed WMA C corrective measures will be undertaken in the Phase 2 RFI/CMS report based on the results of this Phase 2 field investigation for WMA C and the field investigation report for WMAs C and A-AX (RPP-35484). An accelerated CMS would be required if an imminent threat or danger to the public or environment arises.

Current interim measures that have been implemented include the following (DOE/ORP-2008-01 Appendix K):

a. All waterlines within WMA C have been cut and capped or pressure tested.
b. All groundwater wells and drywells have watertight caps.
c. Several run-on control structures were constructed adjacent to WMA C.

Some waterlines were not needed, thus they were abandoned, effectively removing them as sources of inadvertent recharge.

RPP-5002, *Engineering Report Single-Shell Tank Farms Interim Measures to Limit Infiltration Through the Vadose Zone* identified wells and drywells as "unfit for use." These wells are potential preferential pathways for downward contaminant migration. The majority of wells identified in RPP-5002 are the drywells used to monitor movement of contaminants through the vadose zone. The Tank Summary Data Reports associated with GJO-98-39-TAR discuss drywells (i.e., boreholes) that should be sealed and abandoned or decommissioned in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells." These

include boreholes 30-00-10, 30-00-06, 30-00-03, 30-00-09, and 30-00-12. Borehole 30-00-10 is blocked at a depth of ~52 ft, and the perforated casing in this borehole might provide a migration path for shallow contaminants to reach greater depths. The other boreholes all are perforated and provide a potential avenue for enhanced migration downward into the vadose zone. Borehole 30-08-03 should be plugged and abandoned (GJO-98-39-TAR and RPP-35484).

Upgradient surface water run-on control measures consist of some combination of regarded ground surfaces, soil/gravel berms, asphalt pavement, concrete curbs, gutters and valley drains, and culverts. All of these were constructed outside the SST farms to prevent surface water from pressurized waterline leaks outside of the tank farm boundary and unusual meteorological events from flowing onto the tank farm areas.

During FY 2002, several run-on control structures were designed and constructed adjacent to WMA C. Berms were placed to redirect surface water away from the tank farm surfaces, and curbs and gutters were placed along the roadways to redirect runoff.

In addition, historical pipeline leak events (e.g., UPR-200-E-82 and UPR-200-E-86) have gunite caps placed on the surface. These gunite caps provide an interim solution to the long-term threats posed by contaminant releases by minimizing infiltration, contaminant migration to groundwater, and contaminant exposure to present-day workers.

4. WORK PLAN RATIONALE AND APPROACH

The Phase 2 RCRA corrective action process is the RCRA-specified method by which UPRs 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. Furthermore, this RCRA-specified method is consistent with the CERCLA method for characterization and remediation. The HFFACO (Section 7.1) lists and compares the major steps involved with cleanup of RCRA and CERCLA "past practices" and concludes they are functionally equivalent (see also Section 3.1.2 of RPP-PLAN-37243). Objectives and data needs must be identified before designing a data collection program to support the Phase 2 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. The data needs for field characterization efforts at WMA C were identified through a DQO process (RPP-RPT-38152) that was executed based on the requirements established in the HFFACO commitments (Ecology and DOE 2007). The data identified in the DQO process will be collected in accordance with HFFACO Milestone M-045-60 (i.e., this work plan), HFFACO Milestone M-045-00, and HFFACO Appendix I.

4.1 RATIONALE

Further understanding of subsurface conditions and contaminant migration processes is required to support decision-making on interim measures and corrective measures (Section 3.2.3). A comprehensive list of data needed to support these decisions was developed based on the current level of understanding in a DQO process (RPP-RPT-38152). However, it is generally recognized on both a technical and regulatory basis that present knowledge of existing contaminant concentrations, contaminant inventory, distribution of contaminants in the vadose zone from past releases, and uncertainties associated with contaminant migration processes is insufficient to support future decision-making for corrective actions. Therefore, there is a need to collect additional information through Phase 2 field and laboratory investigations, which will be supplemented by ongoing groundwater and vadose zone monitoring data, to support decisions on corrective actions and WMA closure. Groundwater monitoring data are collected on a regular basis as part of the RCRA groundwater monitoring program, while vadose monitoring (HRR leak detection monitoring and leak detection mitigation and monitoring) takes place during waste retrieval operations.

Characterization objectives and data needs for WMA C were developed during the DQO process (RPP-RPT-38152) carried out under the Phase 2 Master Work Plan (RPP-PLAN-37243) and this work plan. The development of this document and characterization activities for Phase 2 were supported by the DQO process.

The DQO process (EPA/240/B-06/001) is a planning approach, based on the scientific method,[15] for defining the decisions that any data collected should satisfy. The EPA seven-step DQO

[15] The scientific method involves the principles and processes regarded as characteristic of or needed for scientific investigation, including rules for concept formation, conduct of observations and experiments, and validation of hypotheses by observations or experiments.

process and several associated activities and workshops were implemented to support preparation of this work plan. These workshops included participants from the TOC, Ecology, DOE, and other key Hanford Site programs (see also Section 1.2). As appropriate, the DQO process included project managers from Ecology and DOE, with technical support by the TOC staff, and input from other key Hanford Site programs and agencies.

The DQO process provides assurance that the type, quantity, and quality of environmental data used to support remediation decisions are suitable for the intended application. The process establishes a consistent, cooperative, and streamlined approach that encourages optimum use of available data, information, and technical resources.

Before initiating meetings to discuss characterization activities to be conducted during Phase 2, the Tank Farm Vadose Zone Program 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 Phase 2 characterization effort, a review of the available information on the current state of knowledge of WMA C subsurface contamination was conducted by the Tank Farm Vadose Zone Program technical team. The review results are summarized in Chapters 2, 3, and 5 of this work plan.

A series of DQO meetings were held from February 6, 2008, to June 18, 2008, that focused specifically on the data needs for the field characterization efforts to be conducted at WMA C. These meetings served to identify the following:

a. Existing data and what is currently known about WMA C.
b. Data needs that will likely be satisfied by Phase 2 characterization activities.
c. Options for data collection from the additional characterization activities.

These meetings included representatives from Ecology, DOE, and Hanford Site contractors. Meetings held as a part of the DQO process involved varying levels of involvement by all participants. The DQO meetings provided a foundation of existing information and identified characterization options for consideration by the decision makers.

Through the DQO process, the primary goal of the WMA C field investigation was determined to be implementation of 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. This work plan focuses on additional characterization data needed to support near-term CMA decisions as they relate to soils within and immediately surrounding WMA C. The characterization effort is designed to provide data that, when combined with historical data, including data collected under the Phase 1 RCAP and near-term field investigations, will allow informed corrective measures decisions to be made. Additional engineering data associated with corrective measure technologies provided in RPP-ENV-34028, *Central Plateau Vadose Zone Remediation Technology Screening Evaluation* and cost and implementability studies will provide the additional information needed to make CMA decisions. This work plan only

implements the additional soil characterization data needed to fulfill the WMA C DQO (RPP-RPT-38152).

The rationale for this Phase 2 RFI/CMS work plan is based on the various conceptual site models presented in Section 3.3 and regulator input through the DQO process. Ecology expressed the desire to achieve the following goals during this Phase 2 characterization effort: (1) evaluating UPR sites associated with WMA C, (2) addressing stakeholder concerns related to contaminant migration, (3) near-surface (less than 15 ft bgs) soil sampling to support direct contact and ecological risk assessment, and (4) other potential areas of unintentional releases associated with the ^{99}Tc groundwater contamination and ability to close WMA C after retrieval completion. The sampling strategy is focused on addressing these data needs. The rationale for site selection is given in Section 4.4.

4.2 DATA NEEDS

Current understanding of the nature and extent of contamination at WMA C 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 100 to 150 ft bgs using drywells located around the tanks and groundwater monitoring from groundwater monitoring wells. Historical drywell gross gamma data were collected from the early 1960s through 1994; however, detailed analysis of the gross gamma data has only recently been conducted. For the C Farm, RPP-8321 was issued on this subject.

Comprehensive spectral gamma logging of all drywells in WMA C was completed in the 1996 through 1999 period as a baseline, then revisited in 2000, and after 2000 as necessary to support waste retrieval leak loss determinations as specified in tank waste retrieval work plans and additional vadose zone characterization investigation needs. In 2000, a new analysis technique, a high rate logging system, was deployed to measure ^{137}Cs concentration levels in high gamma flux zones where the spectral gamma logging system was unable to collect usable data because of high dead times and detector saturation from the baseline period. Spectral gamma logging reports were issued for C Farm (GJO-98-39-TAR and GJO-98-39-TARA). Spectral gamma logging data provide insight into the distribution and movement of specific gamma-emitting contaminants (e.g., ^{137}Cs, ^{60}Co). More recently, soil characterization data have been collected that partially indicate the distribution of non-gamma-emitting mobile tank waste contaminants including ^{99}Tc, hexavalent chromium, and nitrate (see Section 3.2). While there are 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 contaminants responsible for the observed groundwater contamination. Specific sources were identified through field investigations conducted at tank C-105 (borehole C4297), and direct pushes at UPR-200-E-82, UPR-200-E-86, and UPR-200-E-81. At UPR-200-E-82, ^{99}Tc and nitrate were found at a depth of ~80 ft bgs with maximum and coincident concentration of water-extractable ^{99}Tc (10 to 30 pCi/g dry sediment) and nitrate (10 to 20 µg/g dry sediment) (RPP-35484).

In borehole C4297, elevated concentrations of several constituents in the sediments are attributed to fluids from tank C-105. An elevated pH zone (8.0 to 9.3) occurs between 40 and 52 ft bgs. The primary set of tank waste constituents includes ^{99}Tc, sulfate, nitrate, and sodium. Elevated concentrations of water-extractable ^{99}Tc (~0.14 to 8.4 pCi/g dry sediment) extend between 40 and 159 ft bgs, and show a bimodal distribution with depth. Peak concentrations of water-extractable ^{99}Tc and nitrate were measured at depths between 133 and 154 ft bgs. Elevated water-extractable sodium concentrations (20 to 131 µg/g) range from 20 to 60 ft bgs, with a well-defined peak concentration zone between 40 and 60 ft bgs (RPP-35484).

During the DQO process, the participants determined that the primary focus of the Phase 2 data collection effort at WMA C should be directed toward further characterizing the contamination sources in association with CMAs for the soils. This effort should improve the understanding of 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 contaminated vadose zone is still limited and is based primarily on indirect evidence, the focus of the Phase 2 data collection program at WMA C will be on sampling the vadose zone soils in areas of known releases that include spills, tank leaks, and overfill events within the tank farms, and analyzing the samples for a range of contaminants of interest and in areas where it is suspected there has been a release that has not been documented in WIDS. These sites have been identified in a review of process records.

Isotopic analysis of vadose zone porewater and groundwater to identify sources was not considered in the DQO process (RPP-RPT-38152) for the following reasons:

1. No other liquid waste disposal facilities (e.g., cribs, trenches, ditches) nearby WMA C; releases from WMA C are considered the source of contamination to the groundwater (RPP-35484).

2. The difficulty in identifying a particular tank as a source because of the timing and nature of the waste streams to each individual tank (see Table 2-5).

Guidance under RCRA (EPA 530/SW-89-031, *Interim Final RCRA Facility Investigation (RFI) Guidance Volume I of IV Development of an RFI Work Plan and General Considerations for RCRA Facility Investigations*) and CERCLA (EPA/540/G-89-004, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA – Interim Final*) states that if suspected releases are confirmed during initial investigations, further characterization of such releases will be necessary. This characterization includes identification of the type and concentration of hazardous waste or hazardous constituents released, the rate and direction at which the releases are migrating, and the distance over which releases have migrated. Therefore, UPRs will be addressed as potentially contributing sources to the vadose zone in WMA C and the characterization efforts will support the risk assessment and subsequent alternatives evaluation to select a corrective action. In addition to the UPRs that exist within the WMA boundary, there are UPRs that are either adjacent to the boundary but outside the fenceline or are in close enough proximity to the WMA and therefore warrant integration in RCRA corrective action process planning.

4.3 CHARACTERIZATION OPTIONS

Known or suspected release sites are described in Sections 2.4.3.and 2.4.4. They are the sources for the potentially contaminated soils still remaining to be characterized and are briefly discussed in Sections 3.1.1 and 3.1.2. These known or suspected release sites present characterization options for further investigation.

RPP-ENV-38838, *Tank Farm Vadose Zone Program Characterization Processes* identifies and describes the possible characterization technologies that could be deployed for this effort, including a description of the advantages and disadvantages of each characterization technology. Through the DQO process (RPP-RPT-38152), characterization options include direct push technology, targeted and WMA C SGE, as well as drywell and groundwater monitoring well spectral gamma logging to investigate possible contamination in the soils at WMA C. The selection of characterization technologies is described in Section 4.6.

The direct push technology has been capable of obtaining a sample as deep as 240 ft bgs. It has the capability of obtaining more than one sample per probehole and does not bring up drill cuttings. Any drill cuttings brought to the surface would require appropriate disposal. This meets the same objective as drilling a deep borehole but without drill cuttings brought to the surface, given the data collection objectives.

The SGE technology provides a nonintrusive method of delineating potential release sites across an area. This method is being tested at three locations within WMA C DQO boundary to determine if deep electrodes will provide valuable vertical dissemination of potential releases high in salt content. The first test of the high-resolution, three-dimensional SGE with deep electrodes was conducted as part of Revision 0 of this work plan. The test ran from October 2008 to July 2009 at UPR-200-E-81 with the results documented in RPP-RPT-41236, *Surface Geophysical Exploration of UPR 200-E-81 Near the C Tank Farm*. The SGE testing at UPR-200-E-81 acquired three-dimensional resistivity data using electrodes placed at depth coupled with incorporation of a priori information on infrastructure, and resulted in a quantitative reduction in the magnitude, size and depth of the low resistivity feature identified at UPR-200-E-81. Depth of the buried electrodes relative to the depth of the low resistivity feature was the most relevant variable in the analysis.

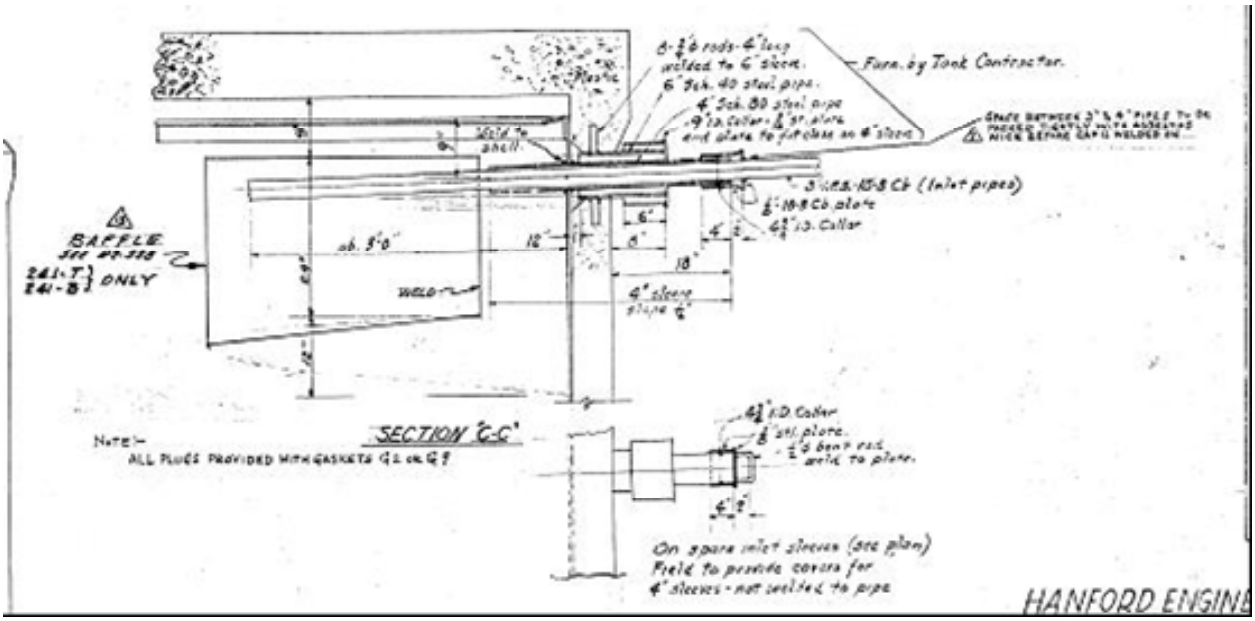
Drywell and groundwater monitoring well spectral gamma logging has been used in the tank farms and is a proven technology. Based on review of this data, it was determined some of the groundwater monitoring wells have not been logged and 8 years have passed since the last drywells were logged. Thus, this effort is to resolve data gaps that could support migration of contaminants, in particular ^{60}Co migration.

Some of the characterization options will have to address the spare inlet ports that may have been breached as discussed in Section 2.4.4. Additional information is provided in Section 4.3.1 to understand why these spare inlet ports were specifically selected. Additional probable contamination areas that exist in other supporting facilities associated in and around WMA C are discussed in Section 4.3.2.

4.3.1 Potential Waste Losses from Spare Inlet Nozzles

The SSTs in the C Farm are each equipped with four horizontal inlet nozzles, as shown in Figure 4-1 (W-72742, *Hanford Engineer Works 20'-0" Dia. Storage Tanks Arrangement Bldg# 241-T, 241-U, 241-B, 241-C*, and W-72743, *Hanford Engineer Works-B'l'd. #241 75'-0" Dia. Storage Tanks T-U-B & C Arrangement*). While Figure 4-1 depicts a typical inlet nozzle for the 200-series SSTs, the inlet nozzles were constructed the same way in the 100-series SSTs. An inlet nozzle consists of an inner 4-in.-diameter schedule 80 steel pipe with an outer 6-in.-diameter schedule 40 steel pipe. The outer 6-in.-diameter steel pipe is imbedded in the concrete sidewall of the SST, attached to the exterior of the carbon steel sidewall using mastic, and protrudes ~8 in. from the exterior of the tank wall. The 4-in.-diameter steel pipe is inserted through the 6-in.-diameter steel pipe, protrudes ~12 in. inside the SST and ~18 in. beyond the exterior of the concrete sidewall of the SST. The 4-in.-diameter steel pipe is welded to the sidewall of the carbon steel tank. An 8-in.-diameter steel collar is tightly fitted around the 6-in.-diameter steel pipe where the 4-in.-diameter steel pipe exits this outer pipe. Process waste lines, which are 3-in. inner diameter, 11 gauge 18-8Cb (i.e., an early form of stainless steel) tubing, are inserted through the 4-in.-diameter steel pipe and extend ~4 ft inside the SST.

Figure 4-1. 20-Foot Diameter Single-Shell Tank Detail Showing Inlet Nozzles (Best Image Available)



The elevation of the four inlet nozzles for the 100-series SSTs is 17 ft 4 in. from the center of the tank bottom (H-2-1744, *Tank Farm Riser & Nozzle Elev*). The elevation of the four inlet nozzles for the 200-series SSTs is 24 ft 7 in. from the center of the tank bottom (H-2-1744). All inlet nozzles on the 100-series SSTs in C Farm are located at approximately the 8 o'clock position relative to north being 12 o'clock. For the 200-series SSTs, two spare inlets are located approximately at the 12:30 o'clock position, and two spare inlets are located approximately at the 9:30 o'clock position relative to north being 12 o'clock.

The process waste lines connecting to the inlet nozzles on SSTs C-101, C-104, C-107, C-108, C-110, and C-111 are supported by concrete troughs (W-74108 and H-2-2929, *Waste Fill Lines & Clean Outs 1st Cycle Waste 241-C Tank Farm*). The concrete supports are 30 in. tall and 32 in. wide, except for those at tank C-101, which are 30 in. tall but only 26 in. wide. The concrete support beams have a 4-in.-tall shoulder, resulting in a 24-in.- (only 18 in.- for tank C-101) wide trough running down the center of the beam.

Process waste lines from diversion box 241-C-252 connect to two inlet nozzles on each of the C-200 series SSTs and are supported by concrete troughs [W-74317, *Hanford Engineering Works Building No. 241 T-U-B & -C Concrete Details of Pipe Supports (20' Dia. Tanks)*]. The other two inlet nozzles are spares on the C-200 series SSTs and are not supported. For the 200-series SSTs, the concrete-support troughs are 37 in. tall and 20 in. wide with a 4-in.-tall shoulder. The interior width of the trough supporting the pipelines is 12 in.

Some of the inlet nozzles on the SSTs are spares and do not have installed process waste lines. The design for the SSTs identified that a 4.5-in.-diameter cover was to be placed over the 4-in.-diameter spare inlet nozzles (see Figure 4-1). It is known that some of the spare inlet nozzles are poorly sealed. Tank BX-102 was overfilled in February 1951 and waste was lost to the ground through the spare inlet nozzles (HW-20742, *Loss of Depleted Metal Waste Supernatant to Soil*). As part of the investigation into the waste loss from SST BX-102, spare inlet nozzles on several SSTs were examined (specific tanks were not identified). This investigation revealed "…that some [inlet nozzles] have blanks which are welded tight, some have tapered wooden plugs driven in the spare nozzle covered by a cap and sealed with waterproofing, and some have caps covered with a waterproofing membrane and then sealed in cement" (HW-20742, page 5).

Based on the SST BX-102 waste loss investigation, the potential exists that some waste may have been similarly released in the C Farm if any of the SSTs were filled above the height of the spare inlet nozzles. If waste losses occurred through the spare inlets for SSTs C-101, C-104, C-107, C-108, C-110, and C-111, the waste may have been contained and channeled along the concrete troughs.

The waste volumes in all WMA C SSTs were reported monthly from January 1945 through December 1960 (except no data for August 1951 through March 1952), semiannually from January 1961 through June 1965, quarterly from September 1965 through September 1976, and monthly thereafter. Single-shell tanks were removed from service in January 1981 and no waste additions were allowed after this date.

Based on a review of waste volume data for the WMA C tanks, SSTs C-101, C-103, C-104, C-106, C-109, C-111, C-201, C-202, and C-204 were filled with waste above the elevation of the spare inlet nozzles on several occasions. This overfilling could have potentially resulted in waste leaking from these SSTs into the surrounding soil. Information available as of the issuance of Revision 1 of this work plan regarding the date and waste type present in each SST when the tank was filled with waste above the elevation of the spare inlet nozzles is summarized in Table 2-7. Subsequent reviews of historic records indicate that it is likely that all of the WMA C tanks except C-203 were overfilled at least once during operations.

4.3.2 Planned Release Facilities Such As Cribs, Drains and Discovery Sites

There are several facilities in and around WMA C which were designed to discharge into the vadose zone. No documentation that discharges occurred has been located. These facilities include the following:

a. **Cesium Loadout Facility Drain** – The cask loading area within the 241-C-801 building has a drain line connecting to the valve pit. The valve pit and cask loading area have separate drain lines connecting to a drywell located outside of the tank farm fence (drawings H-2-4573 and H-2-4565). This drywell is located ~23 m (75 ft) north of the C-801 building, outside the tank farm fence (DOE/RL-88-30, page 659). No record was located that provides information on the volume and types of wastes potentially discharged to this drywell. An unknown amount of PUREX P1 and P2 waste types along with decontamination solutions may have been discharged to this drywell as a result of operations conducted at the C-801 building.

b. **271-CR French Drains, Drywell Drain, and Tile Fields** – The 271-CR Building had several drains associated with it that were located both inside and outside of the WMA C fenceline. Drains included a French drain, drywell drains, and two tile fields. The two tile fields were associated with the septic tank system. An original tile field was replaced with a second expanded system along with a new septic tank. One of the drains appears to have been associated with a condensate line. Waste releases to the remainder of the drain systems, if any, are unknown and do not have associated documentation.

c. **200-E-115** – The site is located east of C Farm, south of 8th Street, across an unnamed gravel road. As a result of routine surveys confirming radiological contamination in this area, the Dyncorp Integrated Soil, Vegetation, and Animal Control group submitted a Waste Site Information Form to WIDS in 2000. The site was classified as Discovery until programmatic responsibility and ownership were determined in March 2001. No surveys can be found to provide information about the radiological conditions inside the posted area. Very little is known about this posted area. During an interview with the Dyncorp Radiological Group in October 2000, an assumption was made that the area was posted by the CH2M HILL Hanford Group, Inc. East Tank Farm Radiological Control Group. A review of underground pipeline locations did not indicate a pipeline at this location. In 1980, a larger area of posted contamination (see UPR-200-E-91) was located in the same vicinity. The contaminated soil from UPR-200-E-91 was removed in 1981. Because so much time has passed, it is difficult to determine if the two sites are related. In June 2004, 200-E-115 was stabilized with gravel and posted as an Underground Radioactive Material Area.

4.4 SITE SELECTION

During the DQO process, it was determined that 23 areas of interest, referred to as sites, would be characterized using a variety of characterization techniques. Sections 4.4.1 through 4.4.7 provide the rationale for choosing these 23 sites and describe modifications to the original plan

that have been agreed upon based on information generated as the characterization effort proceeded.

4.4.1 Site Selection using Alternative 1: Phase 1 Conceptual Model

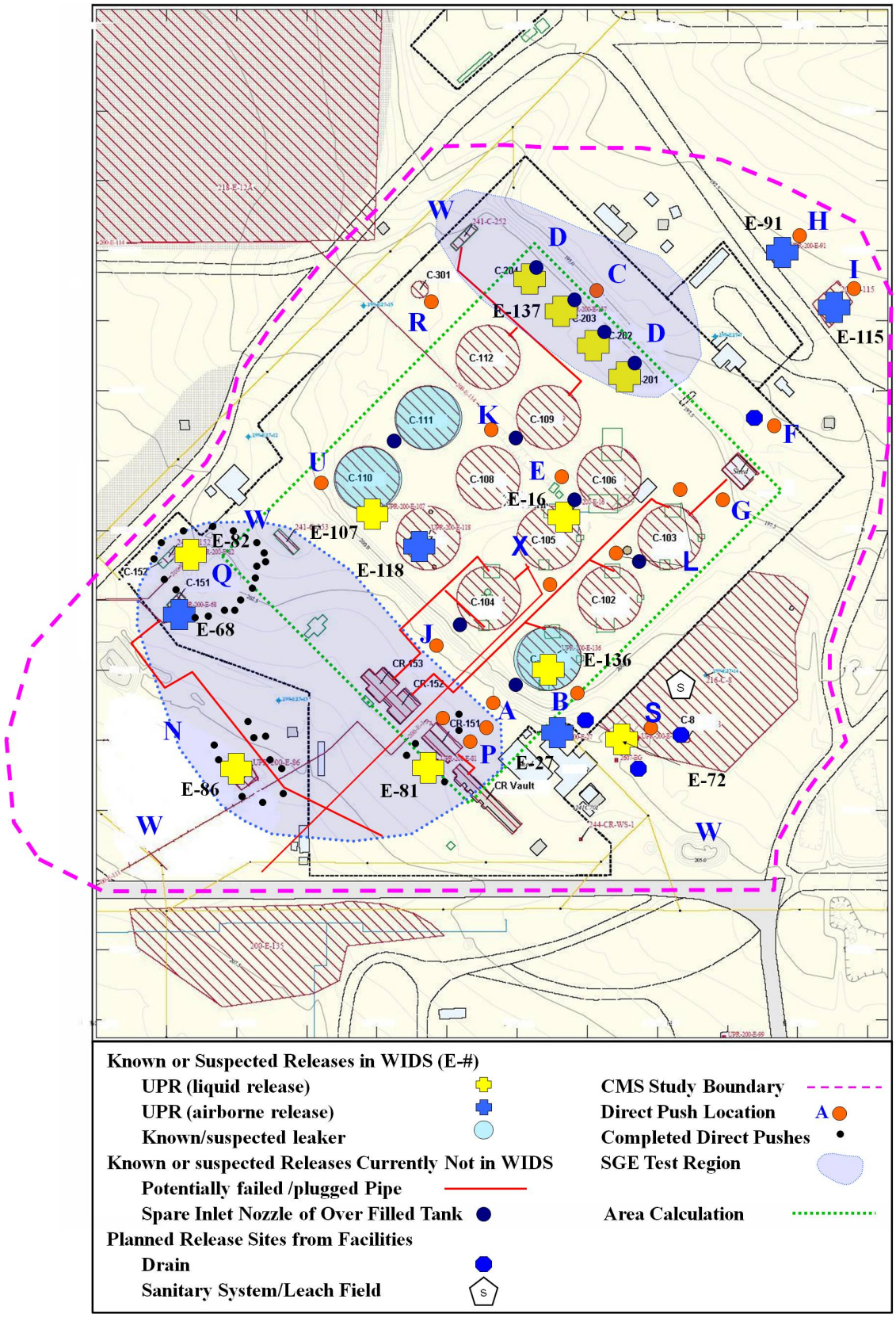
The Phase 1 conceptual model was used to select a number of sites to investigate. These sites consist of known or potential release sites that may have impacted the soils (Figure 4-2). To support tanks that may have been overfilled and potentially lost waste out the spare inlet ports, sites A (C-101) and J (C-104) were chosen.

Sites B, C, D, R, U, and V were chosen to investigate possible tank leaks and/or overfill events that lack existing drywell monitoring coverage. This includes southeast side of C-101 (Site B), the C-200-series tanks (Sites C and D), and C-801 (Site R). Sites B, C, D, U, and V are also being investigated to evaluate alternative conceptual model 2.

At sites C and D, RPP-RPT-38152 called for installation of up to nine direct push sampling boreholes to determine whether the C-200-series tanks leaked. Installation of the first of these boreholes was initiated in FY 2011. While planning for installation of this first borehole was in progress, the final results of the SGE investigations at site N became available. Through a series of discussions, the Tri-Parties agreed to modify the investigation of sites C and D to include use of SGE. Four boreholes near the C-200 tanks will be equipped with deep electrodes to allow for three-dimensional SGE investigation of the area to identify geophysical anomalies that could indicate that soils have been affected by tank waste. The presence and intensity of any detected anomalies would be evaluated together with soil analytical results from the area, to determine whether there is a need for any further investigation using direct push sampling. This approach was deemed more effective than direct push sampling alone to identify both historic waste losses and leaks that may have occurred during retrieval of the C-200 tanks.

Sites U and V are associated with tanks C-110 and C-111 respectively; both tanks were previously assumed to have leaked in the past. However, recent assessments concluded that it is likely that neither of these tanks leaked (RPP-ASMT-38219, *Tank 241-C-110 Leak Assessment Report*, and RPP-ASMT-39155, *Tank 241-C-111 Leak Assessment Report*). Low gamma activity on the east side of tank C-110, in drywell 30-10-09 (site U) was determined to be the result of a supernate release from the tank spare inlets during periods when the tank was overfilled. Because no liquid level decrease was observed in the tank, the release was estimated to be less than 2,000 gal. The direct push sample at site U was planned to attempt to further confirm the release near tank C-110 was an overflow. Similarly, historical logs and spectral gamma logging show no evidence of a past leak from tank C-111. Tank C-111 was previously classified an “assumed leaker” based on a liquid level decrease of 8.5 in. from 1965 through 1969 that would equal a total of 23,400 gal. Some of the loss was attributed to evaporation, and in 1989, assuming a tank waste temperature of 100°F, a leak loss of a 5.5 kgal was estimated. However, new data show that the tank temperature was at least 190°F at the time of the liquid level decrease. Calculations indicate that at 190°F, the entire liquid level decrease can be attributed to evaporation. Therefore, it is likely that little or no supernate was released from tank C-111 to the soil (RPP-ASMT-39155). As a result, it has been determined that a direct push sample near site V is unlikely to yield information valuable to the soil characterization effort and is not needed.

Figure 4-2. Sample Locations for Phase 2 Characterization



Although UPR-200-E-82 (Site Q) was investigated during Phase 1, it will be further investigated as part of this work plan. At UPR-200-E-82, the highest concentration of ^{99}Tc and nitrate was found at 80 ft bgs (RPP-35484). This limiting depth (80 ft bgs) was a result of the characterization limitations of the direct push technology deployed at that time using a slant probehole to collect the sample. This slant probehole at the time of deployment eliminated the possibility of going deeper in light of the gunite cap on top of this UPR. A vertical push through the gunite cap had been proposed but not implemented due to radiological control requirements, and has been eliminated from the plan. Instead, four direct push holes will be placed to a depth of ~200 ft, one on each side of the UPR, and multi-depth electrodes will be placed.
A three-dimensional SGE survey will be conducted to map the extent of any electrical anomaly resulting from this release. Since the time of the leak in December 1969 to sometime after 1991, UPR-82 was covered in sand and gravel. Sometime after 1991, the gunite cap was placed over it. This provided for over 20 years of recharge over this UPR at 100 mm/yr, providing an opportunity to evaluate the Phase 1 conceptual model or evaluate alternative conceptual models 2 and 4.

Sites P and S are also being investigated under this conceptual model. Site P (UPR-200-E-81) was chosen because a 36,000-gal pipeline leak occurred in 1969. At Site S (216-C-8 French drain) ~32,000 gal of treated tank farm processing condensate was discharged to the French drain 216-C-8 from January 1960 through March 1965. Site S is also being investigated to evaluate alternative conceptual model 2.

4.4.2 Site Selection using Alternative 2: Movement of Contaminants Down Stratigraphic Dip

Data to support the alternative conceptual model 2 of movement of contaminants down stratigraphic dip, are from sites X (C-105, new location), E (between C-109 and C-106), L (C-103 and C-106), and F (Building C-801 chemical drain). One of the problems is that waste loss from locations L and F could be commingled with other waste loss sources. As documented in RPP-35484, migration of ^{60}Co both laterally and vertically has occurred in the vadose zone from the tank C-108 transfer line leak and migrated to the northeast (downdip) toward tank C-106. Investigation at these sites will provide data to support this conceptual model.

Movement of ^{60}Co has been detected from the vicinity of tank C-108 laterally to the east and downward to greater than 120 ft bgs near drywell 30-06-10. It is possible this contamination originated from a transfer line leak (GJO-98-39-TARA).

Between tanks C-108 and C-109, a transfer line leak source is indicated by contamination in drywell 30-08-02 (RPP-14430). High ^{137}Cs concentrations occur between 20 and 22 ft bgs and peak at 1,100 pCi/g in this zone. A ^{154}Eu peak (24 pCi/g) is coincident with ^{137}Cs and the more mobile ^{60}Co is present between 50 and 80 ft bgs at concentrations up to 10 pCi/g. These contaminants were present when the drywell was installed in 1974. This contaminant plume appears to extend at least to drywell 30-06-10 where a similar ^{60}Co plume occurs between 86 and 115 ft bgs at lesser concentrations (up to 1 pCi/g). Cobalt-60 also occurs to a lesser degree in drywell 30-09-01 at 90 to 95 ft bgs. This location may represent the eastern extent of this contaminant plume. Other nearby drywells may also contain contamination that has migrated from this source.

These drywells (30-09-06, 30-09-07, and 30-09-02) along with drywells 30-08-02 and 30-06-10 contain mobile ^{60}Co that migrated in the 1980s between 40 and 115 ft bgs, according to the gross gamma record. The apparent lag time between initial discharge to the vadose zone before 1974 and the observed ^{60}Co migration in the 1980s may indicate additional leakage or enhanced migration instigated by artificial recharge (RPP-14430).

At the tank C-108/C-109 anomaly, neither of the drywells within the anomaly footprint contains significant levels of gamma-emitting contamination. The closest indication of a source term is at drywell 30-08-02, where ^{137}Cs and ^{154}Eu peak at ~20 ft bgs, suggesting another transfer line leak. Examination of more recent geophysical logging shows at least four episodes of contamination in this drywell: one prior to 1976, between 1989 and 1997, between 1997 and 2002, and between 2002 and 2006. From 1976 to 2006, ^{60}Co appears to have migrated from ~40 ft bgs to ~80 ft bgs. Whether this anomaly is related to the apparent anomaly just to the west is unclear.

Site B (southeast side of tank C-101) and S (216-C-8) are also being investigated under this conceptual model because low levels (0.6 pCi/g) of ^{60}Co were measured in the vadose zone between 130 and 250 ft bgs at groundwater well 299-E27-14. It has been speculated that the ^{60}Co has migrated to this well from either a C-101 tank leak or is the result of disposal to 216-C-8 French drain.

Additional direct push logging and sampling is also under consideration to further investigate the extent of the high activity (10^7 pCi/g) ^{137}Cs plume in drywell 30-05-07 near tank C-105. Current estimates assume that the ^{137}Cs plume may be small because it was detected in only one drywell and nearby in direct push hole C7469, and because geophysical theory suggests that ^{137}Cs would be expected to migrate about the same horizontal distance in all directions in the soil. The assumption that the plume is small seems to be supported by the observation that high activity ^{137}Cs has not been detected to date in any of the other drywells or in borehole C4297 that were installed to investigate the extent of the tank C-105 plume. Another possibility is that a tank leak (either through a cascade/spare inlet line overfill release or tank liner breach) may have migrated from the point of release below the tank, may be much larger than assumed, and may be the source of ^{60}Co activity in drywells between tank C-105 and tank C-103 and northeast of tank C-103. A direct push hole or slant hole from the east/northeast side of tank C-105 extending under the tank could further investigate this concept. However, access near C-105 is restricted by retrieval operations; thus, it likely will not be possible to install a direct push hole or borehole in this vicinity before FY 2014.

4.4.3 Site Selection using Alternative 3: Preferential Pathways Conceptual Model

Alternative conceptual model 3, preferential pathways, is a possible transport mechanism, but as noted in Section 3.3.3, it could not be addressed in the DQO and no characterization sites were selected using this conceptual model. In addition, Section 3.6 identifies drywells and groundwater monitoring wells that may provide a conduit for preferential pathways for contaminant migration to the groundwater.

4.4.4 Site Selection using Alternative 4: Unknown Leak Event Conceptual Model

Another possible conceptual model is the unknown leak event or events (alternative conceptual model 4). Each WMA contains miles of pipelines and infrastructure, like catch tanks and valve boxes. It is plausible that leaks could occur along these pipelines. With the numerous waterline leaks that have been documented in the past within tank farms as the hydraulic driving force, contaminants could have migrated downward faster than under normal recharge. This conceptual model could also be applied to small releases from tanks, like catch tank C-301. These are known as "hot spots." However, the ability to locate hot spots at WMA C is problematic. For locating hot spots, the EPA recommends using a systematic grid sampling design (EPA/240/R-02/005, *Guidance on Choosing a Sampling Design for Environmental Data Collection for Use in Developing a Quality Assurance Project Plan EPA QA/G-5S*). This methodology places a sampling grid over an area and sampling within the grid to find a hot spot. The size of individual grid elements is dependent on the size of the hot spot. Applying this technique at WMA C is impracticable for two reasons:

a. Because the size of the area to be sampled (WMA C) is large (~700,000 ft^2 or 16 acres) and the hot spots are expected to be relatively small (<625 ft^2 or 25 ft × 25 ft), a very large number of samples would have to be taken to locate a hot spot.

b. A portion of the WMA C is inaccessible to a drill rig/direct push rig due to the underground infrastructure (tanks, pipelines, and diversion boxes), aboveground retrieval equipment, and topography. For example, the most likely area for finding hot spots would be near and around the SSTs. This area is shown by the green dotted rectangle in Figure 4-2. The area of this rectangle is ~210,000 ft^2; however, the area within this rectangle that cannot be sampled due to underground infrastructure is ~90,000 ft^2. Thus, 45% of the sampling grid in the area of the SSTs could not be sampled.

To address site selection of unknown leak events, the following two methods will be employed: judgmental sampling and SGE. Judgmental sampling (EPA/240/R-02/005) uses historical information to best select a site. Judgemental sampling will be used, for example, to investigate possible pipeline leaks such as those described in Section 2.4.3.6. As an example, according to historical records, a pipeline was installed to complete an alternative effluent return route from building C-801 to tank C-103. Because a line to perform this function already existed, this new line installation could indicate that a problem existed in the old line, including a leaking pipeline. Site G was chosen to investigate this area.

The judgemental sampling approach will also be applied in the vicinity of groundwater monitoring well 299-E27-23, where elevated levels of ^{99}Tc have been measured in the groundwater. As described in Section 3.2.2, groundwater contamination patterns in this vicinity suggest that there may be a nearby source of groundwater contamination in the vadose zone. Soil samples were not taken during the drilling of well 299-E27-23, because it was drilled as a replacement for immediately adjacent borehole 299-E27-20, which was drilled to groundwater but then decommissioned after hitting refusal. However, archived samples taken during the drilling of decommissioned borehole 299-E27-20 are available. A limited number of samples from borehole 299-E27-20 will be retrieved and analyzed to investigate the soil column for the presence of ^{99}Tc.

The other method of investigating unknown leak events is SGE, in which the resistivity of the underlying strata is measured, thereby providing an indirect indication of where pipelines, tanks, and other infrastructure may have leaked into the environment. Because waste fluids at tank farms contain nitrate that can reduce the electrical resistivity of the underlying strata, the resistivity measurements will be made at site N (UPR-81, UPR-82, and UPR-86) and compared against samples taken at these sites. Furthermore, samples collected at site P (UPR-81) will be used to compare analytical data against resistivity data. Using the results from the testing of SGE at site N, a plan will be developed to interrogate WMA C and surrounding environment using SGE as appropriate. This is designated as Site O. Advances that are realized in the application of SGE will be considered in developing additional deployments of this characterization approach, such as at sites C and D near the C-200 tanks. Additionally, as advances in data processing technologies are realized, new opportunities to further evaluate historical datasets are presented. In 2011, a reanalysis of the C Farm well-to-well SGE data was completed. Section 4.5.5 below, Surface Geophysical Exploration, describes in some detail recent advances and resulting interpretations as they apply to site O.

4.4.5 Site Selection for Surface Contamination

UPR-200-E-91 (Site H) was a large area of contaminated soil, located north and east of the C Farm. In 1981 contaminated soil was removed from this area and taken to another location (UPR-200-E-56). The radiological posting was removed in 1981. This release site is no longer marked or posted. This site was selected to verify the soils were removed. Waste site 200-E-115 (Site I) is selected as a site with surficial contamination that was discovered in October 2001.

4.4.6 Site Selection for Geophysical Logging

In addition to the list of sites that will be investigated using SGE and/or soil sampling, updated drywell spectral gamma monitoring of tanks C-103, C-104, C-106, C-108, C-109, C-110, C-111, and C-112 (Sites L and M) will be conducted to investigate changes that may have occurred since 2000 as it relates to ^{60}Co migration. In addition to the drywells inside the WMA fenceline, the following groundwater wells will also be logged: 299-E27-12, 299-E27-13, and 299-E27-15 (Site W). These wells were selected because they are the only groundwater wells near WMA C that have not been logged in recent years (since 2003). Spectral gamma logging may also be conducted in other locations at WMA C to gain additional information about contaminant distribution.

4.4.7 Groundwater Sampling Activities

Groundwater sampling activities at the WMA C RCRA wells are conducted under the Soil and Groundwater Remediation Project. Groundwater samples are collected and analyzed in accordance with DOE/RL-2009-77, *Interim Status Groundwater Quality Assessment Plan for the Single Shell Tank Waste Management Area – C*. This monitoring plan supersedes the previous groundwater monitoring plan (PNNL-13024, as revised) to incorporate changes that have occurred at WMA C. The most significant change at WMA C is the recent exceedance of the critical mean by the indicator parameter specific conductance. Furthermore, the dangerous constituent cyanide has been found in groundwater beneath the WMA C, and no upgradient

source for cyanide has been identified. The first round of groundwater sampling under the new groundwater plan is scheduled to occur late in the 2009 calendar year. The analytes in the first round of sampling were developed from RPP-23403 and Appendix IX, "Ground-Water Monitoring List" of Title 40 CFR Part 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities." The results from these groundwater sampling activities will be available to the preparers of the RFI/CMS. No sampling of groundwater will be conducted as part of these soil characterization efforts.

If any new RCRA groundwater monitoring wells are installed, the monitoring results from the new wells would be used to further access the conceptual models as they relate to groundwater flow. Analysis of soil samples taken during drilling of groundwater monitoring wells may also provide information valuable to the WMA C investigation.

4.5 SITE CHARACTERIZATION

For this work plan, site characterization will be performed at the sites identified in Figure 4-2. The site characterization activities include the following:

a. Soil collection and analysis through direct push technology (Section 4.5.1).
b. Tissue sampling for ERA (Section 4.5.2).
c. Drywell and groundwater monitoring well geophysical logging (Section 4.5.3).
d. SGE (Section 4.5.4).

The characterization options selected for implementation at WMA C for this work plan are provided in Table 4-1. Table 4-1 includes the sampling method, implementation design, and objective. Not shown in Table 4-1 is the development of a geophysical logging tool that can detect beta emitters, which is also addressed in this work plan (Section 4.5.6).

Soil samples for chemical analysis will be collected using direct push technology at WMA C sites as identified in Table 4-1. The number of sampling direct pushes ranges from one to three at each site.

High-resolution, three-dimensional SGE with deep electrodes has been completed as planned at Site N, which includes unplanned release sites UPR-200-E-81, UPR-200-E-82, and UPR-200-E-86. The results of these SGE investigations are documented in RPP-RPT-41236, RPP-RPT-47486, *Surface Geophysical Exploration of UPR-200-E-86 Near the C Tank Farm*, and RPP-RPT-50052, *Surface Geophysical Exploration of UPR-200-E-82 Near the C Tank Farm*. The WMA C DQO called for the demonstration of SGE technology at Site N, followed by development of a plan to deploy SGE to encompass the WMA C DQO boundary (investigation site O). In keeping with this expectation, SGE using surface and/or deep electrodes is being deployed elsewhere at WMA C to guide soil investigations within the WMA C DQO boundary. As an example, deep electrodes will be deployed near the C-200 tanks to inform the need for installation of additional sampling direct push boreholes at sites C and D. Furthermore, historical SGE well-to-well information has been reevaluated to further

Table 4-1. Sample Plan WMA C Phase 2 Characterization for RFI/CMS (6 sheets)

Map Design. Site	Group[a]	Location	Deployment	Number of Sampling Direct Pushes	Average Number of Samples[c]	Known or Suspected Event	Objective	Access Availability	Ecology/ Stakeholder Interest	Status as of November 2011
A	G3	Spare inlet 241-C-101	Direct push, slant	1-2	8	Tank over fill. Loss through spare inlet	Characterize C-101 release and refine conceptual models 1, 2, and 4	Fair	High	Sampled in FY 2011
B	G2	241-C-101, south side	Direct push, vertical or slant	1	8	Tank release	Characterize C-101 release and refine conceptual models 1 and 2	Good	High	Sampled in FY 2011
C	G4	241-C-203 and 200-UPR-E-137	(1) Direct push, slant (2) 4 adjacent vertical direct pushes at Sites C and D combined to support placement of deep electrodes for 3D SGE; (3) Direct push slant, depending on SGE results[b]	1 or more, based on SGE results	8	Tank leak and/or tank over fill. Loss through spare inlet	Determine if C-200s actually leaked and refine conceptual models 1, 2, and 4; determine if any C-200 tank leaked during retrieval	Fair	Moderate to high	One slant direct push was logged in FY 2011; its companion slant direct push was sampled in FY 2012; SGE planned in 2013; additional sampling dependent on SGE results.
D	G4	241-C-201 241-C-202 241-C-204	(1) 4 adjacent vertical direct pushes at Sites C and D combined to support placement of deep electrodes for 3D SGE; (2) Direct push, slant, depending on SGE results[b]	TBD based on SGE results	TBD	200 series tank leaks	Determine if C-200s actually leaked and refine conceptual models 1, 2, and 4; determine if any C-200 tank leaked during retrieval	Fair	Moderate, depending on C-203 results	SGE planned in 2013; sampling dependent on SGE results

Table 4-1. Sample Plan WMA C Phase 2 Characterization for RFI/CMS (6 sheets)

Map Design. Site	Group[a]	Location	Deployment	Number of Sampling Direct Pushes	Average Number of Samples[c]	Known or Suspected Event	Objective	Access Availability	Ecology/ Stakeholder Interest	Status as of November 2011
E	G2	Between 241-C-106 and 200-C-109	Direct push, vertical	1	8	Suspected release	Assess ^{60}Co and refine conceptual models 1, 2, and 4	Fair	High	Sampled in FY 2010
F	G2	Bldg C-801 chemical drain	Direct push, vertical	1	8	Suspected release site	Assess release of PUREX waste, ^{137}Cs and ^{99}Tc, and ^{60}Co and refine conceptual models 1, 2, and 4	Good	Moderate to high	Sampled in FY 2010
G	G2	Between Bldg C-801 and 241-C-103	Direct push, vertical	1	8	Suspected transfer line release site	Assess release and ^{60}Co and refine conceptual models 1, 2, and 4	Good	High	Sampled in FY 2009
H	G5	Northeast side of E-91	Direct push, vertical	1	8	Surface release	Surface exposures and assess ^{60}Co and surface release conceptual model	Good	High	Sampled in FY 2010
I	G5	Northeast side of E-115	Direct push, vertical or slant	1	8	Surface release	Surface exposures and assess ^{60}Co and surface release conceptual model, refine conceptual models 1, 2, and 4	Good	High	Sampled in FY 2010
J	G3	241-C-104	Direct push, slant	1	8	Tank release	Assess suspected release and refine conceptual models 1, 2, and 4	Fair	High	Sampled in FY 2011

Table 4-1. Sample Plan WMA C Phase 2 Characterization for RFI/CMS (6 sheets)

Map Design. Site	Group[a]	Location	Deployment	Number of Sampling Direct Pushes	Average Number of Samples[c]	Known or Suspected Event	Objective	Access Availability	Ecology/ Stakeholder Interest	Status as of November 2011
K	G2	241-C-108	Direct push, vertical or slant	1	8	Transfer line leak, hot drywell (09-02)	Assess suspected release and refine conceptual models 1, 2, and 4	Poor due to retrieval operations	High	Deleted; replaced with site X to investigate C-105
L	G2	241-C-103 and 241-C-106	Drywell logging and direct push, vertical	2	8	Potential transfer line leak and tank over fill	Update logging data for ^{60}Co, ^{137}Cs, uranium, and moisture and assess potential release and refine conceptual models 1, 2, and 4	Fair	Moderate	All drywells logged with SGLS; 73% moisture logged in FY 2009 through FY 2011. Sampled in FY 2009 and FY 2010
M	G7	241-C-104, -108, -109, -110, -111, and -112	Drywell logging	N/A	N/A		Update logging data for ^{60}Co, ^{137}Cs, uranium, and moisture	Fair to good	Moderate	44% of drywells logged with SGLS; 67% moisture logged in FY 2009 through FY 2011. Discontinue further logging.
N	G8	UPR-86, UPR-82 and UPR-81	SGE	N/A	N/A		Test SGE, define plume at UPR-82 and -86; refine conceptual models 1, 2, and 4	Good	High	SGE work completed FY 2009 through FY 2011

Table 4-1. Sample Plan WMA C Phase 2 Characterization for RFI/CMS (6 sheets)

Map Design. Site	Group[a]	Location	Deployment	Number of Sampling Direct Pushes	Average Number of Samples[c]	Known or Suspected Event	Objective	Access Availability	Ecology/ Stakeholder Interest	Status as of November 2011
O	G9	WMA C	SGE	N/A	N/A		3D vision of suspected releases – may lead to supplemental sample locations	Good	High	Reanalysis of well-to-well data completed in FY 2011 Additional SGE to be deployed selectively (e.g., at sites C/D).
P	G1	UPR-81	Balance of direct pushes to complete characterization	3	8	Known release site	Characterize release and refine conceptual models 1, 2, and 4	Good	High	Sampled in FY 2009
Q	G6	UPR-82	(1) 4 adjacent direct pushes to support placement of strings of deep electrodes for 3D SGE per Map Design. Site N; (2) Direct push through center depending on SGE results[b]	1	8	Known release site	Test SGE: resolve depth with deep electrodes; define plume at UPR-82; refine conceptual models 1, 2, and 4	Poor due to shotcrete cover	High	SGE completed in FY 2011; direct push through center deleted.
R	G2	241-C-301 Catch Tank	Direct push vertical	1	8	Unlined concrete catch tank	Assess potential catch tank release and refine conceptual models 1, 2, and 4	Good	Moderate to high	Sampled in FY 2010

Table 4-1. Sample Plan WMA C Phase 2 Characterization for RFI/CMS (6 sheets)

Map Design. Site	Group[a]	Location	Deployment	Number of Sampling Direct Pushes	Average Number of Samples[c]	Known or Suspected Event	Objective	Access Availability	Ecology/ Stakeholder Interest	Status as of November 2011
S	G5	UPR-72 and C-8 Drain	Direct push vertical	1	8	Buried radioactive material and French drain from 241 CR Building are in this area	Assess presence of buried material and potential releases to C-8 drain and refine conceptual models 1, 2, and 4	Good	Moderate to high	Deleted
T	TBD	TBD, based on SGE data for entire WMA	TBD, direct push vertical and/or slant	TBD	TBD	Previously unknown release sites	TBD	TBD	Moderate to high	Sampling dependent on SGE results
U	G3	C-110	Direct push, slant or vertical	1	8	Tank leak and/or tank over fill. Loss through spare inlet	Characterize C-110 release and conceptual models 1, 2, and 4	Fair	High	Sampled in FY 2010
V	G2	C-111	Direct push vertical	1	8	Tank leak and/or tank overfill. Loss through spare inlet	Characterize C-111 release and conceptual models 1, 2, and 4	Good	High	Deleted
W	G9	299-E27-4 299-E27-12, 299-E27-13, 299-E27-14, 299-E27-15	Log groundwater monitoring wells outside of WMA C	N/A	N/A		Log wells to collect data on U, ^{60}Co, ^{137}Cs, and moisture	Good	High	Logging data found for 299-E27-4 and -14. Logging of 299-E27-12, -13, and -15 deleted

Table 4-1. Sample Plan WMA C Phase 2 Characterization for RFI/CMS (6 sheets)

Map Design. Site	Group[a]	Location	Deployment	Number of Sampling Direct Pushes	Average Number of Samples[c]	Known or Suspected Event	Objective	Access Availability	Ecology/ Stakeholder Interest	Status as of November 2011
299-E27-20	TBD	Well 299-E27-20, adjacent to 299-E27-23	Analysis of archived soil samples	N/A	4	Previously unknown release site	Assess presence of potential release (^{99}Tc) to soil column impacting groundwater and conceptual models 1, 2, and 4	N/A	Moderate to high	Planned for FY 2013
X	TBD	C-105	Direct push, slant	1	8	Cascade line leak. Possible tank leak and/or tank over fill.	Investigate extent of high activity (10^7 pCi/g) ^{137}Cs plume in drywell 30-05-07 near tank C-105 and refine conceptual models 1, 2, and 4	Fair	Moderate to high	Planned for 2013

[a] Group refers to the expected work package associated with the characterization effort broadly defined as follows:

G1 = Direct push at UPR-81 (covered by existing work package).
G2 = Vertical direct pushes at nine investigative sites around the 100-series single-shell tanks.
G3 = Slant direct pushes at three investigative sites around the 100-series single-shell tanks.
G4 = Slant direct push at the C-200 Series tanks.
G5 = Outside the WMA, vertical direct push at the investigative sites.
G6 = Vertical direct push through gunite at UPR-82.
G7 = Drywell logging at select drywells.
G8 = Three separate SGE areas at the following locations: UPR-81, UPR-82, and UPR-86.
G9 = Deploy SGE at WMA C taking into account the results from testing at site N.

[b] Sampling design details for Map Design. Sites D and Q and for future work at site C are applicable to only to probeholes installed for sampling. Additional probeholes will be placed to support logging/electrode placement.

[c] Value includes one surface sample.

3D = three-dimensional
Ecology = State of Washington Department of Ecology
FY = fiscal year
N/A = Not Applicable
PUREX = plutonium uranium extraction (plant)
RCRA = *Resource Conservation and Recovery Act of 1976*
RFI/CMS = RCRA facility investigation/corrective measures study
SGE = surface geophysical exploration
SGLS = spectral gamma logging system
TBD = to be determined
UPR = unplanned release site
WMA = Waste Management Area

characterize and resolve regions within the WMA C DQO boundary. The resulting data has refined previous results making use of the most recent advances in the imaging technology as they apply to the well-to-well acquisition technique. However, implementation of full three-dimensional SGE across the entirety of WMA C is unlikely to occur in the near term due to prioritization of tank waste retrieval and construction activities in C Farm.

Spectral gamma and moisture logging is being performed at tanks C-103, C-104, C-106, and C-108 through C-112 in accordance with RPP-RPT-38152. As with the SGE technology, spectral gamma and moisture logging may be performed at other locations at WMA C to guide soil investigations within the WMA C DQO boundary.

The specific timing and scope of the WMA C soil investigation work is contingent on available funding and prioritization of the investigative work relative to other tank farm activities, such as waste retrieval operations. Additional characterization technology development (see Section 4.5.5) also is contingent on available funding.

The initial (Phase 1) site-specific soil investigation conducted between FY 2004 through FY 2007 entailed the installation of one vertical borehole near tank C-105 along with the application of direct push technology at UPR-82 (vertical and slant probeholes). To complement these data, direct pushes were conducted around UPR-86 and UPR-81 in FY 2008 (RPP-35169) that provide additional information about contamination in the south portion of C Farm. The Phase 2 soil investigation consists of vertical and slant probeholes using direct push technology near selected waste releases, application of SGE at various locations in and next to WMA C, and targeted analysis of archive samples from nearby boreholes. Spectral gamma and moisture logging will be undertaken around certain tanks with drywells in which ^{60}Co has been detected. Logging will also be undertaken in groundwater monitoring wells that have not been spectral gamma logged in the past.

Table 4-1 shows the current understanding of access availability (as of November 2011) for each of the sites remaining to be investigated. Specific sample locations will be selected based on defined site limitations (slope of the ground surface), and infrastructure constraints (see Figures 4-3 and 4-4). The actual sample locations will be established following the field survey with ground-penetrating radar (GPR) and other site preparation activities. This work plan calls for a sample to be taken at ground surface (i.e., 0 to 1 ft bgs). Although every attempt will be made to collect this sample, the gravel surface in tank farms may prevent taking a sample that contains environmentally sensitive media (i.e., soil particles less than 2 mm in diameter). If this is the case, pictures of the sampling site showing the gravelly nature of the land surface and the reason as to why a sample will not be taken will be documented in borehole/site completion reports.

The GPR and electrical surveys will define where subsurface conflicts exist, which will help define acceptable sample locations. During the survey, aboveground conflicts will also be defined.

Figure 4-3. Surface Facilities, Candidate Sample Locations, and Surface Geophysical Exploration Interrogation Areas

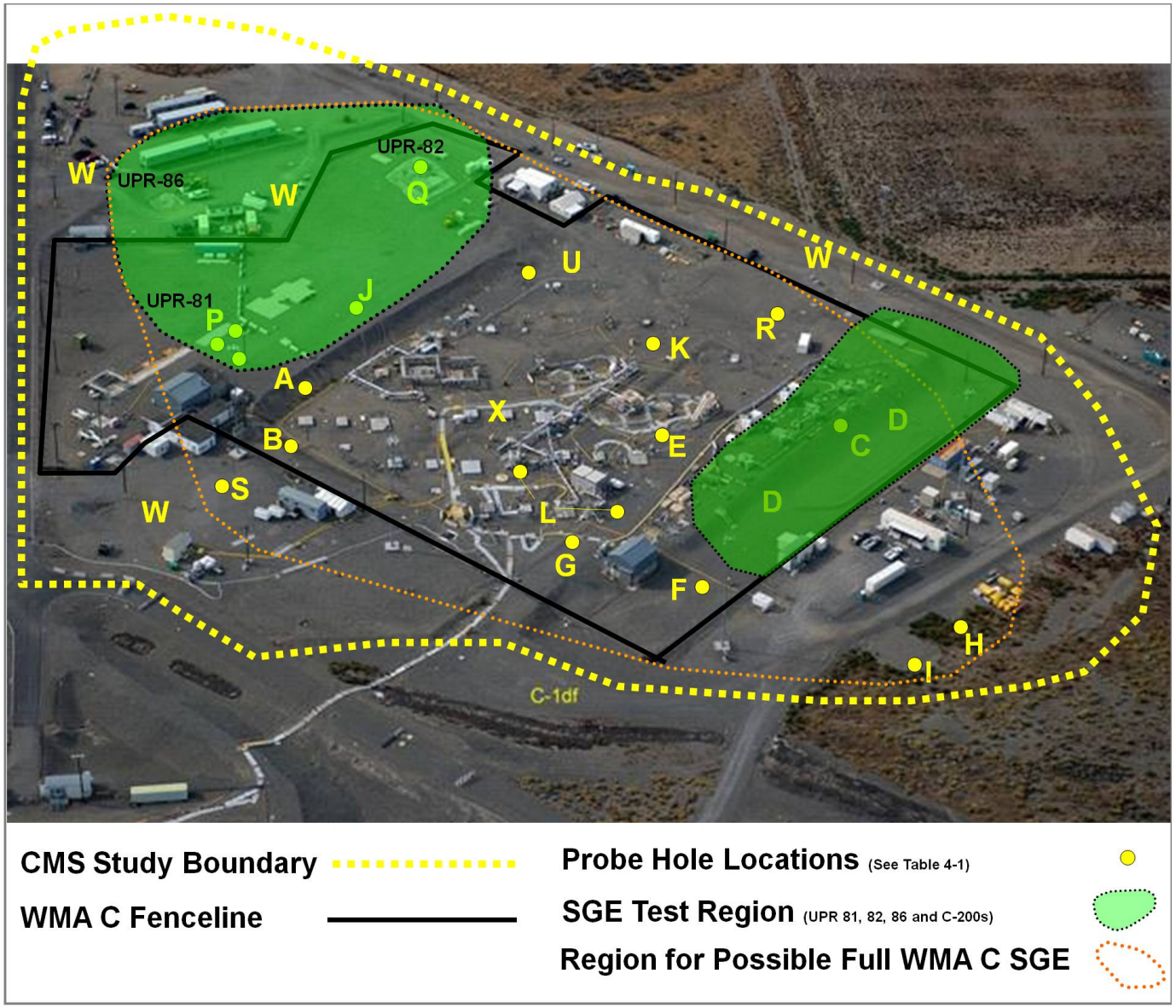
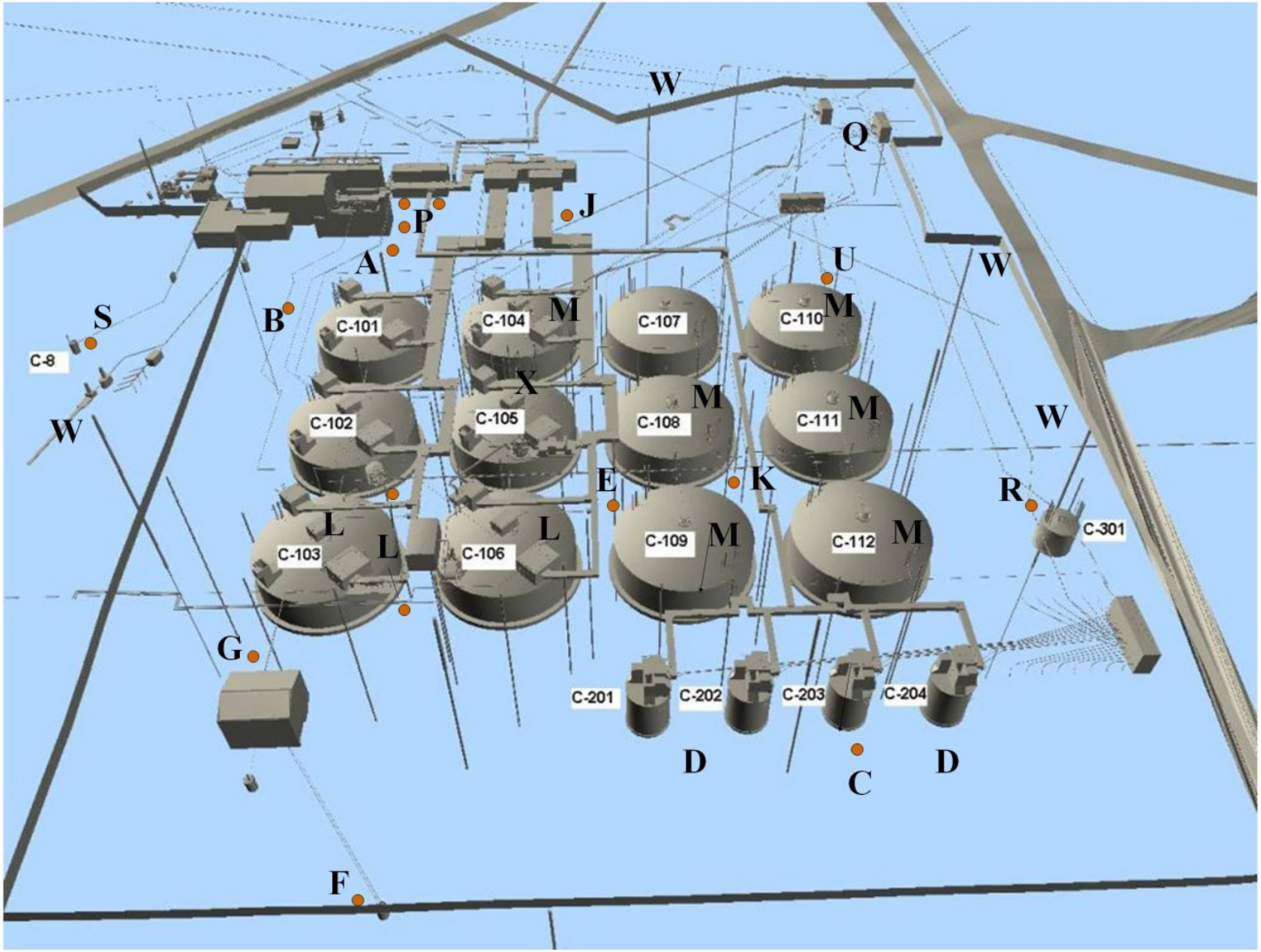


Figure 4-4. Candidate Sample Locations and Infrastructure Constraints



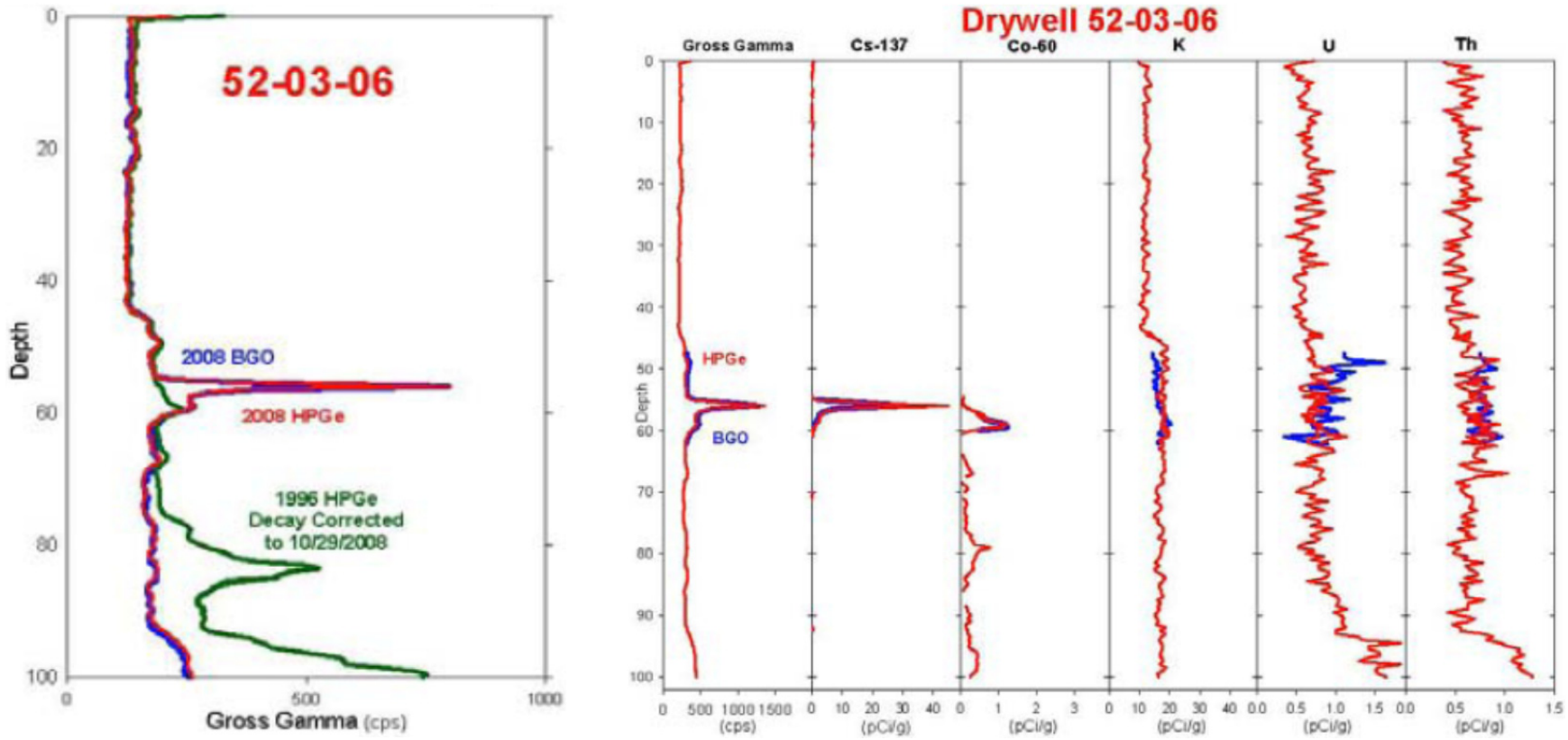
Although the Phase 2 WMA C DQO drives the majority of the Phase 2 characterization actions, additional characterization work is being undertaken for a variety of reasons. For example, a request to twin soil samples from new groundwater well boreholes with soil samples from direct push was provided by the Nez Perce in review of Revision 0 of this work plan. At the time of that review, installation of new groundwater wells near WMA C was in planning. Although soil samples from direct pushes have been acquired, they are spatially separated by tens of feet from soil samples associated with boreholes. These soil samples can be compared and have shown similarities in pH and moisture content. However, with the potential changes in soil properties that might occur over those distances, a meaningful comparison related to the differences in techniques is problematic. It would be more beneficial to have direct push soil samples located a few feet (~2 ft) apart from soil samples from new groundwater monitoring well borehole(s) to allow a more valid comparison. The DOE-ORP agreed that soil samples from direct pushes and the new groundwater well(s) that were proposed at the time of the Nez Perce review could be compared, and similarities in analytical values demonstrated. This twinning exercise would also support the technical merits of using moisture as an indicator for soil sampling targets. The DOE agreed that if the two planned new groundwater wells were installed within 100 ft of the WMA C boundary, twin direct push probeholes could be installed with those groundwater wells. The DOE further agreed that if the new wells could not be placed as planned, direct push probeholes would be installed to twin the geophysical logging of existing wells. The goal of twinning existing wells that are undergoing geophysical logging would be to obtain direct comparison of the results obtained using spectral gamma logging tools and bismuth-germanium oxide (BGO) direct push logging tools.

The preferred location as recommended by the Nez Perce and concurred with DOE-ORP and the contractor would be close to existing groundwater wells 299-E27-7 or 299-E27-14, which have shown groundwater impacts related to regional contamination as well as contamination associated with WMA C; however, the location may be modified due to existing site conditions and waste retrieval operations.

Subsequent to the initial approval and issuance of this work plan, two new groundwater wells were installed west of WMA C: 299-E27-24 and 299-E27-25. Well 299-E27-25 is well over 100 ft from the WMA C boundary. Well 299-E27-24 is inside but near the 100-ft boundary. However, geophysical logs from well 299-E27-24 do not indicate the presence of contamination at depths attainable using direct push methods. Therefore twinning using direct push was not undertaken at either of these locations.

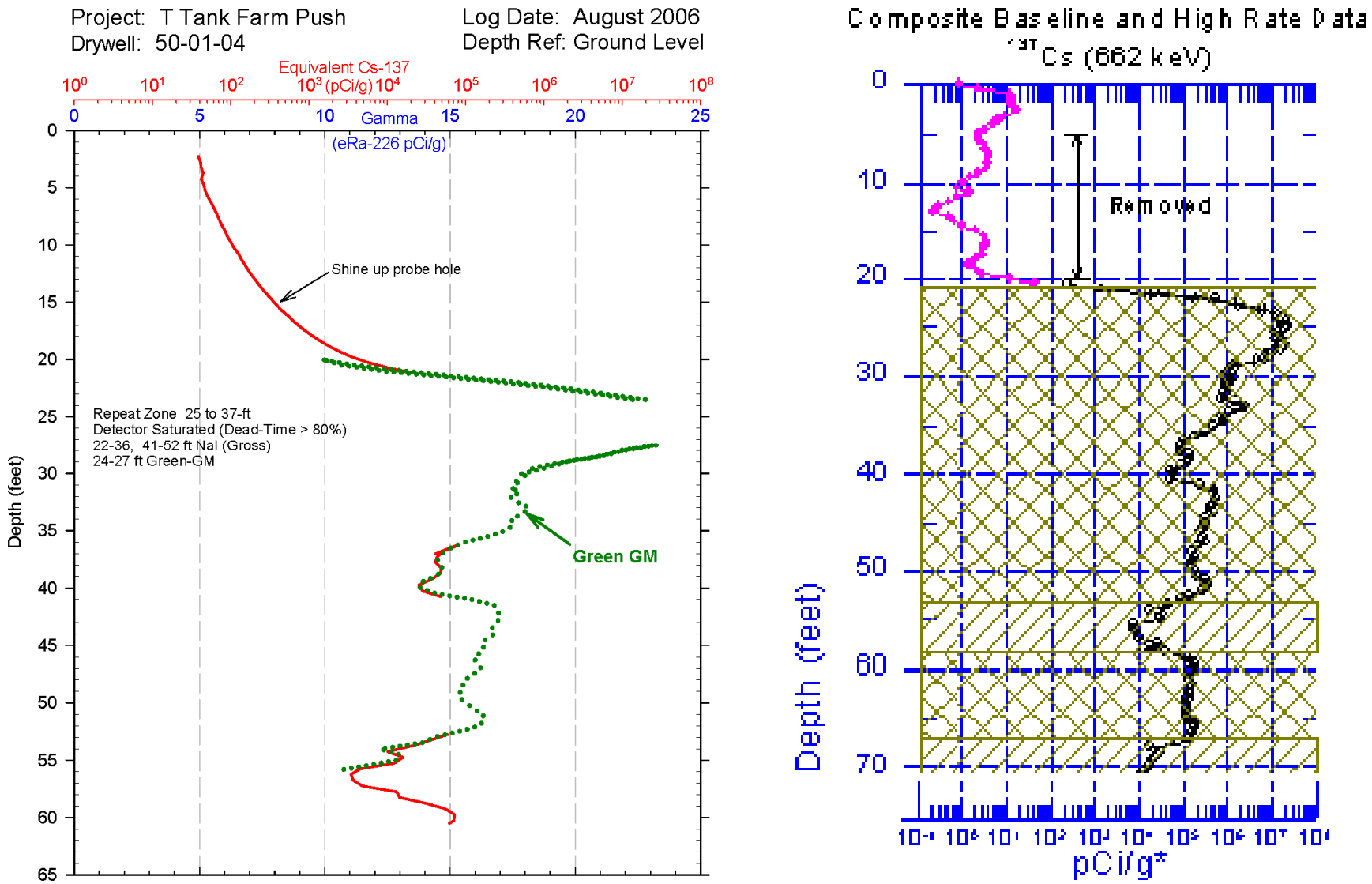
Direct comparisons of spectral gamma logging and BGO direct push logging results were accomplished outside WMA C at three locations inside other tank farms. In each of the three locations, a single drywell was logged using both geophysical tools. This work was completed at drywells 52-03-06 in 241-TY Tank Farm, 50-01-04 in T Farm, and 21-02-04 in BX Farm. Testing showed good correlation of the results at all three locations (Figures 4-5 through 4-7). Therefore, the intent of the twinning requirement is considered met.

Figure 4-5. Comparison of Spectral Gamma and Bismuth-Germanium Oxide Logging Results



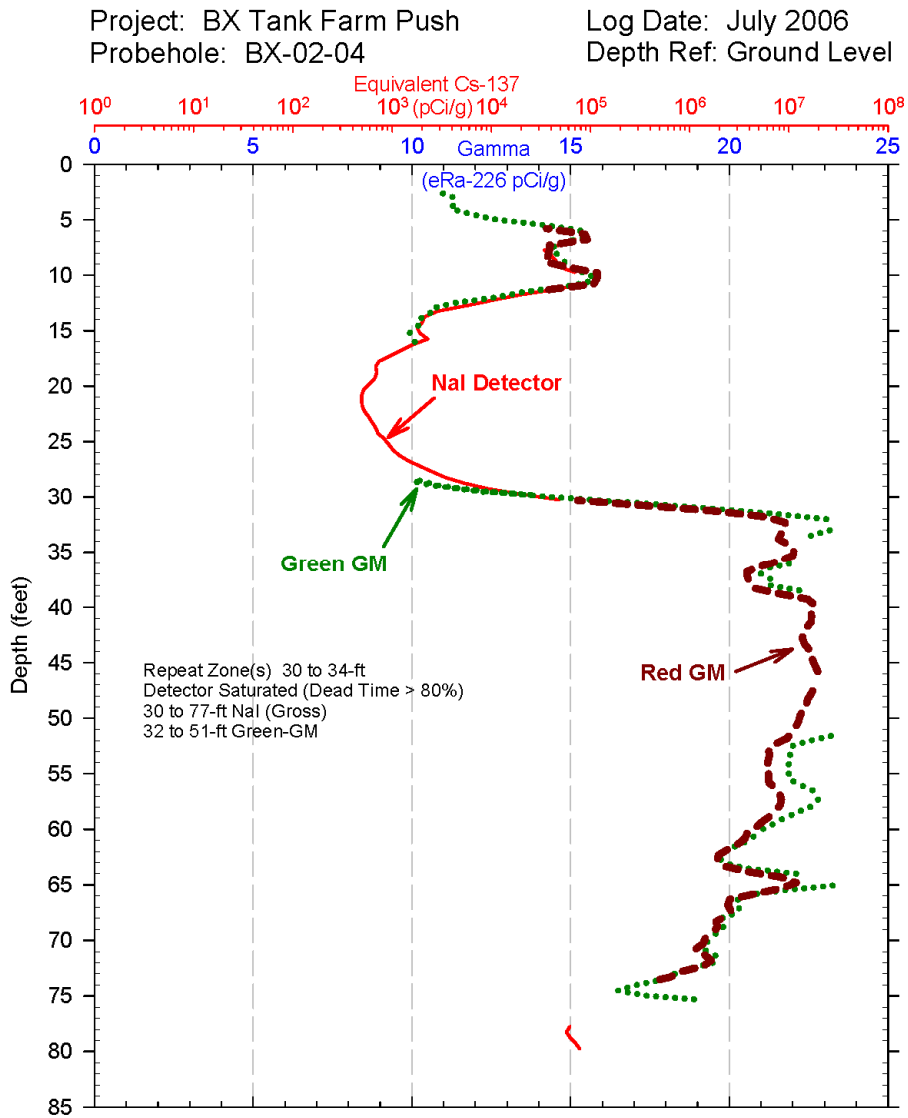
Reference: RPP-RPT-41100, *Completion Report for TY Single-Shell Tanks Direct Push Barrier Investigation*, p. E-44.

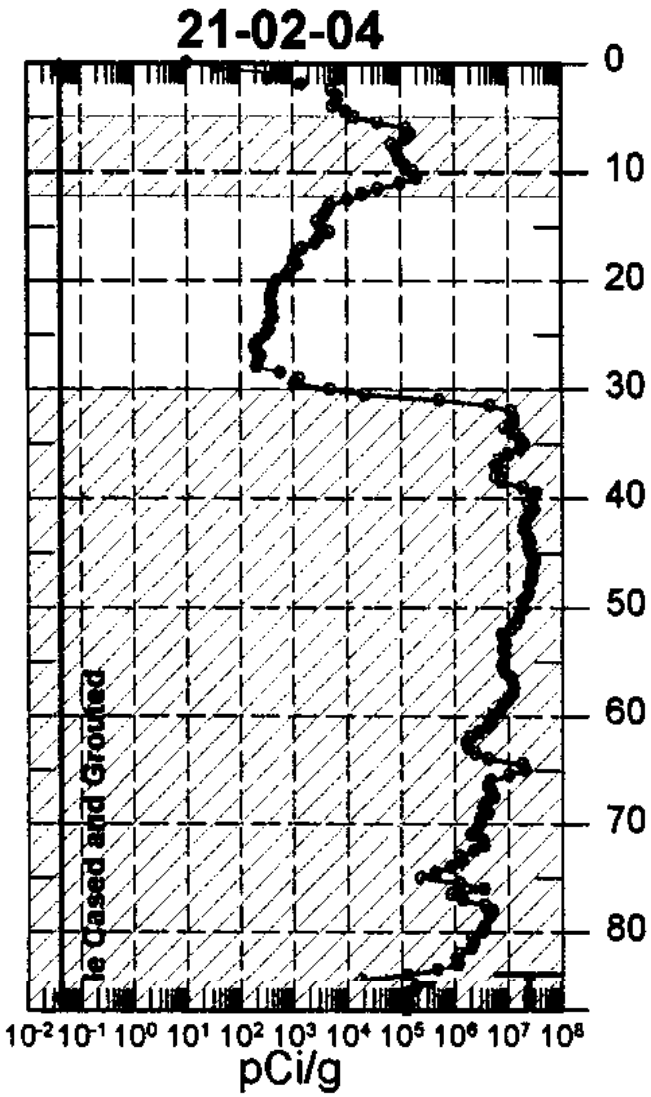
Figure 4-6. Comparison of Spectral Gamma and Bismuth-Germanium Oxide Logging Results



References: GJO-99-101-TARA/GJO-HAN-27, *Hanford Tank Farms Vadose Zone: Addendum to the T Tank Farm Report.*
RPP-34645, *Small Diameter Geophysical Logging In the 241-T Tank Farm.*

Figure 4-7. Comparison of Spectral Gamma and Bismuth-Germanium Oxide Logging Results





References: GJO-98-40-TARA/GJO-HAN-19, *Hanford Tank Farms Vadose Zone: Addendum to the BX Tank Farm Report.*
RPP-34623, *Small Diameter Geophysical Logging In the 241-BX Tank Farm.*

Deployment of direct push technology at the proposed locations in WMA C would be expected to continue to address a number of questions related to the concentration and distribution of contaminants, including the following:

a. What contaminants are present that are routinely identified as contaminants of concern (COC) from a groundwater impact standpoint (e.g., ^{99}Tc, nitrate)?

b. What are the contaminant concentrations of ^{137}Cs and other COC in the upper 15 ft of the soils to provide soil data to support direct exposure and ecological risk assessment?

c. What is the vertical extent of the COC in the backfill material?

d. What is the horizontal extent of the COC across the areas of interest?

e. 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?

Installation of probeholes as noted in Table 4-1 was selected because these locations would provide source characterization data over the majority of WMA C along with distribution of contaminants at the locations of interest from WMA C. Source characterization would:

a. provide a basis for the current location of COC inventory in the vadose zone

b. support evaluation of the spatial correlations between concentrations of COC and existing gamma data

c. support assessment of contaminant mobility, potential drivers (e.g., moisture content), and the effects of releases on soil properties to support predictive numerical modeling efforts necessary to evaluate potential future groundwater impacts, the associated risks, corrective measures, 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 and closure decisions as they relate to soil and groundwater contamination.

4.5.1 Installation of Vertical/Slant Probeholes

Several options were considered for collection of vadose zone data. The preferred option is installation of direct push probehole(s). The direct push technology has been capable of obtaining a sample as deep as 240 ft bgs. It has the capability of obtaining more than one sample per probehole and does not bring up cuttings that need to be disposed. Furthermore, it does not take up as much space as a conventional drilling rig, which allows it to be deployed at more locations within the WMA C. The direct push technology provides the same objective as drilling a deep borehole given the data collection objectives. Up to 27 direct push probeholes are planned for 16 sampling locations. While the approximate locations for each probehole are shown on Figures 4-2 through 4-4, the exact locations for each probehole are dependent on the

accessibility and subsurface interferences to the site, which will be determined after the results of a GPR survey become available. Vadose zone samples will be collected after the initial push is conducted and evaluated with soil moisture and gamma data. The precise sampling depths will be based on review of the geophysical logging data collected from the exploratory probehole. It is expected that the modified BGO logging tool (Section 4.6) will reduce the risk of selecting the wrong horizon to sample because of the lower detection limits associated with this tool.

For planning purposes, it is assumed that all direct push probeholes will be vertical, except for the probeholes at Sites A, C, D, J, and possibly Site U. At those sites, the probeholes would be slanted because the slope of the hill on the southwestern side of tanks C-101, C-104, C-110 (Sites A, J, and U) and the northeastern side of the C-200-series tanks (Figure 2-2, cross-sections A and B) prohibit placing the direct push rig close to the outlet ports at these tanks.

The goal of slanted direct push probeholes is to find evidence of tank fluids that have leaked into the vadose zone. Therefore, at these sites, the target region for samples is within 10 ft of the tank bottom. The exact angle, 30, 45, or 60 degrees, of the probehole to intersect the target region will be determined by field conditions (e.g., where can the direct push rig set up to avoid existing infrastructure). Figures 4-8 and 4-9 delineate possible angles for the slant holes at the 100-series tanks and 200-series tanks, respectively. In these figures, the lines represent the probehole divided into 50-ft lengths with every 10-ft length marked. The slant boreholes at the C-200-series would also be extended to the southwest beyond the tanks to collect soil samples directly below pipelines running between the C-200-series and C-100-series tanks.

4.5.1.1 Direct Push Sampling Technique. The direct push technology uses a dual-wall percussion system to obtain multiple samples in a single probehole location. Driving will be conducted with outer push tubing that is currently planned to be 6.67 cm (2.625 in.) OD × 4.76 cm (1.875 in.) ID and inner tubing that is 3.17 cm (1.25 in.) OD × 2.7 cm (1.08 in.) ID. The dual-wall system with a "dummy" tip will be advanced to the predetermined sample depth. The tubing will be back-pulled 0.06 m (~2 in.) to 0.12 m (~5 in.) to relieve pressure and materials from the drive shoe and tip. When sampling depth is achieved and the rods back-pulled for sampling, the removable tip will be removed by extracting the inner rods. On removal of the inner string of tubing, a sampler will be attached to the inner string and returned to the bottom of the outer casing/push tubing and positioned against the inner receiver face of the drive shoe. The inner and outer tubing strings are "locked" together by use of a proprietary method, and the entire assembly is advanced through the targeted sample interval.

The sampler body holds three stainless steel liners that are currently planned to be 3.17 cm (1.25 in.) OD × 2.7 cm (1.08 in.) ID. After the sampler is advanced ~0.6 m (2 ft), the inner string is released and retrieved to the surface. The liners are removed from the sampler body and surveyed. Trained sample-handling technicians document recovery, sample condition, and volume recovery percent, and then package and transport the sample to the selected laboratory for analysis. The "dummy" tip is reattached to the inner string and returned to the bottom and placed in the casing shoe. The entire assembly is advanced to the next designated sample depth, and the process is repeated until all sample depths are achieved or the tubing meets refusal (i.e., the inability of the direct push method to advance further into the vadose zone). On completion of the final sample extraction or on meeting refusal, the dummy tip or sampler is removed and the probehole is decommissioned in accordance with WAC 173-160 requirements.

Figure 4-8. Possible Configurations for a Slant Probehole at the 100-Series Tanks

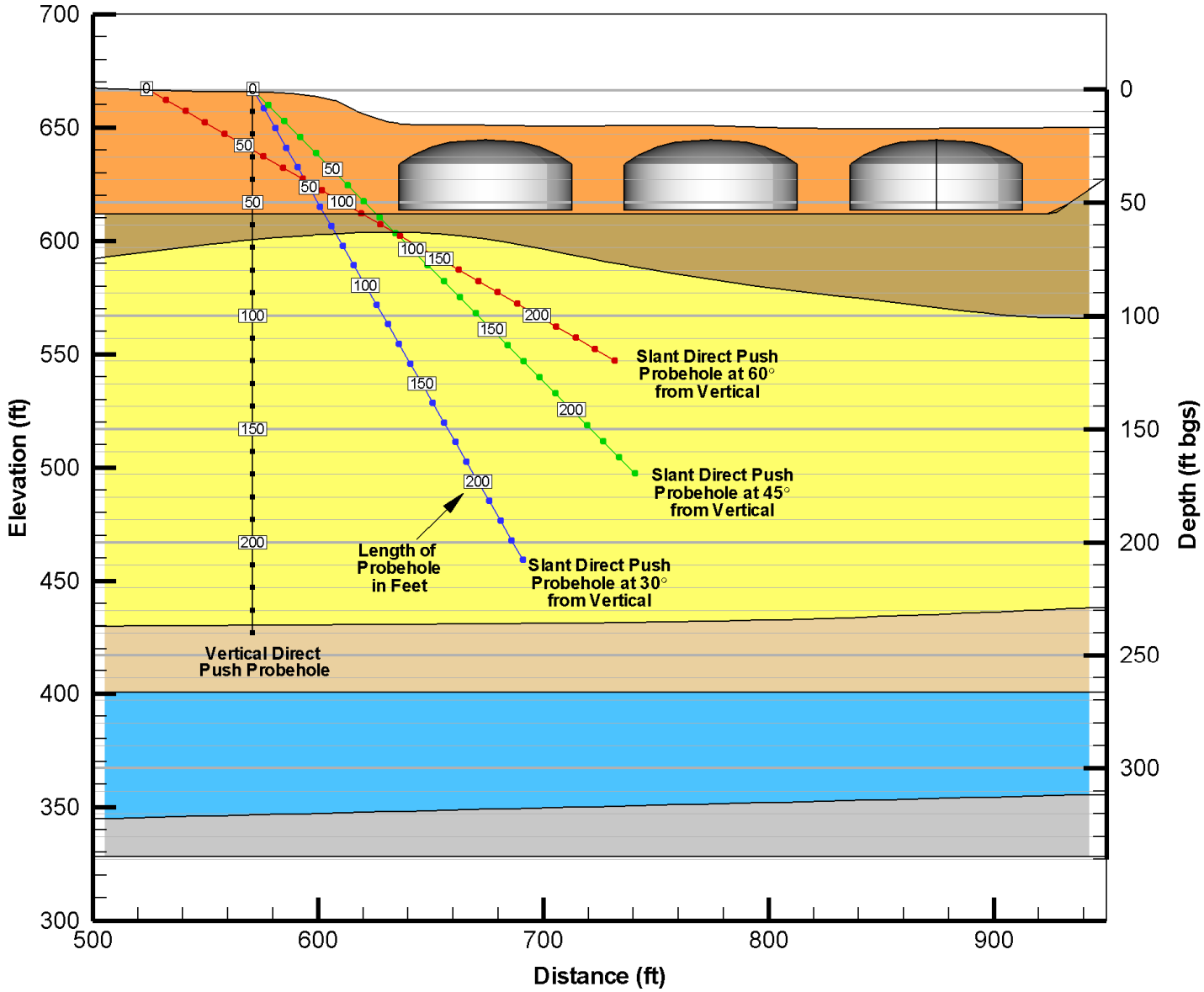
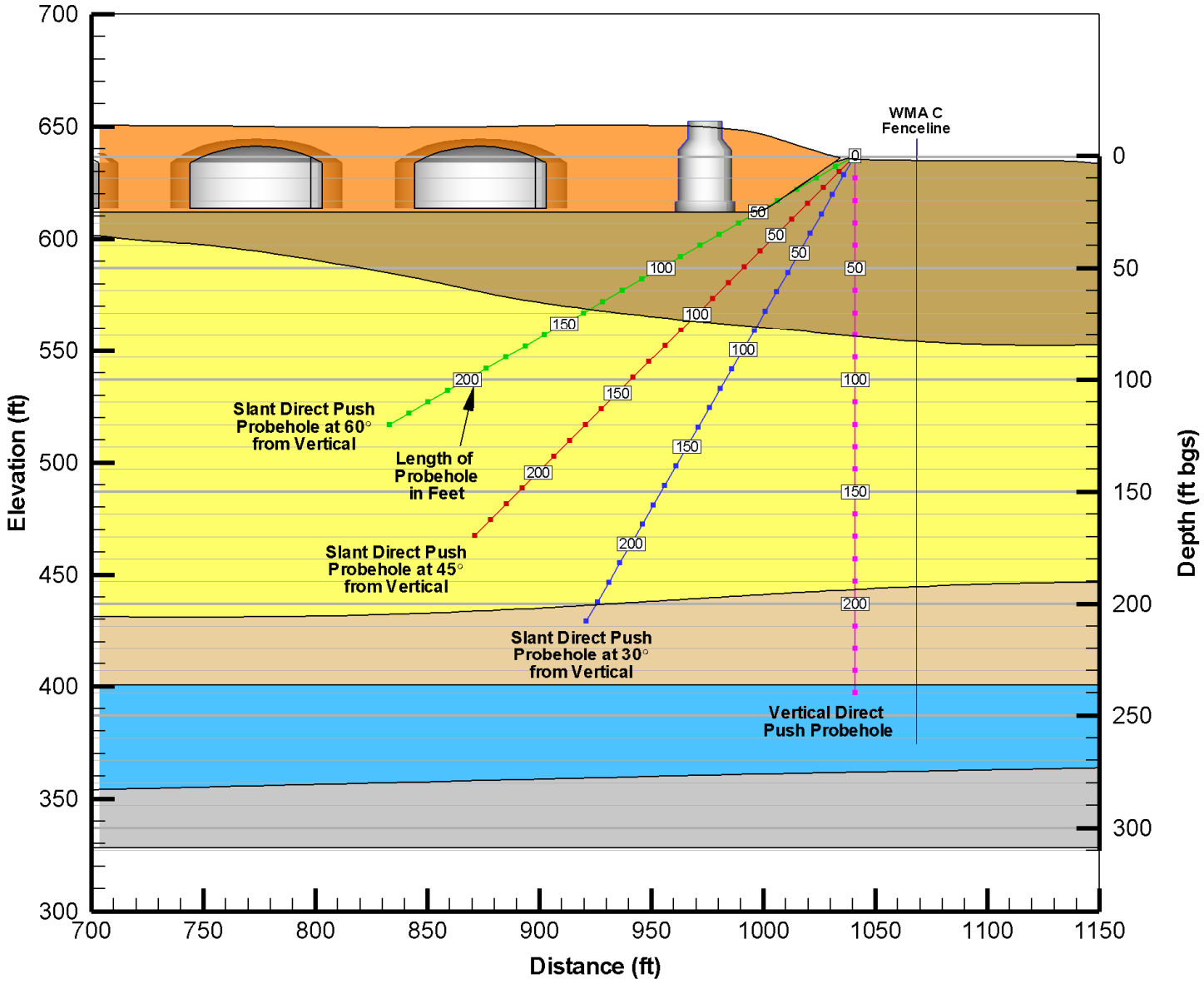


Figure 4-9. Possible Configurations for a Slant Probehole at the 200-Series Tanks



4.5.1.2 Sequencing Direct Push Sampling. Technically, to collect the data to meet the goals of the DQO, sampling should be sequenced correctly. Sites to be used for the evaluation of organic data (Section 3.8.2) should be the first sites investigated. For WMA C, these sites are Sites P and L (Table 4-1). Before soil sampling at other sites as listed in Table 4-1, the results of the organic analyses at Sites P and L should be reported to determine if further organic analyses at other sites associated with this work plan is warranted. However, while preparing this work plan, the waste retrieval schedule was modified to include 244-CR vault which may prohibit accessibility at the identified organic sampling site P. Furthermore, above ground infrastructure near tank C-103 may prevent early sampling at site L. Therefore, discussions with DOE and Ecology will be initiated during the review of this work plan by Ecology for determining how to proceed with identifying new organic sites within the DQO boundary of WMA C or analogous organic sites at new locations other than WMA C for the purpose of evaluating organic chemical data.

4.5.1.3 Ground-Scanning. Prior to implementing direct push sampling and SGE activities, ground scans are conducted to verify drawings that show areas containing buried equipment, underground structures, and pipelines. Ground scans typically use GPR, which uses a transducer to transmit frequency modulated electromagnetic energy into the ground. Interfaces in the ground, defined by contrasts in dielectric constants, magnetic susceptibility, and, to some extent, electrical conductivity, reflect the transmitted energy. The GPR system measures the travel time between transmitted pulses and the arrival of reflected energy. The reflected energy provides the means for mapping subsurface features of interest. The display and interpretation of GPR data are similar to those used for seismic reflection data. When numerous adjacent profiles are collected, often in two orthogonal directions, a plan view map showing the location and depth of underground features can be generated.

4.5.1.4 Direct Push Sampling Strategy. For planning purposes, the following summarizes the sampling strategy (from RPP-ENV-38838) at each vertical direct push site. Note that the specified depths are only approximate and are subject to constraints in the field.

a. At each site, a minimum of two direct push probeholes pushes will be completed. The initial probehole will be logged for both gross gamma using the modified bismuth-germinate oxide tool (Section 4.6) and neutron moisture. Following logging, single depth or multi-depth electrodes will be installed for SGE. The second push will be for soil sampling based on the data observed from the first push. An exception to this process will be applied at UPR-82, where four pushes will be made for the sole purpose of installing multi-depth electrodes in support of SGE at that location. Resulting resistivity data will be used to determine whether additional characterization action is appropriate at UPR-82.

b. The depth of the first probehole push will be ~200 ft bgs or to refusal at all sites except H, I, and S. This target depth is based on the observation of ^{99}Tc and nitrate at 160 ft bgs at borehole C4297 and ^{60}Co concentrations above 0.1 pCi/g between 150 and 160 ft bgs at well 299-E27-4. However, the depth at Site S is expected to be to 260 ft bgs or refusal based on ^{60}Co above 0.1 pCi/g at nearby well 299-E27-14. At Sites H and I, the depth of the direct push will be 150 ft unless data from Sites F and G indicate that the direct pushes at Sites H and I should be deeper.

c. In general, strings of electrodes will be placed starting near the base of the initial probehole. Multi-depth electrodes will have an electrode every 20 ft from the bottom to a depth of ~40 ft bgs (near the base of the SSTs). Actual borehole conditions may result in modification of this design.

d. For the second probehole push (i.e., the sampling probehole), three samples will be taken at depths less than 15 ft bgs. Generally speaking, targeted sample depths will be at 5, 10, and 14 ft bgs in the vadose zone. The purpose of collecting samples in the first 15 ft is to provide data for the direct exposure pathway and to provide initial data for ecological risk by comparing soil concentrations against WAC Table 749-3 (WAC 173-340-900) and RESRAD-Biota Level 1 BCGs (ANL 2006).

e. For sampling probeholes pushed to depths greater than 15 ft bgs, the depth for sampling individual horizons will be selected by reviewing the gamma and moisture logs of the first direct push, along with the following information: any leak loss inventory information pertinent to the site, geologic summary of the area, operational history, and historical characterization data at that site. The sampling horizons will be selected in an open meeting to which TOC staff, DOE, Ecology, EPA, and other site contractors are invited.

The sampling strategy for the sites with slant probeholes is the same as for vertical probeholes with the following exceptions.

a. The angle of the slant probehole will be determined after the GPR survey is completed.

b. The length of slant direct pushes at the C-100-series tanks will be ~200 ft of pipe run or refusal, while for the 200-series tanks, the length will be ~160 ft of pipe run or refusal. The exact length will depend on the setup location and the angle of the direct push. The goal of the probeholes is to determine whether tank fluids were released into the environment. The direct push probeholes placed at the C-200-series tanks will be extended to sample soils beneath the pipelines running between the C-200 series and the C-100-series tanks.

c. For slant probeholes, three soil samples (direct exposure and ecological risk) will be taken in the upper 15 ft of the vadose zone. The location along the length of these probeholes will be determined by the angle of the probehole, but samples will be collected at ~5, 10, and 14 ft bgs. See item d for the vertical probeholes; deeper samples will be taken using the same methodology as outlined in item e of the vertical probeholes.

d. One deep electrode will be installed in the initial slant probehole. If the angle of the slant probehole permits, a second electrode may be set.

Should contamination be found in any of the soil sampling probeholes at their total depth, additional or other characterization technologies may be deployed to define the maximum depth of contamination at an unspecified date in the future. This data would be shared with Ecology to determine a path forward to be implemented before corrective measures in the deep vadose zone

area of interest. If the decision is to collect additional samples at greater depths, then either this work plan will be amended or a separate work plan will be prepared which states the characterization technique to be used (direct push, borehole, etc.), the number of samples to be taken at depth, the total depth of the new characterization hole, and how to complete the new hole in accordance with WAC 173-160.

4.5.1.5 Surficial Sampling at Direct Push Locations. A soil sample will be taken from 0 to 1 ft bgs at each planned direct push site. The purpose of these surficial samples is to collect data to be used in calculating direct exposure pathway, as well as the ecological risk. The sample will be analyzed for the chemicals and radionuclides listed in Tables 3-1 and 3-2, respectively, using the approach given in Section 3.5. This work plan calls for a sample to be taken at ground surface (i.e., 0 to 1 ft bgs). Although every attempt will be made to collect this sample, the gravel surface in tank farms may prevent taking a sample that contains environmentally sensitive media (i.e., soil particles less than 2 mm in diameter). If this is the case, pictures of the sampling site showing the gravelly nature of the land surface and the reason why a sample was not be taken will be documented in borehole/site completion reports.

4.5.2 Analysis of Archived Soil Samples

In 2003, groundwater monitoring well 299-E27-23 was installed southeast of UPR-200-E-86. Groundwater sampling for ^{99}Tc began at this well in December 2010. As described in Section 3.2.2, ^{99}Tc levels in the groundwater in this vicinity are significantly elevated over levels elsewhere around WMA C. The ^{99}Tc levels suggest that there may be a source of ^{99}Tc contamination in the vadose zone in the vicinity of well 299-E27-23.

To begin the evaluation of the possibility of a nearby source, groundwater well drill cuttings will be retrieved from achive holding and analyzed for evidence of contamination. No soil samples were taken during the drilling of well 299-E27-23, which was installed after refusal was met within the aquifer during the drilling of immediately adjacent (and now decommissioned) well 299-E27-20. However, drill cuttings were archived every 5 ft throughout the vadose zone during the 2003 drilling of well 299-E27-20.

Some of the archived drill cuttings taken during drilling of well 299-E27-20 will be retrieved from storage, transported to a laboratory, and analyzed for evidence of a ^{99}Tc contamination source in the vadose zone. One or more samples of archived drill cuttings will be analyzed for (at minimum) ^{99}Tc, nitrate and moisture content.

4.5.3 Tissue Sampling

Waste Management Area C is managed in a way to eliminate, to the extent possible, the intrusion of plants and animals into the facilities. However, WMA C may have an impact on animals located outside WMA C. Therefore, in addition to the soil samples taken to evaluate ecological risk (Section 4.5.1.4), small mammal tissue sampling and analysis will be completed as a supplemental method for evaluating contaminant pathways and risks to wildlife receptors. Animals will be collected from around the perimeter of WMA C for tissue sampling. Appendix B provides the sampling and analysis instruction for collecting these samples.

4.5.4 Geophysical Logging

Based on concerns raised by stakeholders and Tribal Nations related to the presence and mobility of ^{60}Co, spectral gamma as well as moisture logging will be done for the drywells associated with tanks C-103 and C-106 (site L). Past releases from transfer lines as well as tank overfill events may have impacted the soil in this vicinity. The purpose of the spectral gamma logging would be to update the data collected during the baseline spectral gamma analysis conducted in 1998 (GJO-98-39-TAR/GJO-HAN-18) and 2000 (GJO-98-39-TARA/GJO-HAN-18). In addition, spectral gamma analysis in drywells around tanks C-104 and C-108 through C-112 (site M) will be performed to update the spectral gamma and moisture logging data to provide insight into changes that may have occurred since 2000. Figure 4-10 shows the locations of the drywells in WMA C and identifies the drywells that will be logged. The final list of drywells to be logged will depend on actual field conditions during the investigation, as some drywells may be inaccessible (due to retrieval operations, for example).

Furthermore, three RCRA groundwater monitoring wells have not been logged with the spectral gamma tool (299-E27-12, 299-E27-13, and 299-E27-15). Therefore, geophysical logging will also be conducted at these wells (site W). All other groundwater monitoring wells have been logged since 2003 and will not be relogged. The spectral gamma tool deployed should measure ^{137}Cs, ^{60}Co, ^{235}U, ^{238}U, and other gamma emitters in the soils as well as calculate a region of interest to provide a minimum detection limit for the tool. As part of the spectral gamma logging, KUT (potassium, uranium, thorium) logs are also generated which are used to evaluate the location for tops of the stratigraphic layers.

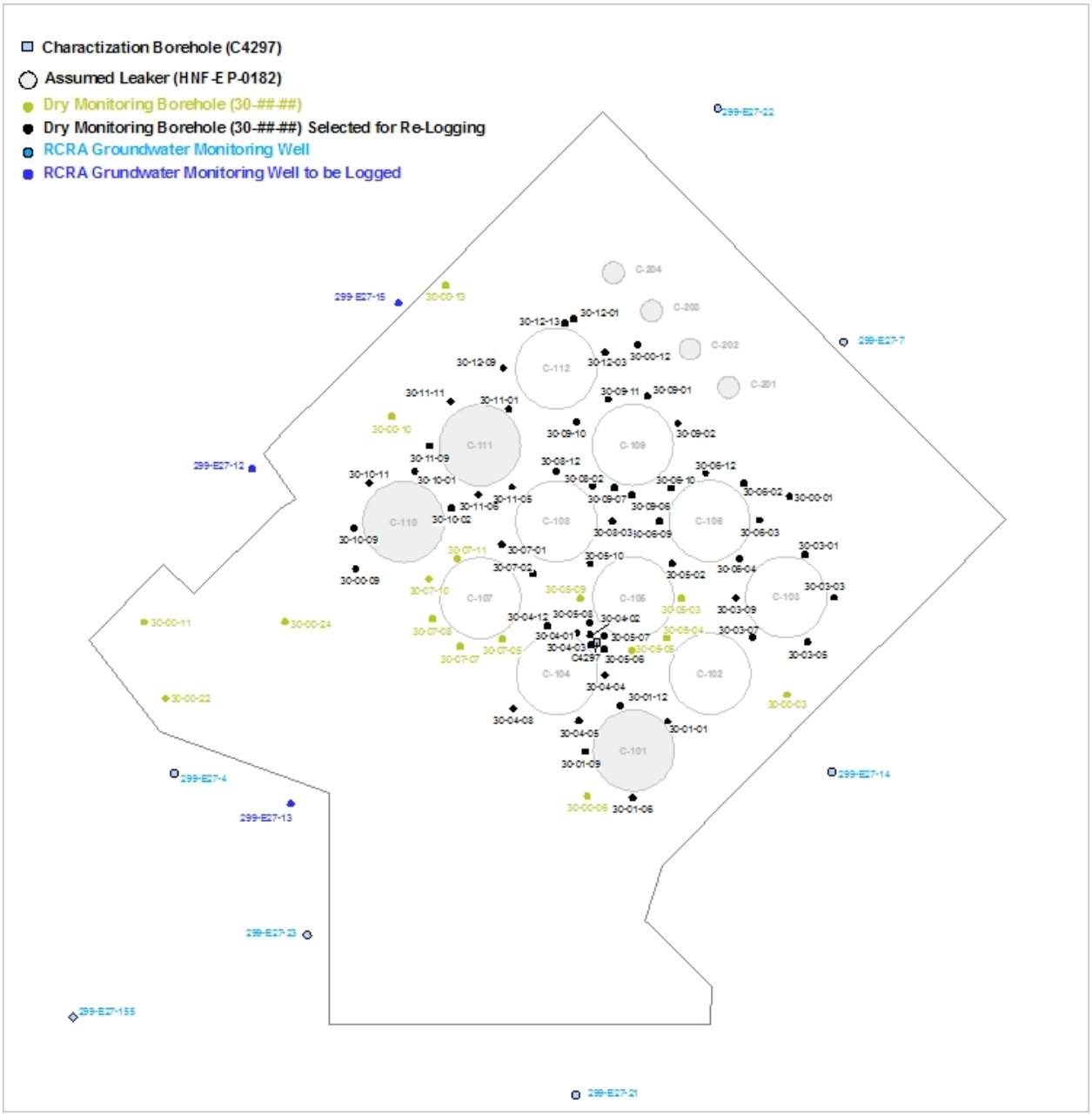
Spectral gamma logging may also be conducted in other locations at WMA C to gain additional information about contaminant distribution.

4.5.5 Surface Geophysical Exploration

One of the characterization options considered and selected during the DQO process was SGE. This method of indirect investigation has been deployed around UPR-200-E-81, UPR-200-E-82, and UPR-200-E-86 (site N). Surface geophysical exploration has also been proposed for the C-200 tank investigation. Electrodes were installed at depth near UPR-200-E-81, UPR-200-E-82, and UPR-200-E-86 (site N). Additional electrodes are to be installed to address the C-200 tanks and UPR-200-E-137.

Each of the site N UPRs is reported as the location of significant loss of waste to the environment. Direct push investigation in each UPR region as part of the near-term work plan (RPP-PLAN-35341) will be used to verify the identified waste signatures of each UPR commensurate with the leak loss estimate for each UPR, and contrasted to the SGE results for each UPR. The results from the deployment of two- and three-dimensional resistivity surveys at the UPRs will influence how SGE will be deployed elsewhere at WMA C. In anticipation of the use of SGE elsewhere at WMA C, single depth or strings of multi-depth electrodes will be placed at each direct push location during logging hole decommissioning.

Figure 4-10. Drywell and RCRA Groundwater Monitoring Locations to be Logged



RCRA = *Resource Conservation and Recovery Act of 1976*

The results of the deployment of the three-dimensional resistivity surveys at the UPRs indicate that SGE can be an important aid in locating investigative direct pushes or boreholes to find waste with high ionic strength that has been associated with ^{99}Tc and other mobile contaminants. Therefore, a decision has been made to employ two- and three-dimensional resistivity surveys around the C-200 tanks before completing direct push probehole installations at sites C and D. The results of this SGE application will be evaluated together with existing information about the area to optimize placement of future direct push probeholes.

The purpose of the SGE investigation of sites C and D is to interrogate the subsurface beneath the C-200 tanks and the surrounding vicinity for the presence of tank farm related waste. Although multiple C-200 tanks are assumed to have released waste to the environment in the past, only one UPR is identified for these tanks, UPR-200-E-137 for tank C-203 (HNF-EP-0182). Evidence suggests that the C-200 tanks were filled several times, and liquid level decreases may in part have been the result of a tank overflow through spare inlet ports, or more likely can be attributed to evaporation (RPP-RPT-42294, *Hanford Waste Management Area C Soil Contamination Inventory Estimates*). The SGE investigation will also evaluate whether there is any evidence of a leak from any of the C-200 tanks during retrieval.

Results from gamma logging at groundwater monitoring well 299-E27-7 in January 2008 detected contamination indicative of tank farm waste streams. Uranium-238 and -235 were detected between 93 and 108 ft bgs, while ^{60}Co was detected at multiple isolated depth intervals, including 133 to 135 ft bgs and 150 to 158 ft bgs. Groundwater level at the time was measured at 237.75 ft bgs (HGLP-LDR-174, *299-E27-07 (A4816) Log Data Report*). Well 299-E27-7 is located on the northeast border of the C Farm, due east of tank C-202, and ~110 ft from tank C-201. Surface geophysical exploration investigation of this area is designed to maximize the subsurface information between the C-200 tanks and well 299-E27-7 in an effort to determine the source of the uranium and cobalt contamination, while also informing the soil sampling and characterization efforts around the C-200 tanks.

It is envisioned that the SGE investigation of the C-200 tanks will require installation of five direct push boreholes for electrode emplacement, as follows:

- one angled direct push, placed north of tank C-203/UPR 200-E-137 and extending at an angle beneath tank C-203
- three vertical direct pushes placed ~50 ft apart on a northwest to southeast trend northeast of the C-200 tanks
- one vertical direct push southwest of tank C-203 between the 200- and 100-series tanks.

Additional WMA C-specific SGE work completed recently includes the reanalysis of the well-to-well resistivity data acquired in 2006 (RPP-RPT-31558). Advances in computing processing capability and speeds, as well as advances in geophysical data processing codes, presented an opportunity to reexamine the data acquired in 2006, resulting in a model that used the complete data set acquired, as well as optimizations recently implemented in the processing code. The initial investigation acquired an extensive amount of data that could not be effectively processed in its entirety given computer processing limitations. Report RPP-RPT-49288, *C Farm Surface Geophysical Exploration-Reprocessing* presents the results of the C Farm well-to-well resistivity reanalysis completed in 2011. The results of the 2006 SGE survey identified a large resistivity target adjacent to SST C-104, which was not consistent with historical documentation. The results of the 2011 reanalysis saw a laterally reduced target size and a shift in the resistivity target position now centered under tank C-101, previously identified as a suspected leaking tank, and consistent with RPP-ENV-33418.

During collection of the resistivity data, it is necessary to deactivate cathodic protection and electrical leak detection systems in the region. Because of increased tripping hazards associated with the cables and perceived electrical hazards, access to the farm will be severely restricted during this activity.

4.5.6 Develop New Characterization Technology

At the present time, the only way to measure levels of ^{99}Tc contamination in the soil is to take samples to send to the laboratory for analysis. This methodology is labor-intensive and provides samples only at chosen intervals (see Section 4.5.1.3). The development of a ^{99}Tc sensor that can be deployed during the placement or decommissioning of direct push probeholes could quickly indicate where sampling intervals should be located and avoid costs associated with null sample results. Such a sensor would be based on robust, existing technology of silicon beta detectors, noting that very few long-lived beta-emitting radionuclides exist in the Hanford sediments. The development of this sensor would be in two stages, a laboratory testing stage followed by deployment in the field. The prototype ^{99}Tc sensor would first be built and tested in the laboratory. If testing of the laboratory prototype proved successful, then a ^{99}Tc sensor that could log small-diameter probeholes would be built and field tested.

This work is contingent on available funding. If successful, development of this ^{99}Tc sensor would provide cost-effective soil sampling related to the mobile contaminants of ^{99}Tc and nitrate that impact groundwater by only sampling in direct push probeholes that the ^{99}Tc sensor identified as having ^{99}Tc. The interest in this new technology was recognized through data needs workshops conducted for Phase 2 RFI/CMS processes and was shared with Ecology, who expressed an interest in deployment in WMA C. This new characterization technology, ^{99}Tc sensor, could aid in the selection of soil samples in addition to the standard use of gross gamma and neutron moisture logging data that is conducted before soil sampling decision-making (see Section 4.5.1.4). However, due to the developmental nature of this technology, it is not apparent that the ^{99}Tc sensor will be ready for field deployment in time to support site characterization activities at WMA C.

4.6 OPTIMIZING SAMPLING

Based on data needs identified in the DQO meetings, a number of options were considered for the Phase 2 characterization effort at WMA C. These characterization options included using direct push technology and nonintrusive geophysical techniques (e.g., SGE) and updating spectral gamma logging around tanks C-103, C-104, C-106, C-108, C-109, C-110, C-111, and C-112 as well as groundwater monitoring wells 299-E27-12, 299-E27-13, and 299-E27-15. These options are based on characterization techniques and innovative technologies identified in RPP-PLAN-37243 and RPP-ENV-38838 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 Phase 2. 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 beginning in FY 2009. The accessibility of some of these sites is limited by waste retrieval operation equipment located on the surface and subsurface infrastructure interferences for WMA C. The list of characterization options considered during the DQO process, along with the rationale for including or omitting each option from Phase 2 effort, is provided.

RPP-16608, *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* evaluated sampling and analysis options and alternative field sampling technologies. That evaluation and the experience gained during implementation of the Phase 1 RFI field investigation has resulted in identifying the following sampling technologies for the initial Phase 2 characterization efforts: direct push, SGE, and borehole logging. These technologies allow for investigations for the presence of contaminants in the vadose zone to be conducted using both indirect and direct evaluation techniques. Subsurface investigations will include geophysical logging using spectral gamma and moisture, SGE, and soil sampling using direct push technology.

Direct push technology is planned for use during the initial Phase 2 characterization of the vadose zone in WMA C. The advantage of this technology is ease in deployment, better option of evaluating lateral extent of contamination, no contaminated soil cutting being brought to the surface, and lower costs. The direct push technology would use a dual string in order to collect multiple samples out of single direct push. The dual string (2.625 in. OD) approach can collect a 1.08 in. × 24 in. sample at multiple depths. In the 200 East Area, the direct push technology has demonstrated the ability to go to great depths (~200 ft), thus providing the opportunity to use its advantages, especially no contaminated soil cuttings being brought to the surface. This is an advantage over traditional drilling of a borehole, which is more expensive, provides no ability to easily evaluate lateral extent of contamination, and brings contaminated soil cuttings to the surface.

The disadvantages of this technology are (1) the quantity of sample material available for analysis, and (2) the small diameter of the probeholes, which prevents use of high resolution logging tools. The depth limitations mean that the lateral extent of contamination may be determined, but not necessarily the full vertical extent. The ability to collect multiple samples in a given probehole results in a 51% decrease in the volume of sample that can be collected. In the past, gamma geophysical logging in small diameter probeholes was limited to sodium iodide crystal. The vadose zone program used this tool for a rapid scan (4 ft/minute) for identifying zones of elevated gamma counts. At times, zones of elevated gamma counts were re-logged with longer count times to acquire a limited spectral speciation. The lower limit of detection with the sodium iodide crystal is about 10 pCi/g. Lower detections limits, such as 0.1 pCi/g, and better spectral speciation requires a 4-in. cased well. However, recently at 241-TY Tank Farm, a modified BGO logging tool was successfully deployed by Pacific Northwest Geophysics that contains a small diameter (~2.54 cm) crystal, which allows detecting gamma radiation at lower levels than the sodium-iodide crystal. This tool and its modifications are briefly described.

The BGO crystal has a high density matrix which allows for capture of high energy gamma rays, especially in comparison to a sodium iodide detector, which has a lower density crystalline structure. The ability to capture high energy gamma rays allows the tool to be utilized for

spectral interpretation of high-energy gamma-emitting nuclides such as thorium (2,775 KeV) and more precise quantification of mid-level energetic gamma rays such as the 1,173 and 1,332 KeV energy spectra from cobalt.

The BGO tool was previously deployed in C Farm for characterization of direct push exploration probes surrounding the C-152 Diversion Box in 2005. At that time the BGO instrumentation was operating in an analog mode. That is, all detector signals were transmitted up-hole for processing at surface. Pacific Northwest Geophysics identified two problems with the original BGO tool that caused degradation of the signal clarity and resolution. These were: (1) using complete analog mode created a baseline drift issue caused by heat buildup in the down-hole electronics and surface processors; and (2) magnetic fields generated by the impacts on the direct push tubing created electromagnetic interference, which led to signal degradation. The first problem was corrected by converting the system to a digital mode where all energy changes detected by the BGO crystal are processed by a downhole processor (multi-channel analyzer) and transmitted to a surface recorder in a digital mode. The second problem was addressed by containing the detector within three layers of mumetal (a nickel alloy), which shields the electronics from the magnetic field effects, instead of one layer. These changes have resulted in reduced signal noise and removal of baseline drift.

In this modified configuration, recent calibration efforts and field deployment data have demonstrated that the detector is capable of detecting cesium concentrations as low as 0.5 pCi/g and cobalt as low as 0.6 pCi/g. In addition to the low man-made radionuclide detection levels, the KUT (potassium, uranium, thorium) ratios provided by the BGO have allowed for improved lithologic interpretations from geophysical log data. The major drawback to this logging tool is the longer count times (3.3 minutes/ft). The calibration of the BGO logging tool will be described in the logging report for the TY Farm direct push due out in the second quarter of 2009.

In the event that sampling via direct push technology does not provide the necessary information, subsequent revisions of the DQO would be used to address supplemental sampling approaches. The data gathered through application of direct push technology will be available to target those regions requiring deeper investigation through other established techniques (drill and sample, drive and sample, etc.).

The Tank Farm Vadose Zone Program technical team plans to use existing information and the characterization data collected during the Phase 1 and near-term (FY 2008) characterization to develop a best basis or best estimate of the concentration and distribution of COC in WMA C in addition to the sampling and analysis in this work plan. 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 to be used to evaluate human health and environmental risks.

4.7 INVESTIGATIVE SAMPLING AND ANALYSIS AND DATA VALIDATION

Samples and data will be collected during the vertical/slant probehole installation while driving the casing and by conducting geophysical surveying as described in the SAP presented in Appendix A. 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 Appendix A. 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 leak chemistry (e.g., cementation, discoloration).

Data from the vertical probeholes 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 QAPD in Attachment 1.

5. RCRA FACILITY INVESTIGATION/CORRECTIVE MEASURES STUDY PROCESS

This chapter provides the summary of the Phase 2 RCRA corrective action process and the tasks that will be performed within this process for the WMA C field investigation. The development of and rationale for the Phase 2 RCAP is provided in RPP-PLAN-37243 and summarized only to inform the reader of the links the field information supports in meeting the requirements. Phase 2 RFI/CMS tasks are designed to satisfy the DQOs identified in Chapter 4 and RPP-RPT-38152, document investigation results, and provide CMAs analysis in the forthcoming Phase 2 RFI/CMS to be submitted to Ecology in December 2010.

A SAP for this work plan is included in Appendix A. Data-collection objectives for Phase 2 were identified in the DQO process (RPP-RPT-38152) and are discussed in Chapter 4 of this work plan. Tasks to be completed following the field investigation include preparation of a Phase 2 RFI/CMS for WMA C to fulfill HFFACO Milestone M-045-61. Attachment 1 provides the overall QAPD for the Phase 2 RFI/CMS for WMA C. Environmental monitoring requirements for protecting the health and safety of onsite investigators are provided in Attachment 2. Attachment 3 includes a review of data-management activities that apply to the Phase 2 RFI/CMS for WMA C and describes the process for the collection/control of data, records, documents, correspondence, and other information associated with RFI/CMS activities.

This work plan will not be modified after its approval by Ecology without the 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 HFFACO Section 9.3 (Ecology et al. 1989).

To satisfy the data needs and DQO process specified in Chapter 4, the following tasks will be performed during the field investigation:

a. Integration/project management
b. Vadose zone investigation (soils only)
c. Data evaluation.

The tasks and their components, subtasks, and activities are outlined in Sections 5.1 through 5.6. Information about each task is provided to allow estimation of the project schedule (see Chapter 6) and costs.

A separate plan developed by the Hanford Groundwater Performance Assessment Project will cover groundwater investigations for WMA C as defined in HFFACO Milestones M-015-00, M-015-00C, and M-015-21A (Ecology et al. 1989). Currently, DOE/RL-2007-18 is the work plan associated with WMA C.

5.1 INTEGRATION WITH OTHER PROGRAMS AND AGENCIES

Several ongoing Hanford Site characterization, remediation, and other activities may impact or be impacted by the Phase 2 RCAP activities. Integration of these activities is important to optimize the use of resources and provide an understanding of cumulative impacts. Currently, the Soil and Groundwater Remediation Project has lead contractor responsibility for integrating all groundwater and vadose zone activities. The Soil and Groundwater Remediation Project is managed by the Plateau Remediation Contractor. The RCAP is committed to integrating planning, field activities, and analyses with principal interfaces in support of these integration projects. The Phase 2 master work plan (RPP-PLAN-37243) discusses project scope, points of contact, and integration needs.

Integration will primarily occur through monthly project reporting as well as coordination and involvement during DQO activities. Additional benefit can be gained through communication on innovative technology lessons learned and by coordinating resources through multi-project teams. The overall integration management plan discusses these interfaces (DOE/RL-2007-20, *Hanford Integrated Groundwater and Vadose Zone Management Plan*). The overall integration strategy is also provided in Chapter 5 of the Phase 2 master work plan (RPP-PLAN-37243).

Project management occurs throughout the RCRA corrective action process. Project management is used to direct and document project activities so that the objectives of the work plan are met and the project remains within budget and on schedule. Other project management activities include day-to-day supervision of, and communication with, project staff and support personnel; meetings; control of cost, schedule, and work; records management; progress and final reports; quality assurance; health and safety; and community relations.

The project management objectives throughout the course of the Phase 2 WMA C process as identified in HFFACO Milestones M-045-60, M-045-61 and M-045-62 (Ecology et al. 1989) 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 to (1) ensure the safety of the work force and the affected environment, (2) direct and document project activities, (3) ensure that project goals and objectives are met, and (4) administer the project within budget and schedule. The Phase 2 WMA C DQO workshop defined the specific scope and schedule elements. These elements resulted in the development of a DQO report (RPP-RPT-38152) that provided the data needs and characterization locations identified in the DQO process.

5.2 FIELD INVESTIGATION ACTIVITIES

The following sections summarize the planned tasks that will be performed during the Phase 2 RFI/CMS work plan for WMA C for the soils within and immediately surrounding the WMA C that were impacted by tank farm activities. Planned tasks include the following:

a. Planning
b. Field investigation

c. Management of waste

d. Laboratory analysis and data validation.

These tasks and subtasks reflect the work structure that will be used to manage the work and develop the project schedule provided in Chapter 6.

5.2.1 Planning

The planning subtask includes tracking and coordinating activities to be completed and documentation that must be completed before the Phase 2 RFI/CMS field activities can begin. This includes interfacing with other organizations and/or project managers who will be providing information for presentation in the Phase 2 RFI/CMS report due to Ecology on December 31, 2014, to fulfill HFFACO Milestone M-045-61. It also included conducting a DQO process with Ecology, ORP, TOC, and integration with Plateau Remediation Contractor and RL personnel for coordination of activities associated with the groundwater operable unit 200-BP-5 that is under WMA C (RPP-RPT-38152).

In addition to this work plan, which fulfills HFFACO Milestone M-045-60, radiological work permits, excavation permits, supporting surveys (e.g., cultural, radiological, wildlife, utilities), work instructions, personnel training, and the procurement of materials and services (e.g., drilling and geophysical logging services) also will be required. In addition, characterization locations identified in the SAP (Appendix A) will be located using GPR and staked using a global positioning satellite system.

Attachment 2 provides a health and safety plan that outlines health and safety requirements for field investigation activities. This health and safety plan in coordination with TFC-PLN-43, Treatment, Storage and Disposal Facility Hazardous Waste Operations ensures protection of onsite investigators. Initial surface radiological surveys will be performed to document any radiological surface contamination and background levels in and around the sampling locations. This information will be used to document initial site conditions.

5.2.2 Field Investigation

The field investigation task involves performing data-gathering activities in the field that are required to satisfy the DQOs. The field characterization approach is summarized in Section 4.2 and detailed in the SAP and sampling and analysis instructions provided in Appendixes A and B. The scope includes soil sampling and analysis to characterize the vadose zone soil at selected locations and geophysical logging. Groundwater is another component of WMA C and is being evaluated under DOE/RL-2007-18. Major subtasks associated with the field investigation include the following.

a. Conduct direct push installations for geophysical logging, soil sample collection, and deep electrode placement.

b. Conduct probehole geophysical surveying and analysis (e.g., neutron, gross gamma).

c. Obtain sediment samples to analyze for the presence and concentration of contaminants and to evaluate alterations of the sediments from waste chemistry effects.

d. Obtain tissue samples from surrounding environment for ERA.

e. Conduct geophysical logging of drywells within WMA C and groundwater wells within the DQO boundary.

f. Conduct testing SGE at UPR-81, UPR-82, and UPR-86. Based on lessons learned from the UPRs, deploy SGE across WMA C.

The vadose zone investigation for Phase 2 WMA C will comprise compiling pertinent existing data and collecting data from field investigation activities in the vadose zone. The types of data needed from the surface and vadose zone include the following:

a. Thickness and areal extent of geologic units.

b. Lithology, bedding types, facies geometry, particle size, and sorting.

c. Presence, concentration, and nature of contaminants in sediments of the vadose zone.

d. The vadose zone information will be evaluated to determine the following:

    1. Refinement of WMA C conceptual vadose zone model.
    2. Release and movement of contaminants.
    3. Development and evaluation of CMS alternatives.

Chapter 4 provides the rationale and approach for the field investigation. The requirements for geologic and geophysical surveying and sediment sampling for physical and laboratory analytical parameters in the vadose zone are provided in Appendix A.

Based on Chapter 4 and the DQO (RPP-RPT-38152), soil investigation (i.e., 200 ft bgs) will be conducted within the area of the DQO boundary. The investigation will comprise collecting sediment samples between the ground surface and refusal using direct push technology at the locations identified in Table 4-1. The samples will be transported to the laboratory and analyzed for the constituents identified in Appendix A. The physical and operational constraints will require evaluation prior to identifying the specific target locations. This work plan calls for a sample to be taken at ground surface (i.e., 0 to 1 ft bgs). Although every attempt will be made to collect this sample, the gravel surface in tank farms may prevent taking a sample that contains environmentally sensitive media (i.e., soil particles less than 2 mm in diameter). If this is the case, pictures of the sampling site showing the gravelly nature of the land surface and the reason why a sample will not be taken will be documented in borehole/site completion reports.

Soil characterization will be carried out principally using a hydraulic hammer direct push-technology-based system. 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 probe. The depth of investigation will be determined at least partly by the depth to which the direct push boring can be advanced using standard deployment. Each direct push location requires a nonsampling direct push for gamma and neutron logging to target a location to sample (i.e., high moisture and/or high gamma) followed by a direct push to collect the soil.

The graphical log developed using the gross 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.

Subsurface conditions are variable, and the process of the field investigation must be flexible. Some or all of the work described in Appendix A may require modification. This work plan 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 appropriate field documentation, memoranda, or letters. A complete documented record of activities will be maintained for preparation of a final summary report.

5.2.3 Management of Waste

Waste generated during the RFI/CMS will be managed in accordance with a waste-control plan for the sampling activity. Attachment 4 provides general waste management processes and requirements for the waste. Since this field investigation will principally use direct push technology, no waste to minimal waste will be generated.

All waste will be handled in accordance with the requirements of WAC 173-303 and as reflected in the site-specific waste control plan. These techniques are based on the practice of minimizing the exposure of field personnel to both radiation and chemical pollutants to as low as reasonably achievable (ALARA) and are in compliance with regulatory requirements.

Appropriate permits and compliance with the notice of construction permit (DOE/ORP-2000-05, *Notice of Construction for Tank Waste Remediation System Vadose Zone Characterization*) will be maintained during the field operations inside the tank farm. The selected field interrogation methods 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.

5.2.4 Laboratory Analysis and Data Validation

Soil samples will be analyzed for a suite of radionuclides and nonradionuclide constituents identified during the Phase 2 WMA C DQO process. The list of analytes, methods, and associated target-detection limits is provided in the SAP (Appendix A). The SAP also specifies quality assurance, quality control, and data-reporting requirements for the laboratory analysis. Validation of a representative number of laboratory data packages will be performed.

Data validation will be completed in accordance with a vadose zone data management plan. Validation activities will be based on EPA laboratory data validation functional guidelines

(EPA/540/R/94/083, *Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses* and EPA/540/R-94/082, *Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses*).

5.3 PHASE 1 DATA EVALUATION

All Phase 1 characterization data is compiled and reviewed in DOE/ORP-2008-01, *RCRA Facility Investigation Report for Hanford Single-Shell Tank Waste Management Areas*, since the completion of field operations and receipt of laboratory results for Phase 1. Field screening results, geophysical logging data, and laboratory analyses were included and summarized in the report. Results were tabulated and maps and plots prepared to show the contaminant distribution. Based on the results of Phase 1, an assessment was completed concerning the need for additional data collection for each of the SST WMAs. It was determined that additional characterization data was needed to support risk assessment evaluations and corrective measures decision-making, and planning for Phase 2 was initiated. The results were modification of the HFFACO (Ecology et al. 1989) to add an additional three interim milestones (M-045-60 through M-045-62), modify an existing interim milestone (M-045-58) and amend Appendix I, Section 2.3, to elaborate on the Phase 2 activities and modified specific Phase 1 master work plan deliverables for the RFI. The modification no longer required a comprehensive and ecological risk assessment, as a summary of impacts from the initial SST performance assessment was required in the HFFACO Milestone M-045-55 and included the field investigation reports for WMAs C, A-AX, and U. Phase 1 results were used to determine Phase 2 data needs in WMA C.

5.4 PHASE 2 RCRA FACILITY INVESTIGATION/CORRECTIVE MEASURES STUDY

Phase 2 will entail gathering additional data to support corrective action decisions, including no action. Results of both near-term and Phase 2 of the characterization data will be presented in the Phase 2 RFI/CMS report for WMA C fulfilling HFFACO Milestone M-045-61 (Ecology et al. 1989). Data generated during the field investigation will be integrated and evaluated with previous field investigations, coordinated with Central Plateau RI/FS 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 Phase 2 RFI/CMS report for WMA C. The results of these evaluations will be made available to project management personnel to keep project staff informed of progress made. The interpretations developed under this task will be used to refine the conceptual model and refine the CMAs to support future closure requirements and risk assessments.

5.4.1 Data-Quality Assessment

A data quality assessment in accordance with HASQARD will be performed on the analytical data to determine if they are the right type, quality, and quantity for their intended use. The data

quality assessment completes the data life cycle of planning, implementation, and assessment that began with the DQO process. In this task, the data will be examined to see if they meet the analytical quality criteria outlined in the DQO and are adequate to evaluate the decision rules in the DQO.

5.4.2 Data Evaluation and Conceptual-Model Refinement

This task will consist of evaluating the information that has been collected. The nonradiological and radiological data associated with the soil samples will be compiled, tabulated, and evaluated to satisfy data needs as defined in the DQO (RPP-RPT-38152). Data evaluation tasks may include the following.

a. Perform initial screening for contamination by evaluating the data with respect to background, using simple comparisons of maximum values to background concentrations.

b. Compare the data to potential cleanup levels.

c. Describe the distribution of contamination within the vadose zone based on field screening and laboratory analytical results.

d. Describe the vertical and lateral distribution of contamination in soil based on geophysical logging results and analytical data for soil samples.

e. Construct data diagrams and plots to evaluate spatial correlations within and between samples. This evaluation will be used to assess whether contamination is concentrated in a particular area, in relationships between contaminant levels and locations in surrounding soil.

f. If sufficient data are available, perform statistical analyses. This step has many facets, including determining the distribution of the data and selecting the appropriate statistical tests.

If available data are not sufficient for statistical analysis, maximum concentrations will be used in the data evaluation process. The combined chemical and geophysical data will be used for refining the initial conceptual contaminant-distribution models and as inputs to the risk assessment.

5.4.3 Waste Management Area C Performance Assessment

After submittal of Revision 0 of this document to Ecology in December 2008, a process was developed in February 2009 and is ongoing that addresses performance assessment scope, methods, and assumptions. The ongoing process started with Ecology, NRC, EPA, Tribal Nations, and interested stakeholders to develop the scope (conceptual exposure model, conceptual site model, selection of numerical codes, etc.) of the performance assessment through a series of working sessions or workshops that will address various performance assessment

attributes. These working sessions will address the exposure scenarios to be used including a baseline risk assessment. This performance assessment will be the assessment used for the Phase 2 RFI/CMS report.

As part of the WMA C performance assessment and to meet the requirements of the Phase 2 RFI/CMS report for WMA C, a risk assessment with a "no action" alternative to address CERCLA requirements will be prepared as part of the report for all potential pathways: human-health direct contact, ecological, and protection of groundwater.

The risk assessment with a "no action" alternative will evaluate risk to human and ecological receptors from potential exposure to contaminants in surface sediments and accessible shallow subsurface soils. The risk assessment also will evaluate the potential for contaminants that are currently in the vadose zone soil to impact groundwater in the future. Risks from current groundwater contamination will not be evaluated; this evaluation will be conducted as part of the RI/FS process for the Central Plateau respective groundwater operable units through the CERCLA process and HFFACO Milestone M-015-00.

A risk assessment with a "no action" alternative analysis for those COC detected within the soils will be completed. Initial screening will consider the constituents to be directly accessible to potential receptors as applicable for their exposure pathways. These modeling results will be considered in the risk evaluations associated with various potential leave-in-place CMAs (e.g., no action, decontamination flushes, grouting).

5.4.3.1 Standards, Guidance Documents, and Computer Codes. The human-health risk assessment will be conducted in accordance with appropriate subsections of WAC 173-340, with agreements with Ecology on the WMA C performance assessment as described in RPP-PLAN-37243, and with the following DOE and EPA guidance documents:

a. DOE/RL-91-45, *Hanford Site Baseline Risk Assessment Methodology*

b. EPA/540/1-89/002, *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A) Interim Final*

c. OSWER Directive 9285.6-03, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance "Standard Default Exposure Factors" Interim Final*

d. EPA/600/P-95/002Fa, *Volume 1 - General Factors Exposure Factors Handbook*

e. EPA/540/R-99/005, *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final*

f. EPA/600/P-92/003C, *Proposed Guidelines for Carcinogen Risk Assessment*

g. OSWER Publication 9285.6-10, *Calculating the Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites*

h. OSWER Publication 9285.7-081, *Supplemental Guidance to RAGS: Calculating the Concentration Term*

i. EPA-540-R-070-002, Jan 2009. *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment) Final*

j. EPA/600/R-07/038, *ProUCL Version 4.00.02 User Guide*.

The RESidual RADioactivity (RESRAD) computer program (ANL 2002) will be used to obtain risk and dose estimates from direct-contact exposure (i.e., top 15 ft) to radiological constituents present in the shallow zone of the waste sites. Additional analysis may be performed using other appropriate fate and transport models (e.g., PNNL-12030, *STOMP Subsurface Transport Over Multiple Phases, Version 2.0 Theory Guide* and PNNL-15782, *STOMP Subsurface Transport Over Multiple Phases Version 4.0 User's Guide*) to assess impact to the groundwater from chemicals and radionuclides in the vadose zone (in accordance with WAC 173-340-747, "Deriving Soil Concentrations for Groundwater Protection," item (8) "Alternative fate and transport models").

5.4.3.2 Additional Risk Assessment Information. For WMA C, risk assessment will be performed for an industrial-exposure scenario and residential/unrestricted use scenario to establish the "no action" alternative. As part of the Phase 2 RFI/CMS, additional risk assessment for informational purposes may be performed to evaluate other scenarios (such as Native American or an intruder scenario to evaluate post-remediation residual risks).

Contaminant concentrations, distribution, and pathway availability will be evaluated. Analytical data and hydrogeologic information used in risk calculations include the following:

a. Laboratory analytical results from sampled media (soils only)

b. Waste-site configuration and construction

c. Depth of burial [above or below the 4.6 m (15-ft) direct human-exposure point of compliance] [in accordance with WAC 173-340-740, "Unrestricted Land Use Soil Cleanup Standards," item (6) "Point of compliance," subsection (d), and item (3) "Method B soil cleanup levels for unrestricted land use," subsection (b) "Standard Method B soil cleanup levels," as appropriate]

d. Known or estimated volume of a waste stream released in relation to the available pore volume of soil

e. Comparison of concentrations of contaminants relative to concentrations considered protective of groundwater (e.g., compared with WAC 173-340-747 derived concentration values)

f. Contaminant inventory (types and location)

g. Release mechanism

h. Expected distribution of contamination based on configuration of the release

i. Geological setting

j. Neighboring waste sites, structures, or utilities

k. Potential for hydrologic and contaminant impacts to groundwater.

Information and assessments completed for each release into the environment that is known will be a part of the Phase 2 RFI/CMS work plan for WMA C and will be incorporated into the Phase 2 RFI/CMS report for WMA C. Results of the risk assessment will be used to support the evaluation and selection of the appropriate corrective action. The characterization data that was compiled during Phase 1 and additional characterization data provided from the near-term characterization effort and this Phase 2 effort should provide sufficient information to select CMAs for each soil release site within the study boundary. Following the CMS, additional data collection will be performed as needed to optimize alternative design and verify achievement of cleanup goals under the corrective measures implementation (CMI) (HFFACO M-45-62). For sites that are candidates for a removal action, final verification sampling results will provide sufficient data to document that cleanup levels specified in the RCRA Permit have been achieved.

5.4.4 Ecological Evaluation and Risk Assessment

As part of RCRA corrective action, WAC 173-340-357 requires assessment of ecological risk as part of the determination of cleanup levels and CMAs. The MTCA addresses hazardous chemicals but does not address the radionuclide contaminants that are known to have been released into the environment at WMA C. To address chemical and radiological ecological risks, the SST WMA ERAs will be performed in accordance with the following:

a. WAC 173-340-7490, "Terrestrial Ecological Evaluation Procedures"

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

Information developed under the WMA ERA process will be used in the development and analysis of CMAs, including the no-action alternative. To maintain consistency across the Hanford Site, the ERA for the WMAs will integrate some of the methodology and data that were used in the CPERA. A detailed discussion on the approach to SST WMA ERA is provided in Section 3.4.

5.4.5 Treatability Studies Needs

In conjunction with the Phase 1 RFI data compilation and assessment for WMA C (DOE/ORP-2008-01), the Phase 2 RFI/CMS activities will be initiated and will include the

identification of applicable CMAs. Treatability studies may be required to verify the feasibility of a technology, cost of a remedy, or applicability of a technology or action. Phase 1 RFI/CMS characterization activities have provided additional information that may contribute or be used in lieu of treatability studies needed to complete the Phase 2 RFI/CMS. Information obtained during Phase 1 and 2 characterization activities would provide support in addressing the existing condition of selected soil contamination levels, level of effort and costs to acquire data, and worker-exposure conditions associated with certain corrective measure remedies. Additionally, the results from Phase 2 characterization activities would be used to identify the need for engineering studies. Treatability studies for the deep vadose zone are presently being evaluated as part of the remedial investigation process under CERCLA that is being conducted by DOE-RL and the Plateau Remediation Contractor (DOE/RL-2007-56, *Deep Vadose Zone Treatability Test Plan for the Hanford Central Plateau*). Should deep vadose zone treatability be warranted in WMA C, DOE-RL and its contractor would implement these treatabilities.

5.4.6 Corrective Measures Study Outline

As required by the guidance for the RCAP (OSWER 9902.3-2A), a proposed outline (that may be modified as appropriate following Phase 2 characterization activities) for the RFI/CMS report including a description of how the information will be presented is provided in the following.

a. **Introduction/Purpose:** The purpose of the document and a summary description of the project will be provided.

b. **Summary of Phase 2 RFI Results:** A brief summary/discussion of new characterization performed during the Phase 2 RFI since the Phase 1 RFI report (Appendix L of DOE/ORP-2008-01) was finalized will be provided. The Phase 2 RFI information will form the basis for the evaluation of risks from a no-action alternative and the CMA(s) developed in the CMS.

c. **Media Cleanup Standards:** Proposals of media cleanup standards may be provided. The standards must be based on promulgated federal and state standards, risk derived standards, all data and information gathered during the corrective action process (e.g., from interim measures, RCRA Facility Investigation), and/or applicable guidance documents. Final media cleanup standards are determined by Ecology when the remedy is selected and are documented in the Statement of Basis/Response to Comments or permit modification.

d. **Identification, Screening, and Development of Corrective Measures Alternatives:**

1. **Identification:** The CMS will define potentially applicable corrective measure technologies that may be used to achieve the corrective action objectives.

2. **Screening:** When evaluating a number of corrective measures technologies, an evaluation of the technology limitations will show why certain corrective measures technologies may prove not feasible to implement given existing waste and site-specific conditions (see RPP-ENV-34028).

3. **<u>Corrective Measures Development:</u>** Section 5.4.7 provides a description of the development of CMAs.

e. **Evaluation of CMA(s):** For each alternative a detailed analysis of how the potential alternatives will comply with each of the standards provided in Section 5.4.8 will be developed. After this detailed analysis, a comparative analysis of the alternatives will be developed. In evaluating the selected alternative or alternatives, information shall be presented that documents that the specific remedy will meet the standards listed in Section 5.4.8.

5.4.7 Development of Corrective Measures Alternatives

After completion of the field work, CMAs identified in this section will be more fully developed and will be evaluated against WAC closure performance standards [WAC 173-303-610, "Closure and Post-Closure," item (2) "Closure performance standard"] and evaluation criteria developed in accordance with WAC 173-303-64610, "Purpose and Applicability" through WAC 173-303-64620, "Requirements" and Section 7.4 of the HFFACO and discussed in OSWER Directive 9902.3-2A.

The EPA recommends that all CMAs be developed to address all of the contamination issues at a site. This requires tailoring the evaluation of alternatives based on site-specific circumstances. The CMS would only evaluate implementable approaches, consistent with expected future land uses, and will limit the number of alternatives evaluated to those necessary to demonstrate that the preferred remedy is capable of achieving the following: (1) protection of human health and environment, (2) achieving media cleanup objectives and standards, (3) controlling/remediating sources of release, and (4) acceptable with respect to the balancing/evaluation criteria (e.g., cost, effectiveness, acceptance) (see Section 5.4.8).

The EPA provides an overview of the approach to selecting corrective measures processes consistent with the following (OSWER Directive 9902.3-2A).

a. Define corrective action objectives and RCRA corrective action performance standards and ensure consistency with RCRA closure performance standards.

b. Evaluate only the most likely alternatives that can reasonably be 1) expected to meet corrective action goals and 2) agreed to by the facility and regulators.

c. The level of documentation required is only that necessary to adequately document the decision rationale.

d. Simple, straightforward contamination scenarios may require evaluation of a more limited number of alternatives and less detailed evaluation and documentation.

e. More complex contamination scenarios may require evaluation of a greater number of alternatives and more detailed evaluation and documentation.

f. Identify potential technologies and process options associated with each general response action. See RPP-ENV-34028 for vadose zone soil remediation technologies potentially applicable on the Central Plateau.

g. Screen the process options to select a representative process for each type of technology based on its effectiveness, implementability, and cost. See RPP-ENV-34028 for vadose zone soil remediation technologies potentially applicable on the Central Plateau.

h. Assemble viable technologies or process options into alternatives representing a range of treatment and containment, plus a no-action alternative. Identify technologies to address each COC and medium of concern.

i. Combine technologies into alternatives that address all contamination issues at the site including COCs, media of concern, and risk and exposures.

j. Evaluate alternatives and present information needed to support corrective measure selection and comply with RCRA closure of the unit, pursuant to Hanford Facility RCRA Permit, Condition II.K (WA7 89000 8967, *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion Revision 8C for the Treatment, Storage, and Disposal of Dangerous Waste*).

Potential CMAs identified for this effort, which does not include the deep vadose zone soils and groundwater include the following:

a. Take no action (required for consistency with the CERCLA).
b. Removal (excavation), treat as appropriate, and disposal of waste.
c. Treat contaminants to reduce toxicity, mobility, or volume.
d. Treat vadose zone to reduce mobility of released contaminants.
e. Install surface barrier.
f. Combination of any of the above, except for no action.

Sections of contaminated soils are located in areas where the use of surface cap/barrier may be proposed for corrective actions that will impact other operable units or projects, such as 200-BP-5. Evaluation of CMAs for WMA C will consider the benefits of these proposed barriers and how remedial strategies and decisions can be integrated.

A summary of each of these potential alternatives as it would apply to WMA C will be provided. Two principal categories of CMAs are currently identified: those actions that require removal and those that entail in-place remedies. In-place remedies would include in-situ treatment (stabilization), or maintaining an existing soil cover, if already present, with institutional controls.

5.4.7.1 No Action. To maintain consistency with CERCLA requirements, Title 40 CFR Part 300 requires that a no-action alternative be evaluated as a baseline for comparison with

other remedial/CMAs. The no-action alternative represents a situation where no legal restrictions, access controls, or active remedial measures are applied to the site. No action implies allowing the wastes to remain in the current configuration, thus being affected only by natural processes. No maintenance or other activities will be instituted or continued. Selecting the no-action alternative would require that a waste site pose no unacceptable threat to human health or the environment. Typically, this alternative is used as a comparison to the other CMAs.

5.4.7.2 Removal, Treatment, and Disposal. Contaminated soil is physically removed from the vadose zone and disposed to an engineered landfill designed to prevent release of materials. Key factors to be considered in the selection of removal and disposal include the following.

a. **Volume of material to be excavated**—Involves estimating excavation volume based on preliminary cleanup levels. Costs for excavation and disposal are directly related to the volume of soil to be managed.

b. **Excavation design and strip ratio**—Standard excavation equipment is limited to a depth of ~35 feet without having to bench the side slope. Standard mining techniques can be used to design excavations of considerable depths. With increased depth and the need for benching and laybacks, the effective strip ratio of noncontaminated to contaminated materials increases significantly, adding to the material handling costs.

c. **Underground equipment**—There is a dense array of ancillary equipment (piping, catch tanks, diversion boxes, vaults) that will be routinely encountered from the surface to ~20 ft bgs while removing soil within tank farms. Residuals within this equipment will add significantly to the cost of removal, treatment, and disposal and may result in potentially higher dose rates than for soil removal alone.

d. **Disposal capacity**—Excavating large-diameter, deep waste sites will generate a large amount of waste requiring disposal. Capacity of an approved engineered landfill is typically at a premium.

e. **Worker exposure**—Excavation of highly contaminated sediments can pose significant worker exposure and contamination control issues, both of which increase with depth and size of excavation.

f. **Hot spot removal**—A subalternative would include the removal and disposal to selectively remove near-surface localized areas of high contamination or hot spots. This subalternative could remove the greatest mass of contaminants, while minimizing the volume of material to be handled and disposed. Removing hot spots to shrink the size of surface barriers is another potential use of this subalternative.

g. **Backfilling**—After contaminated materials are removed, the excavation will require backfilling with clean material to bring it back to grade. Backfill will require compacting to achieve conditions as close to undisturbed as possible.

5.4.7.3 Treat Contaminants to Reduce Toxicity, Mobility, or Volume. Some soil locations may have attributes where application of an in-situ treatment technology would be an appropriate remedy to reduce the toxicity, mobility, or volume of contaminated material. The candidate technologies for this alternative include the following: desiccation, in-situ gaseous reduction, multistep geochemical manipulation, nanoparticles, and in-situ phosphate/calcite immobilization.

5.4.7.4 Treat Vadose Zone to Reduce Mobility of Released Contaminants. Other soil locations may have attributes where application of an in-situ treatment technology would be an appropriate remedy that would allow isolation of the contaminants in the vadose zone. The candidate technologies for this alternative include subsurface barriers and permeation grout.

5.4.7.5 Install Surface Barrier. Surface barriers are placed over contaminated sites to control the amount of water that infiltrates into contaminated media to reduce or eliminate leaching of contamination to groundwater. In addition to their hydrological performance, barriers also can function as physical barriers to prevent intrusion by human and ecological receptors, limit wind and water erosion, and attenuate radiation. Surface barriers are effective for all contaminants, are readily implementable, and have been extensively used. A range of surface barriers has been identified for Hanford Site application (e.g., Hanford Barrier, Modified RCRA Subtitle C and D, and evapotranspiration barriers) that are viable process options depending on the site-specific level of protection required (RPP-ENV-34028, DOE/RL-98-28, *200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program*) and predominantly rely on evapotranspiration processes to control the movement of water.

Surface barriers are applicable for groundwater, human health, and ecological protection. Site-specific conditions establish the level of hydraulic or physical barrier performance required. If groundwater protection is required, the barrier will need to limit the infiltration of precipitation. If the prevention of ecological and human intrusion is a performance requirement, then the physical barrier components become more important. For sites with deep vadose contamination (e.g., greater than 150 ft), surface barriers may not sufficiently contain the contamination, and supplemental technologies (e.g., in-situ remediation) may be needed. Site-specific modeling should be performed to evaluate the size and depth over which surface barriers are effective in protecting groundwater. Provisions for groundwater monitoring should be included as part of the alternative for sites with deep vadose zone contamination.

Surface barriers have been designed with a life expectancy up to 1,000 years for the Hanford Site (DOE/RL-93-33, *Focused Feasibility Study of Engineered Barriers for Waste Management Units in the 200 Areas*). For barriers that use naturally stable geologic materials, the primary factor establishing life expectancy is projected erosion rates, which can be minimized by maintaining the vegetation cover and adding armoring appropriately.

5.4.8 Corrective Measures Alternatives, Performance Standards, and Selection Criteria

Section 7.4.3 of the HFFACO requires that the information obtained through the CMS must be functionally equivalent to the information obtained in the CERCLA feasibility study process. In

addition, OSWER Directive 9902.3-2A provides the nine RCRA Corrective Action balancing/evaluation criteria. As such, during the detailed analysis, each alternative will be evaluated against the following:

a. Overall protection of human health and the environment
b. Compliance with applicable or relevant and appropriate requirements (ARAR)
c. Long-term reliability and effectiveness
d. Reduction of toxicity, mobility, or volume of wastes
e. Short-term effectiveness
f. Implementability
g. Cost
h. State acceptance
i. Community acceptance.

The first two criteria are considered threshold criteria, which the CMAs being evaluated must meet. The next five criteria are considered balancing or evaluating criteria, which are used to assist in selecting the most appropriate CMA. The last two criteria are considered modifying criteria, which are used to assist in finalizing the selection of a CMA. The modifying criterion of Ecology acceptance will be documented in the draft RCRA permit modification. The final modifying criterion, community acceptance, will be applied following the CMS during the draft RCRA permit modification public review phase.

Overall protection of human health and the environment is a general mandate from the RCRA statute and is the primary goal of corrective action. This criterion should be evaluated based on reasonably anticipated current and future land use(s). Protection of human health and the environment can be achieved by removing contamination, treating contamination, preventing exposure to contamination, or a combination of these actions.

Compliance with ARARs can occur by achieving the media cleanup objectives/standards and/or control/remediate release sources. Sources include both the location of the original release as well as locations where any significant mass or concentration of contaminants may have migrated.

Long-term reliability and effectiveness criteria should evaluate the degree of certainty that an alternative will remain protective of human health and the environment. The long-term reliability and effectiveness of the criteria should take into consideration the magnitude of risk that will remain and the reliability of any containment systems or institutional controls.

Reduction of toxicity, mobility, or volume of wastes criterion should take into account the degree to which treatment reduces toxicity, mobility, and volume of hazardous waste. Under this criterion, consideration of the amount treated, degree to which treatment is irreversible and the potential toxicity, mobility, and volume of treatment residues should be evaluated.

Short-term effectiveness criterion should take into consideration implementation timeframes and short-term risks posed by the corrective action. This criterion should take into account the potential short-term increases in exposure caused by the corrective action from exposure to contaminated subsurface soil and airborne dust during excavation as well as mobilization of groundwater contamination caused by increased gradients or injected material. Finally, the amount of time required for design, construction, and implementation should be assessed.

The criterion of implementability should take into consideration the ease or difficulty of implementation and should consider the technical feasibility of constructing, operating, and monitoring the implemented corrective measure, its administrative feasibility, and the availability of services and materials required (e.g., disposal services, construction material).

Cost criterion should take into account capital costs, operation and maintenance costs, and net present value of costs. Operation and maintenance costs should reflect realistic timeframe estimates and not be based on an arbitrary time period, such as 30 years. Net present value of costs will provide an equal basis for comparison of alternatives with different durations and assumes current year funds will be invested for payment of future year costs.

Community acceptance should consider the degree to which a CMA will be acceptable to interested community. This community acceptance should consider public participation and community involvement and public comments.

State acceptance should consider the degree to which the CMA is acceptable to the regulating state. This aspect is particularly important when EPA selects the corrective measure rather than the state.

In addition, an analysis of any RCRA or applicable MTCA evaluation criteria not covered by the above will be included in accordance with WAC 173-303-64620(4). The MTCA evaluation criteria are contained in WAC 173-340-360, "Selection of Cleanup Actions." These criteria are consistent with CERCLA and RCRA corrective action evaluation criteria; however they are arranged in a slightly different manner. To ensure that MTCA alternatives are met for SST WMA corrective actions, a separate evaluation of MTCA criteria will likely be accomplished. The criteria include threshold requirements which must be met for an alternative to be selected as a final remedy and "other requirements" and "action specific requirements" that modify the threshold requirements, as follows.

a. Threshold requirements
    1. Protect human health and the environment
    2. Comply with cleanup standards
    3. Comply with applicable state and federal laws
    4. Provide compliance monitoring.

b. Other requirements
   1. Use permanent solutions to the maximum extent practicable
   2. Provide a reasonable restoration time frame
   3. Consider public concerns.

c. Action-specific requirements
   1. Non-permanent groundwater cleanup actions
   2. Institutional controls
   3. Releases and migration/dilution and dispersion
   4. Remediation levels.

The RCRA closure performance standards [WAC 173-303-610(2)] will be used to evaluate whether the alternatives comply with RCRA closure requirements. These standards require the closure of TSD units in a manner that achieves the following:

a. Minimizes the need for further maintenance

b. Controls, minimizes, or eliminates to the extent necessary to protect human health and the environment, post-closure escape of dangerous waste, dangerous waste constituents, leachate, contaminated run-off, or dangerous waste decomposition products to the ground, surface water, groundwater, or the atmosphere

c. Returns the land to the appearance and use of surrounding land areas to the degree possible, given the nature of the previous dangerous waste activity.

In addition, RCRA corrective-action performance standards (WAC 173-303-64620) will be used to evaluate how well the alternatives comply with RCRA corrective-action requirements. These standards state that corrective action must achieve the following:

a. Protect human health and the environment for all releases of dangerous waste and dangerous constituents, including releases from all solid-waste management units at the facility

b. Occur regardless of the time at which waste was managed at the facility or placed in such units and regardless of whether such facilities or units were intended for the management of solid or dangerous waste

c. Be implemented by the owner/operator beyond the facility boundary where necessary to protect human health and the environment.

The Phase 2 RFI/CMS report for WMA C also will include supporting information needed to complete the detailed analysis and meet regulatory integration needs, including the following.

a. Summarize the field investigation findings including the nature and extent of contamination, the contaminant distribution models, and an assessment of the risks to help establish the need for corrective measures and estimate the volume of contaminated media.

b. Refine the conceptual exposure pathway model to identify pathways that may need to be addressed by corrective action.

c. Provide a detailed evaluation of potential ARARs, beginning with potential ARARs identified in the Phase 2 master work plan (RPP-PLAN-37243, Section 3.4).

d. Refine potential corrective action objectives and preliminary remediation goals identified in the DQO report (RPP-RPT-38152), based on the results of the Phase 1 RCRA Facility Investigation report (DOE/ORP-2008-01), ARAR evaluations, and current land-use considerations, and input from the regulators.

e. Refine the list of CMAs identified in the DQO report (RPP-RPT-38152) and in this section.

f. Provide a preferred CMA for the soils within WMA C to fulfill the requirements for a RFI/CMS report.

g. Include as appendixes or separate documents, closure plans to address RCRA TSD units in the operable unit. The closure plans may incorporate, by reference, specific sections of the work plan or RFI report containing specific closure-plan information. The closure plans will include closure performance standards, a closure strategy, general closure activities including verification sampling, and a general post-closure plan for closing soils within WMA C.

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6. SCHEDULE

The approach and work described in Chapters 4 and 5 of this work plan are detailed in the schedule for developing plans and conducting field activities. Figure 6-1 shows the schedule that will be used to measure progress. The majority of the soil characterization activities described in this work plan were identified during the DQO process (RPP-RPT-38152) to support Phase 2 RCRA corrective action activities in WMA C. A limited number of additional soil characterization activities have been added to this work plan based on stakeholder input and on the initial results of the Phase 2 characterization work. Future planned waste retrieval activities may conflict with the schedule.

An RFI/CMS report for soils will be generated for WMA C. The report will meet the site-specific RFI/CMS objectives. In general, the RFI/CMS will assess data that have been collected at the time of report preparation (generally, it is anticipated that available information will include Phase 1 and available Phase 2 soil characterization information). The assessment will be used to

a. Define source areas of contamination;

b. Assess the potential pathways of migration and the potential receptors and associated exposure pathways to the extent necessary to determine whether, or to what extent, a threat to human health or the environment exists; and

c. Develop and evaluate CMAs (including the no-action alternative).

The RFI/CMS will present alternatives that will provide decision makers with a range of options and information to compare alternatives against one another. A general description of ranges for source-control response actions will be developed based on the site-specific information available. A detailed and comparative analysis of CMAs will be assessed against available site-specific information. This information will be used to evaluate various conceptual models (i.e., pre-defined conditions, such as concentrations, depth, and treatability of contaminants for various contaminated soil groups) that will be applied to the CMAs. Through the comparative analysis of alternatives, it is expected that these conceptual models may result in selection of different corrective measures for different soil groupings. The RFI/CMS also may define how the determination of the selected CMA will be made at each site.

Figure 6-1 shows the schedule for the planned Phase 2 RFI/CMS report for WMA C that will fulfill HFFACO Milestone M-045-61 and address interim measures and CMAs for soils to the point of submittal to Ecology.

Figure 6-1 illustrates the activity logic and durations required to complete the field work to collect the soils for analyses, the laboratory analyses of these soils, and the additional planned work required as a part of the Phase 2 investigation. The schedule in Figure 6-1 reflects a temporary suspension of funding for field characterization activities in FY 2012, and assumes full funding will be re-established in FY 2013. If more or less money is available, duration will

be compressed or extended accordingly. The sequencing assumes no interferences from field activities, such as waste retrieval efforts, which are currently ongoing.

Figure 6-1. Project Logic and Schedule

Tc = Technetium
PA = Performance Assessment
TC & WM EIS =

To fullfill this logic and duration schedule, durations assume $4 million/year for 3 years for WMA C soil characterization based on FY08 dollars.
Durations for activities assume no interferences from field activities, such as waste retrieval activities, which are currently ongoing.

[1]If sampling for organic compoiunds are not detected in first five probeholes, schedule is as shown, however, if found, scheluld is severly impacted and made longer.
[2]Vlill only take 3 months to do, there is uncertainty regarding contractor start date.
[3]SGE for UPRs began in October 2009.
[4]Second site begins following completion of 4 FY10 Direct Pushes adjacent to UPR-82.
[5]Begins when soil sample analyses are available and ends one month after last soil sampling analysis is complete.
[6]Can not begin until sufficient small mammal collection has occurred.
[7]Anticipated WMA C Performance Assessment schedule based on ongoing working sessions with Regulators, NRC, Tribal Nations, and other interested stakeholders, as well as on timing of issuance of the TC & WM EIS record of decision.
[8]Additional engineering studies may be needed, but will need the soil analyses to provide meaningful input to those studies.

7. PROJECT MANAGEMENT AND PROGRAM INTEGRATION

This section describes the RCAP management and integration activities necessary to ensure that program objectives are achieved. The objectives of project management during the Phase 2 WMA C RFI/CMS implementation are to (1) ensure the safety of the work force and the affected environment, (2) direct and document project activities, (3) ensure that project goals and objectives are met, and (4) administer the project within budget and schedule. The WMA C DQO workshops defined the specific scope and schedule elements. These elements, as well as others defined during the DQO workshop, will result in the development of the Phase 2 WMA C work plan.

Sections 7.1 and 7.2 present a general discussion of the areas of project management that will be common to all aspects of the program. Section 7.3 provides a general discussion of the schedules for the Phase 2 RCAP activities, including HFFACO milestones for Phase 2. Processes for Tribal Nation and public involvement, an important and necessary part of DOE activities on the Hanford Site, are discussed in Sections 7.4 and 7.5. The overall approach to integration with other Hanford Site programs such as the Soil and Groundwater Remediation Project administered by the Plateau Remediation Contractor are discussed in Chapter 5 and the Phase 2 master work plan (RPP-PLAN-37243).

7.1 WORK BREAKDOWN STRUCTURE

The internal work breakdown structure is developed in a manner consistent with other Hanford Site projects. Based on DOE guidance for establishing a baseline scope, schedule, and budget for the various TOC projects, internal planning, management, and budget documents (e.g., River Protection Project system plan, baseline control, and related work authorizations and directives) were adopted. These documents incorporate milestones defined in the HFFACO (Ecology et al. 1989) and reflect the schedule and commitments made therein. It is anticipated that these documents will define the scope, schedule, and budget to a level of detail that will be adequate for the planning and management of the Phase 2 RFI/CMS activities. Inherent with the approach is that the DQO workshop defined the specific scope associated with this Phase 2 WMA C RFI/CMS work plan.

A detailed draft work breakdown structure has been developed as part of the Tank Operations Contract Performance Management Baseline. This draft work breakdown structure lays out the scope elements that address vadose zone characterization and corrective measures, including interim measures, as well as closure and regulatory actions.

Detailed information in the form of work control instructions (formerly known as work packages) 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 control instructions will reference the appropriate procedure or standards rather than listing the entire procedure for a task and will be in accordance with the HASQARD (DOE/RL-96-68). Any reference to the QAPD (TFC-PLN-02) provided in Attachment 1 as a source of additional information will be referenced.

The work control instructions shall be prepared in accordance with TOC work control procedures. The work control instructions must satisfy the following requirements.

a. Include a scope-of-work introductory section.

b. 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.

c. Include the frequency of measurement.

d. Identify the applicable procedures needed to conduct the work. If a procedure includes several different ways to accomplish the work, the work control instruction should specify the method of choice or reference the specific procedure.

The integrated site baseline provides an integrated technical, cost, and schedule life-cycle baseline for the various projects. It is a tool that is used to forecast activities into the future so appropriate staffing, funding, and schedule needs can be assessed. The major activities for the Phase 2 RFI/CMS as captured in HFFACO milestones are the following:

a. Phase 2 master work plan (HFFACO Milestone M-045-58)

b. Phase 2 WMA C work plan (HFFACO Milestone M-045-60)

c. Field characterization

d. Phase 2 RFI/CMS report (HFFACO Milestone M-045-61)

e. Phase 2 CMI (HFFACO Milestone M-045-62).

A draft Tank Operations Contract Performance Management Baseline has been prepared, providing detailed scope, schedule and logic of activities in the next 5 to 10 years, and broader information regarding long term activities. This draft baseline provides a schedule for the characterization activities described in this work plan, as well as the related activities required to complete corrective measures. The baseline addresses both regulatory and physical actions that must be performed to address closure, and shows how corrective actions are logically related to closure actions. The ORP has initiated a series of workshops with Ecology and the TOC to further define the closure plan for WMA C, including the corrective measures related work described in this work plan. These workshops will be used to better define future activities as the baseline is finalized.

7.2 PROJECT MANAGEMENT

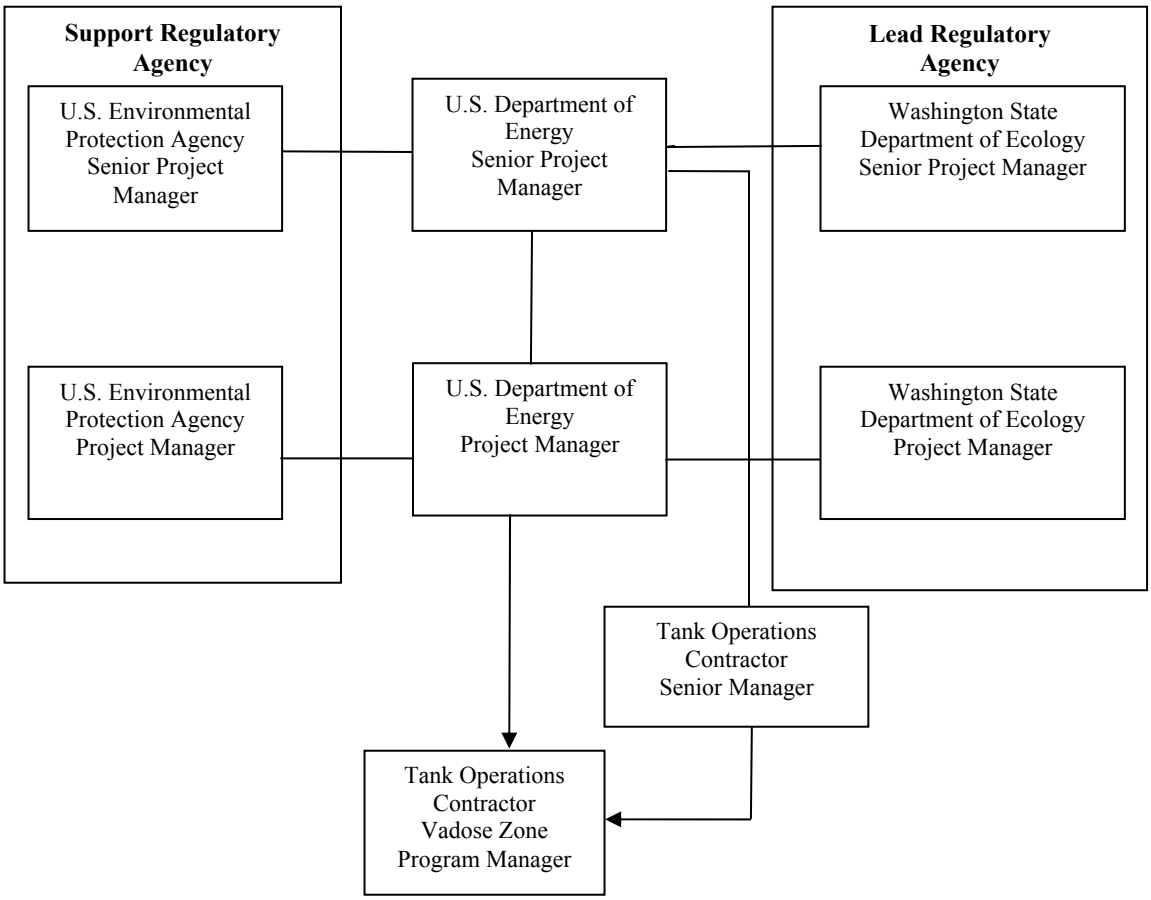
This section addresses the basic concepts of project management that occur throughout the project's life cycle. Specific tasks that will occur throughout the Phase 2 RCAP are described. Individuals associated with the project who interface with other organizations are also described.

Further guidance on schedule control, cost control, meetings, and reporting can be found in the HFFACO Action Plan (Ecology et al. 1989).

7.2.1 Project Organization and Responsibilities

The project organization for implementing activities outlined in this work plan is shown in Figure 7-1. Sections 7.2.1.1 through 7.2.8 describe the functional responsibilities of the project organization for the RCRA corrective action process shown in Figure 7-1. The positions described here have overall functional management authority for the project and are not based on an entities organization. Additional functional support roles are described in further detail in the project management section of Attachment 1.

Figure 7-1. Project Organization for the RCRA Corrective Action Process



RCRA = *Resource Conservation and Recovery Act of 1976*

7.2.1.1 Regulatory Agencies and the U.S. Department of Energy.

Senior Project Managers. Ecology, EPA, and DOE have each designated senior project managers with responsibilities for the RCAP activities. These senior project managers will serve as their agency's primary point of contact for the program under the HFFACO. The

responsibilities of the senior project managers and project managers are defined in Section 4.1 of the HFFACO (Ecology et al. 1989).

Project Managers. Ecology, EPA, and DOE will each designate project managers for each WMA. Ecology is designated as the lead regulatory agency for all WMAs, as indicated in the HFFACO (Ecology et al. 1989). The project manager from DOE will be responsible for maintaining and controlling the schedule and budget and keeping the Ecology and EPA project managers informed of the status of the activities, particularly the status of agreements and commitments.

7.2.1.2 Tank Operations Contractor Vadose Zone Program Manager. A vadose zone program manager has been assigned by the TOC program manager and is responsible for day-to-day management of the program. The responsibilities of the TOC Vadose Zone Program Manager will be to plan, authorize, and control work so it can be completed on schedule and within budget, and to ensure that all planning and work performance activities are technically sound. The TOC Vadose Zone Program Manager works closely with project controls, quality assurance, health and safety, and the field engineer to ensure that the work scope is being performed in accordance with each of these areas of responsibility. Interfaces with tank farm operations are part of the work control, schedule control, and roles and responsibilities assigned to the TOC Vadose Zone Program Manager. Other duties include coordinating communications with DOE, EPA, and Ecology. The TOC Vadose Zone Program Manager reports to the TOC Senior Manager and the DOE project manager (Figure 7-1).

7.2.2 Work Control

The primary goals of work control are to provide methods for planning, authorizing, integrating, and controlling work so tasks can be completed on schedule and within budget. The TOC ensures that all planning and work performance activities are technically sound and conform to management and quality requirements. The TOC Vadose Zone Program Manager will have the overall responsibility for planning and controlling investigation activities and for providing effective technical, cost, and schedule baseline management. If a subcontractor is used, the TOC Vadose Zone Program Manager will maintain overall project management responsibilities. The management control system used for this project must meet the requirements of DOE O 430.1B, *Real Property Asset Management*, or other applicable requirements and guidance (e.g., life-cycle asset management).

7.2.2.1 Cost Control. Project costs including labor, other direct costs, and subcontractor expenses (e.g., drilling and laboratory analyses) will be assessed monthly. The budget tracking activity is computerized and provides the basis for invoice preparation and review, and for preparation of cost performance reports. These reports assess the status of each project task against projected budgets, determine performance, and describe any recovery plans that may be required. Any adjustments to budgets are controlled through a formal management process, which includes the use of baseline change proposals to modify baseline budgets. The DOE Project Manager will update the EPA and Ecology Project Managers about their respective project costs to date (i.e., WMA) at the monthly unit managers' meetings.

7.2.2.2 Schedule Control. The status of scheduled milestones will be updated, at a minimum, on a monthly basis for each task on a given project. This will be performed in conjunction with cost performance reporting associated with cost tracking. The status of milestones will also be updated monthly at unit managers' meetings.

7.2.3 Meetings

Project managers from DOE, EPA, and Ecology meet monthly at unit managers' meetings to discuss progress, address issues, and review near-term plans pertaining to their respective WMA. The meetings are technical in nature with emphasis on technical issues and work progress. The assigned DOE Project Manager for the WMA will be responsible for preparing revisions to the schedule prior to the meeting. The schedule will address all ongoing activities associated with active WMAs. This schedule will be provided to all parties and reviewed at the meeting. Any agreements and commitments (within the project managers' level of authority) resulting from the meeting will be prepared and signed by all parties as soon as possible after the meeting. Unit managers' meeting minutes will be issued by the DOE Project Manager and will summarize the discussion at the meeting, with information copies provided to the project managers.

As indicated by HFFACO Milestone M-045-56 (Ecology et al. 1989), Ecology and DOE will, at a minimum, meet yearly (i.e., by July or as needed) to discuss interim measures. These discussions will focus on defining and determining the need for implementing interim measures. As appropriate, interim milestones will be established in coordination with these activities.

Other meetings will be held, as necessary, with subcontractors and other appropriate entities (e.g., integrating projects identified in Section 7.3) to communicate information, assess project status, and resolve issues. The DOE, Ecology, and EPA project managers will be requested to participate in these meetings as part of the integration effort (e.g., WMA C DQO activities will include an invitation to the Groundwater Remediation Project, DOE, Ecology, and EPA project managers).

7.2.4 Records Management

The HFFACO specifies documentation and records management requirements for remediation activities at the Hanford Site. The HFFACO categorizes applicable supporting documents based on the importance of documenting final data or use in decision-making to support remediation. Under HFFACO, these applicable documents are categorized as either primary or secondary documents. Tables 9-1 and 9-2 of HFFACO provide a general list of primary and secondary documents, respectively. Specific to the Phase 2 RCAP, primary documents include the Phase 2 master work plan, the WMA C work plan, and the Phase 2 RFI/CMS report. The process for document review, comment, and revision will be as described in Section 9.2 of HFFACO Action Plan (Ecology et al. 1989).

The information management overview (Attachment 4 of this work plan) details the applicable programs for records management. As noted in Section 7.2.1, project managers are responsible for implementing HFFACO requirements for the RCAP. Revisions, should they become necessary after finalization of any document, will be in accordance with Section 9.3 of the

HFFACO. 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. The Administrative Record will be maintained to support activities in accordance with Section 9.4 of the HFFACO.

The project file will be maintained in an organized and secure manner and will be accessible to the appropriate project personnel. The project file may also be maintained electronically. All field reports, field logbooks, health and safety documents, quality assurance and quality control documents, laboratory data, memoranda, correspondence, and reports will be logged into the project file on receipt or transmittal.

7.2.5 Progress and Final Reports

Monthly progress will be documented at unit managers' meetings. Meeting minutes will be prepared, distributed to the appropriate personnel and entities (e.g., project managers, coordinators, contractors, and subcontractors), and entered into the project file. The process for document review and comment and maintenance of the Administrative Record is covered by the HFFACO action plan (Ecology et al. 1989).

7.2.6 Quality Assurance

The specific planning documents required to support the RCAP will be developed within the overall quality assurance program structure mandated by DOE for all activities at the Hanford Site. Within that structure, the documents are designed to meet current EPA guidelines for format and content and are supported and implemented through the use of standard operating procedures drawn from the existing program or procedures developed specifically for tank farm quality requirements to environmental investigations.

To ensure that the objectives of the RCAP are met in a manner consistent with applicable DOE guidelines, all work conducted will be performed in compliance with TFC-PLN-02, which specifically describes the application of requirements to environmental investigations.

7.2.7 Health and Safety

The health and safety plan (see Attachment 2) will be used to implement standard health and safety procedures for employees and contractors engaged in RCAP activities. More specific details on the management aspects of the health and safety plan are in Attachment 2. Minor activities that do not require the level of detail found in the health and safety plan will be covered by an activity hazard analysis.

7.2.8 Community Relations

Community relations activities will be conducted in accordance with the *Hanford Site Tri-Party Agreement Public Involvement Community Relations Plan* (Ecology et al. 2002). All community relations activities associated with the RCAP will be conducted under this overall Hanford Site community relations plan.

In addition, a number of organizations participate in providing recommendations that can affect the path of the RCAP. These organizations include the Hanford Advisory Board, the Interagency Management Integration Team, the Washington State Department of Health, Tribal Nations, the State of Oregon, and other interested stakeholders. This participation in project activities is defined in Sections 7.5 and 7.6.

7.3 SCHEDULE

Figure 7-2 provides the current schedule that identifies the HFFACO milestone dates associated with Phase 2. During the fiscal year planning effort, this milestone schedule will be updated. The detailed project schedule will implement the work breakdown structure (see Section 7.1) and will be updated during monthly unit managers' meetings.

7.4 TRIBAL NATION ROLE AND INVOLVEMENT

The Hanford Site is located on land ceded to the Federal government by treaties in the year 1855 with the Yakama Nation and the Confederated Tribes of the Umatilla Indian Reservation (i.e., the Umatilla, Cayuse, and Walla Walla Tribes). The Nez Perce Tribe has treaty rights on the Columbia River. The Yakama Nation and Confederate Tribes of the Umatilla Indian Reservation retain rights and privileges in the ceded areas, including the right to take fish at usual and accustomed places, to erect temporary buildings, to hunt, to gather roots and berries, and to pasture horses and cattle on open and unclaimed land.

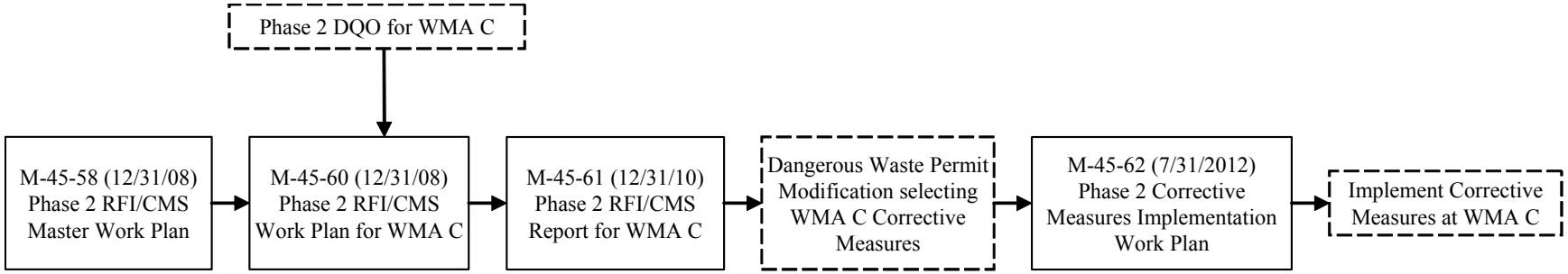
In addition to the treaties of 1855, the following laws apply to Native American rights and culture at the Hanford Site: the *American Indian Religious Freedom Act of 1978*, the *Archaeological and Historic Preservation Act of 1974*, the *National Historic Preservation Act of 1966*, the *Native American Graves Protection and Repatriation Act*, and the *American Antiquities Preservation Act of 1906*.

The DOE provides grants to the Yakama Nation, the Confederated Tribes of the Umatilla Indian Reservation, and the Nez Perce Tribe to ensure their involvement in the environmental restoration and waste management activities for cleanup of the Hanford Site. The tribes will advise the RCAP activities through direct consultation and project involvement (e.g., DQO meetings). The tribes also participate in formal groups such as the State and Tribal Government Working Group, the Hanford Advisory Board, the Hanford Summit Steering Committee, and the Hanford Environmental Dose Reconstruction Project's Native American Working Group.

7.5 PUBLIC INVOLVEMENT

Public involvement is an integral and necessary part of DOE activities on the Hanford Site to ensure that decisions are made with the benefit and consideration of important public perspectives. Public involvement is a mechanism that brings a broad range of diverse viewpoints and values into the DOE decision-making process and enables DOE to make more informed

Figure 7-2. RCRA Corrective Action Process



DQO = data quality objectives (document)
RCRA = *Resource Conservation and Recovery Act of 1976*
RFI/CMS = RCRA facility investigation/corrective measures study
WMA = waste management area

decisions, improve quality through collaborative efforts, and build mutual understanding and trust between DOE and the public. Within the RCAP, opportunities for public involvement will occur throughout the process.

The community relations plan (Ecology et al. 2002) specifies how the public can be involved in the processes that are followed on the Hanford Site. This is discussed further in Section 10.0 of the HFFACO (Ecology et al. 1989).

In addition to other projects operating at the Hanford Site, a number of organizations participate in providing recommendations that can affect the path of the RCAP. These organizations include the Hanford Advisory Board, the Interagency Management Integration Team, the Washington State Department of Health, Tribal Nations, the State of Oregon, and other interested stakeholders.

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APPENDIX A

SAMPLING AND ANALYSIS PLAN FOR THE COLLECTION OF SOIL SAMPLES

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This appendix references the most recent sampling and analysis plan or its equivalent, RPP-PLAN-38777, *Sampling and Analysis Plan for Phase 2 Characterization of Vadose Zone Soil in Waste Management Area C*.

Reference

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APPENDIX B

SAMPLING AND ANALYSIS INSTRUCTIONS FOR SMALL MAMMAL SAMPLING IN WMA C

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ACRONYMS

AEA	alpha energy analysis
AVMA	American Veterinary Medical Association
CFR	*Code of Federal Regulations*
COPEC	contaminant of potential ecological concern
DOE	U.S. Department of Energy
ERA	ecological risk assessment
GEA	gamma energy analysis
GPC	gas proportional counting
HASQARD	*Hanford Analytical Services Quality Assurance Requirements Document*
HEPA	high-efficiency particulate air
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
PCB	polychlorinated biphenyl
QA	quality assurance
RCRA	*Resource Conservation and Recovery Act of 1976*
RCBRA	River Corridor Baseline Risk Assessment
SAI	sampling and analysis instruction
SAP	sampling and analysis plan
SST	single-shell tank
STR	subcontract technical representative
WAC	*Washington Administrative Code*
WMA	waste management area
WRPS	Washington River Protection Solutions, LLC

METRIC CONVERSION CHART

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

B1.0 INTRODUCTION

This sampling and analysis instruction (SAI) guide was prepared to provide the requirements for the sampling and analysis activities to be performed in support of the Corrective Measures Study for Waste Management Area C (WMA C). This SAI describes the field work necessary to collect the data identified in RPP-RPT-38152, *Data Quality Objectives Report Phase 2 Characterization for Waste Management Area C RCRA Field Investigation/Corrective Measures Study*. This SAI defines data collection methods for small mammals to augment the screening-level ecological risk assessment (ERA).

Waste Management Area C is one of several single-shell tank (SST) farm waste management areas located in the 200 East Area of the Hanford Site (see Figure B-1). Past releases to soil have resulted in contamination that will require evaluation and cleanup under the *Resource Conservation and Recovery Act of 1976* (RCRA) corrective action program in accordance with the *Hanford Federal Facility Agreement and Consent Order* (HFFACO) (Ecology et al. 1989), also known as the Tri-Party Agreement. Elements of the corrective action process include soil characterization, assessment of risk from past releases to soil, evaluation and selection of corrective measures alternatives, and implementation of the selected corrective measures.

In support of the evaluation and selection of corrective measures alternatives, contaminant concentrations in abiotic and biotic media will be compared to endpoint criteria specified by Washington State regulations, U.S. Environmental Protection Agency technical guidance, U.S. Department of Energy (DOE) technical guidance, or as supported by the scientific literature. The approach for ERA for WMA C is documented in Section 3.4.2 of this document.

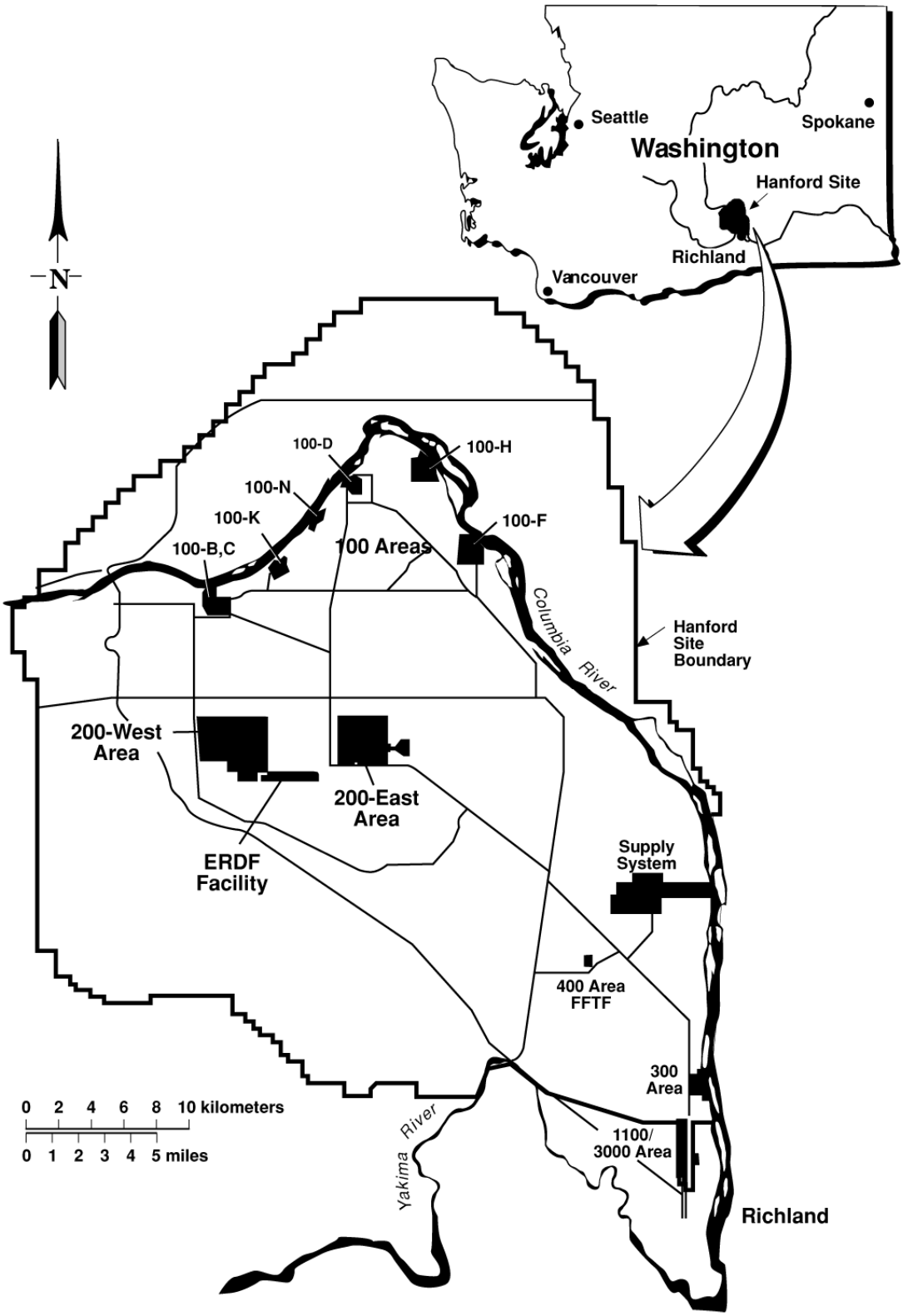
Sampling and analysis of soil at WMA C will follow the specifications documented in the Sampling and Analysis Plan (SAP) provided as Appendix A of the main document. The sampling and analysis tasks presented in this SAI guide are specific to small mammal collection and analysis to obtain data for use in dietary exposure modeling in the ERA for WMA C.

B1.1 BACKGROUND

The Hanford Site became a federal facility in 1943 when the U.S. Government took possession of the land to produce weapons-grade plutonium during World War II. The Hanford Site's production mission continued until the late 1980s when the mission changed from producing nuclear materials to cleaning up the radioactive and hazardous wastes that had been generated during the previous decades. The Central Plateau, which encompasses the tank farms, consists of ~75 mi^2 (195 km^2) near the middle of the Hanford Site (see Figure B-1). The Central Plateau contains ~900 excess facilities formerly used in the plutonium production process.

Waste Management Area C is an SST farm located on the eastern portion of the 200 East Area. Waste Management Area C is currently undergoing Phase 2 investigation to support development and implementation of corrective measures. This SAI documents the methods for the collection of biological data (small mammal tissue) to support ERA in the SST farms.

Figure B-1. Hanford Site Map



B1.2 PREVIOUS INVESTIGATIONS

Phase 1 characterization for soils of WMA C was documented in RPP-35484, *Field Investigation Report for Waste Management Areas C and A-AX*.

Previous investigations of ecological risk at the Hanford Site date back to the early 1990s (WHC-SD-EN-TI-122, *Biological Uptake of 300-FF-5 Operable Unit Contaminants*). Work is being performed concurrently with this project as part of the Central Plateau Ecological Risk Assessment Project (WMP-20570, *Central Plateau Terrestrial Ecological Risk Assessment Data Quality Objectives Summary Report – Phase I*), the River Corridor Baseline Risk Assessment (RCBRA), and WMP-23141, *100-NR-2 Groundwater Operable Unit Ecological Risk Assessment Data Quality Objectives Summary Report*, and DOE/RL-2005-22, *100-NR-2 Study Area Ecological Risk Assessment Sampling and Analysis Plan*. Monitoring activities and data collection efforts to support ERA, performed on an ongoing basis by the Pacific Northwest National Laboratory as part of DOE's Public Safety and Resource Protection Program, are available on request from the DOE Richland Operations Office.

B1.3 INDICATOR CONTAMINANTS

Indicator contaminants for small mammal tissue analysis consist of the nonradionuclide constituents listed in *Washington Administrative Code* (WAC) 173-340-7493, "Site-Specific Terrestrial Ecological Evaluation Procedures" (Table 749-3), for which a wildlife benchmark is provided. While analytical suites are not limited to these contaminants specifically, performance of suite analyses ensures that these indicator contaminants are captured for evaluation as contaminants of potential ecological concern (COPECs). Radionuclides are not addressed by the WAC but potentially pose risk to wildlife at WMA C via the dietary exposure pathway from small mammals. Radionuclide analyses will be performed on small mammal tissues to determine the type and quantity of radionuclides in the ecosystem, and their subsequent risks to predator species. Contaminant suite analyses to be performed for upland soil and tissues are listed in Table B-1, which is derived from Table 3-2 of RPP-PLAN-39114, *Phase 2 RCRA Facility Investigation/Corrective Measures Study Work Plan for Waste Management Area C*.

Environmental conditions often limit the ability to collect a sufficient amount of sample material for the analyses of all indicator contaminants; therefore, the full list of indicator contaminants must be prioritized for samples with limited sample mass. In general, the priorities for these samples (in order from highest to lowest) are gamma spectroscopy, metals (SW-846, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, Methods 6010/6020 and 7471), radiogenic strontium, polychlorinated biphenyls (PCB) and pesticides (SW-846 Methods 8082 and 8081A, respectively), isotopic uranium, isotopic plutonium, isotopic thorium, and semivolatile organic compounds (SW-846 Method 8270A) or most current approved SW-846 methodology. Gamma spectroscopy is listed as the highest analytical priority because it is a nondestructive analysis, requires significantly more mass than other analyses, but may not be feasible for some samples.

Table B-1. Analytical Suites and Methods for Small Mammal Tissues

Analyte Group	Analytical Methods[a]	Analyzed in Tissues[b]	Indicator Contaminants[c]
Inorganic chemicals (Metals)	6010	Yes	Arsenic, barium, cadmium, copper, lead, manganese, molybdenum, nickel, zinc
	200.8	Yes	chromium (total)
	6020/200.8	Yes	Selenium
	7471/200.8	Yes	Mercury (total)
PCBs and pesticides	8082 (PCBs)	Yes	PCB aroclors
	1668A	Yes	PCB Congeners
	8081 (pesticides)	Yes	Aldrin, , chlordane, dieldrin, endrin, DDT, DDD, DDE, heptachlor, heptachlor epoxide, benzene hexachloride (including lindane)
Semivolatile organic compounds	8310 or 8270	Yes	Benzo(a)pyrene
	8270	Yes	Hexachlorobenzene, pentachlorophenol
Radionuclides	Gamma energy analysis (GEA)	Yes	^{134}Cs, ^{137}Cs, ^{60}Co, ^{152}Eu, ^{154}Eu, ^{155}Eu, ^{226}Ra
	Alpha energy analysis (AEA)	Yes	^{241}Am
	Isotopic plutonium (AEA)	Yes	^{238}Pu
	Isotopic thorium (AEA)	Yes	^{228}Th, ^{232}Th
	Isotopic uranium (AEA)	Yes	$^{233/234}$U, ^{235}U, ^{238}U
	Total radioactive strontium (GPC)	Yes	^{90}Sr

[a] All analyses obtained by these methods.
[b] Analyses are subject to obtaining a sufficient amount of small mammal whole organism tissue.
[c] Indicator contaminants for small mammal tissues are those that identified as *Washington Administrative Code* soil indicator contaminants for wildlife plus radionuclides.

GPC = gas proportional counting PCB = polychlorinated biphenyl

B1.4 PROBLEM DEFINITION

The purpose of the ERA for WMA C is to ascertain risk to receptors from COPECs originating from SST farm operations. The presence of contaminants in biological tissue (i.e., small mammals) is indicative of exposure and may serve as an exposure pathway to higher trophic predators, such as raptors and carnivorous mammals. Information gathered from small mammal tissue analyses will substantiate current exposure and aid in the development and implementation of corrective measures to ensure long-term protection of human health and the environment.

B1.5 DIETARY EXPOSURE

Dietary exposure to COPECs will be evaluated using methodology published in EPA/600/R-93/187, *Wildlife Exposure Factors Handbook*. The principal aspect of vertebrate exposure is the measurement of COPEC concentrations in food and abiotic media. The exposure evaluation for higher trophic level receptors (i.e., badger and red-tailed hawk) is based on the food intake rates and diet preference of representative small mammal species. The general equation for dietary exposure to badger and red-tailed hawk is as follows:

$$E_{oral} = C_{soil} \cdot I_{soil} \cdot AUF_{soil} + C_{food} \cdot I_{food} \cdot AUF_{food}$$

where

E_{oral} = the estimated oral daily dose for a COPEC (mg/kg/day)

C_{soil} = the concentration of chemical constituent *x* in soil (mg/kg dry weight)

I_{soil} = the normalized daily soil ingestion rate (kg of soil / [kg of body weight • day])

AUF_{soil} = the area use factor that represents the fraction of soil ingested from a contaminated area (this fraction is set to one)

C_{food} = the concentration of COPEC in food (mg/kg dry weight)

I_{food} = the normalized daily dietary ingestion rate (kg of food [dry weight] / [kg of body weight • day])

AUF_{food} = the fraction of the diet derived from a contaminated area (this fraction is set to one).

B1.6 DECISIONS TO BE MADE

The sampling of small mammal tissue in WMA C will help establish ecological exposure and transport pathways to chemicals and radionuclides present in the SST farms. The quantity of samples collected and the duration of the evaluation will be appropriate to inform the corrective measures study which is being performed concurrently for WMA C. Samples will be collected from three distinct transects: the WMA C perimeter fenceline transect, and two habitat transects located in proximity to but outside of the WMA C perimeter. A composite of kidney and liver tissues from a minimum of six captured organisms per transect group will serve as indicators of bioconcentration of inorganic contaminants in these target organs. The remaining small mammal carcasses (whole organism, minus the liver and kidney) will be composited separately for analysis. Liver and kidneys are target organs for accumulation of some types of COPECs, including metals. In addition, these organs have tissue-specific toxicity reference values for some COPECs which allow for extrapolation between the concentrations observed in the field and laboratory-based effects. In the dietary exposure model, a weighted average of the COPEC

concentrations in carcass and organs (liver and kidney) is used as the exposure point concentration. Liver and kidney weights will be recorded for each sample and their contaminant contributions to diet accounted for on a fraction-of-body-weight basis.

A minimum of six organisms per transect group will be combined into two composite samples (one liver/kidney composite and one carcass composite) per transect group for analysis. The carcass composite will be further subdivided as necessary to support analytical needs. Under this study design, at least nine samples will be submitted for analysis, with at least three samples representing each of the three transect groups. While the number of samples to be collected is not statistically based, the number of samples is sufficient to meet analytical sample mass requirements and also to perform exploratory data analyses (i.e., calculate mean concentrations and upper confidence limits on the mean, and comparing contaminant distributions using boxplots).

A portion of the carcass composite sample from each transect will be analyzed for organic constituents, including PCB aroclors. Another portion of these samples will be reserved for possible subsequent analysis. When available, the aroclor results from each transect will be evaluated together with available RCRA facility investigation analytical results for PCB aroclors and congeners in WMA C soils to determine whether a reserved carcass composite sample from any of the transects should be analyzed for PCB congeners. The carcass composite, rather than liver/kidney composite, will be analyzed for this purpose, because PCBs concentrate in the lipid tissues of the carcass.

B1.7 CONTINGENCIES

It is necessary to prepare for contingency sampling in the event that planned sample numbers are compromised. For example, it may be that insufficient sample mass exists for a particular group targeted for tissue analyses. In the event of low capture frequency, additional sampling may be performed until adequate sample mass requirements are met. For all samples the analytes shall be measured in the following general priority order: gamma spectroscopy (first because it is a nondestructive analysis; it is assumed that samples measured for gamma radiation will be available for other analyses, but it requires a significant mass so it may not always be appropriate), metals, total radioactive strontium, PCBs and pesticides, isotopic uranium, isotopic plutonium, isotopic thorium, and semivolatile organic compounds.

A small quantity of sample mass from each transect will be reserved at the sample preparation laboratory to allow for follow-on analysis of PCB congeners.

B2.0 PROJECT MANAGEMENT

This section addresses the roles and responsibilities of the project management team to ensure that project participants understand the sampling goals and approaches to be used and that the planned outputs are appropriately documented.

B2.1 PROJECT TASK ORGANIZATION

This project will be managed by Washington River Protection Solutions, LLC (WRPS). The WRPS will assign a project manager, a risk assessment manager, and a subcontract technical representative (STR). The risk assessment manager has overall responsibility for this project including oversight of the project schedule and budget. The manager makes final project decisions with the authority to commit the necessary resources to perform activities.

The WRPS STR is responsible for coordination and oversight of all environmental data collection activities, including sampling, field analytical measurements, and field ecological observations. The STR is responsible for tracking and reporting the progress of field work and laboratory analysis and interfacing with quality assurance (QA), health and safety, and cultural resources representatives to ensure work is performed in accordance with all project objectives and requirements, such as those specified in this SAI.

Sample collection will be performed by qualified subcontractors in accordance with this SAI and applicable procedures documented in the SAP (Appendix A of the main document). Subcontractor and WRPS field personnel will provide weekly status during fieldwork and report problems in the field and to the STR.

The project QA representative oversees quality control and laboratories and is independent of the personnel performing data generation. The QA representative is responsible for ensuring field and laboratory activities are performed in accordance with WRPS project quality management plans, WRPS-approved field and laboratory subcontractor QA plans, and applicable procedures. The QA representative is also responsible for coordinating and performing audits and assessments of field and laboratory work.

B2.2 QUALITY OBJECTIVES AND CRITERIA FOR MEASUREMENT DATA

The detection limits and precision and accuracy requirements for each of the analyses performed are summarized for biotic tissue in Table B-2. The process for determining these requirements is documented in existing ERA planning documentation, including data quality objective reports and SAPs for the Central Plateau Terrestrial ERA and the RCBRA. The matrix-specific target COPEC quantitation limits used in this SAI were derived for the RCBRA and Central Plateau Terrestrial ERA by calculating the COPEC concentrations in prey that would result in a predator dose approaching the threshold toxicity reference values. For additional detail on derivation of these numbers, see planning documentation for those reports.

Table B-2. Analytical Performance Requirements for Tissue Analyses (2 sheets)

Indicator Contaminant	Chemical Abstracts Service Number	Analytical Instrument and/or Method	Laboratory Target Detection Limit[a] (pCi/g or mg/kg)	Precision	Accuracy
Radionuclides					
Americium-241	14596-10-2	AEA	0.1	±30%	70-130
Cesium-134	13967-70-9	GEA	0.1	±30%	70-130
Cesium-137	10045-97-3	GEA	0.1	±30%	70-130
Cobalt-60	10198-40-0	GEA	0.05	±30%	70-130
Europium-152	14683-23-9	GEA	0.1	±30%	70-130
Europium-154	15585-10-1	GEA	0.1	±30%	70-130
Europium-155	14391-16-3	GEA	0.1	±30%	70-130
Plutonium-238	13981-16-3	Isotopic Pu - AEA	1.0	±30%	70-130
Radium-226	13982-63-3	GEA	0.1	±30%	70-130
Strontium-90	10098-97-2	Total rad Sr – GPC	1	±30%	70-130
Thorium-228	14274-82-9	Isotopic Th – AEA	1.0	±30%	70-130
Thorium-232	14274-82-9	Isotopic Th - AEA	1	±30%	70-130
Uranium-233/234	13966-29-5	Isotopic U - AEA	1	±30%	70-130
Uranium-235	15117-96-1	Isotopic U - AEA	1	±30%	70-130
Uranium-238	7440-61-1	Isotopic U - AEA	1	±30%	70-130
Pesticides and PCBs					
Aldrin	309-00-2	Method 8081	0.0017	±30%	50-150
Benzene hexachloride (including lindane) (i.e., gamma-BHC [lindane])	58-89-9	Method 8081	0.0017	±30%	50-150
Chlordane	57-74-9	Method 8081	0.017	±30%	50-150
Dieldrin	60-57-1	Method 8081	0.003	±30%	50-150
Endrin	72-20-8	Method 8081	0.003	±30%	50-150
DDT	50-29-3	Method 8081	0.003	±30%	50-150
DDD	72-54-8	Method 8081	0.003	±30%	50-150
DDE	72-55-9	Method 8081	0.003	±30%	50-150
Heptachlor	76-44-8	Method 8081	0.0017	±30%	50-150
Heptachlor epoxide	1024-57-3	Method 8081	0.0017	±30%	50-150
Aroclor-1016	12674-11-2	Method 8082	0.017	±30%	50-150
Aroclor-1221	11104-28-2	Method 8082	0.017	±30%	50-150
Aroclor-1232	11141-16-5	Method 8082	0.017	±30%	50-150
Aroclor-1242	53469-21-9	Method 8082	0.017	±30%	50-150
Aroclor-1248	12672-29-6	Method 8082	0.017	±30%	50-150
Aroclor-1254	11097-69-1	Method 8082	0.017	±30%	50-150
Aroclor-1260	11096-82-5	Method 8082	0.017	±30%	50-150

Table B-2. Analytical Performance Requirements for Tissue Analyses (2 sheets)

Indicator Contaminant	Chemical Abstracts Service Number	Analytical Instrument and/or Method	Laboratory Target Detection Limit[a] (pCi/g or mg/kg)	Precision	Accuracy
Semivolatile Organic Compounds					
Benzo(a)pyrene	50-32-8	Method 8310 or 8270	0.33	±30%	50-150
Hexachlorobenzene	118-74-1	Method 8270	0.33	±30%	50-150
Pentachlorophenol	87-86-5	Method 8270	0.33	±30%	50-150
Metals					
Arsenic	7440-38-2	Method 6010	10	±30%	70-130
Barium	7440-39-3	Method 6010	2	±30%	70-130
Cadmium	7440-43-9	Method 6010	0.5	±30%	70-130
Chromium (total)	7440-47-3	Method 6010	1	±30%	70-130
Copper	7440-50-8	Method 6010	1	±30%	70-130
Lead	7439-92-1	Method 6010	5	±30%	70-130
Manganese	7439-96-5	Method 6010	5	±30%	70-130
Mercury (total)	7439-97-6	Method 7471 or 200.8	0.2	±30%	70-130
Molybdenum	7439-98-7	Method 6010	2	±30%	70-130
Nickel	7440-02-0	Method 6010	4	±30%	70-130
Selenium	7782-49-2	Method 6020 or 200.8	0.1	±30%	70-130
Zinc	7440-66-6	Method 6010	1	±30%	70-130

[a] Achievable detection limits may be affected if insufficient material is available for analysis.

AEA = alpha energy analysis
GEA = gamma energy analysis
GPC = gas proportional counting
SVOA = semivolatile organic analysis

B2.3 SPECIAL TRAINING REQUIREMENTS

Hanford General Employee Training is typically required for subcontractors deployed to the site in support of sampling activities. The following additional training may be required for certain areas:

- Site-specific Waste Management Instruction
- Integrated Work Control Program
- Rad Worker II (for entry into posted radiological control zones)
- 24-hour Hazardous Waste Worker Training (for entry into waste sites with ongoing remedial activities)
- Ecological resource and biological hazard training.

The qualifications of field personnel must be forwarded to the WRPS STR and must be approved by the STR prior to beginning work.

B3.0 MEASUREMENT/DATA ACQUISITION

This chapter presents the sampling design and requirements for sampling methods, sample handling and custody, and analytical methods. The requirements for instrument calibration and maintenance, supply inspections, and data management are also addressed.

B3.1 SAMPLING PROCESS DESIGN

The sample design reflects the project work scope developed in the main body of RPP-PLAN-39114. This SAI contains sample design details, summary tables, and figures that address sampling procedures, sampling locations, sampling frequencies, and field and laboratory requirements.

B3.2 SAMPLING METHOD REQUIREMENTS

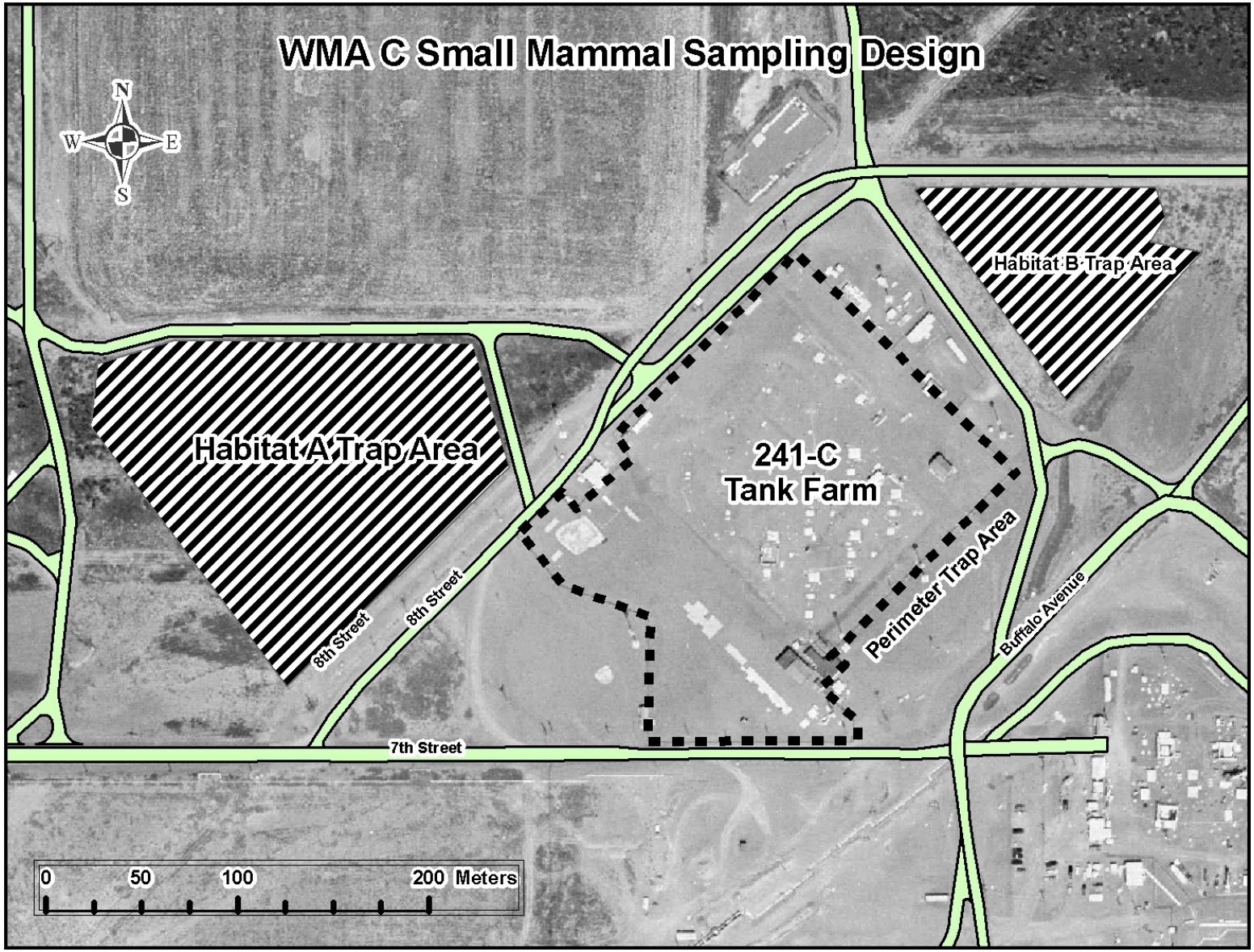
Sampling will be performed in accordance with this SAI guide. The "study area" refers to the perimeter fenceline of the WMA C property and two habitat areas outside of the fenceline in proximity to the industrial area (Figure B-1). The dimension of the study area is based on a deer mouse home range (~0.077 hectares, which is based on average home range data from representative environments listed in EPA/600/R-93/187, p. 2-298), which equates to a median dispersal distance of ~150 m. Dominant small mammal species anticipated for collection in the study include deer mice (*Peromyscus maniculatus*) or pocket mice (*Perognathus parvus*). A minimum of 6 animals per transect group (total of 18 mice) will be collected and prepared for analysis. Collection of a small number of additional animals may occur to support preparation of laboratory quality control samples.

B3.2.1 SMALL MAMMAL SAMPLING

Three transect groups (one perimeter and two habitat transect groups) of live traps [with recommended approximate measurements of 8 cm (3 in.) wide by 9 cm (3.5 in.) high by 23 cm (9 in.) long] will be placed to accommodate the shape of the investigation area. Because WMA C is largely non-vegetated, inhabitation or site use by small mammals is likely to be limited. However, the perimeter transect will capture small mammals directly using the site. The two vegetated transect locations, which offer potential habitat for small mammals, are situated in close proximity to WMA C, thereby increasing likelihood of contaminant exposure and subsequent transport.

Due to the scarcity of habitat within the WMA C property fenceline, it is expected that the capture rate will be less than in vegetated areas. For the perimeter fenceline transect, traps will be spaced systematically at 25-m (82-ft) intervals along the perimeter fenceline of WMA C (Figure B-2). Two habitat transect groups will be established in vegetation communities adjacent to and outside of the WMA C property boundary. Habitat transect groups A and B (Figure B-2) vary in shape, and each group will consist of at least three staggered trap lines. Up to five traps will be placed along each trap line transect, with the distance between traps and trap lines to be ~25 m (82 ft). Each habitat transect group will have a minimum of 10 traps. The location for the trap where an animal is captured will be noted in the field logbook.

Figure B-2. Waste Management Area C Small Mammal Sampling Design



The animals will be trapped over a sufficient number of nights to obtain at least 6 mice for each transect group, for a total of at least 18 mice. Collection of a small number of additional mice may be necessary to support preparation of quality control samples and analysis for PCB congeners. The number of trap-days required to collect at least six animals per transect group will be recorded. This will provide a relative measure of animal density. A minimum of six mice per transect group will be dissected and combined into two composite samples (one liver/kidney composite and one carcass composite) per transect group for analysis. The carcass composite will be further subdivided as necessary to support analytical needs. The composite samples will represent the average concentration of COPECs at each transect that are available for uptake to higher trophic species through the dietary pathway.

Information on species, approximate age, sex, reproductive status (subadults/adults and nonscrotal males/scrotal males, and nonlactating/lactating females), and general external condition (any gross deformities, hair loss, infections, lesions, etc.) will be recorded in the field logbook for all captured animals. Animals captured and released (nontarget animals, such as juvenile mice) should be marked so that the total number of new captures per trap-night can be used to represent relative abundance estimates measured and documented for each study site.

At the laboratory, the mammals will be weighed on a calibrated balance (± 0.01 g) and then rinsed thoroughly with deionized water to remove most exterior soil per HASQARD (DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Documents*). Small mammals are to be analyzed exclusive of external concentrations so that these data will be better suited to developing bioaccumulation models. The exposure models incorporate incidental soil ingestion; therefore, rinsing the mammals prevents double counting soil ingestion in exposure model calculations. Further sample preparation includes dissecting organs (liver/kidney) from the carcass (including the gastrointestinal tract) for weighing and separate homogenization.

B3.2.1.1 Trapping Instructions

Live traps should be used to collect small mammals. The number of small mammal traps installed and the number of nights the traps are left open may vary according to the size and configuration of the study grid and the trapping effort required to satisfy minimum sample size requirements. However, it is important to maintain a systematic distance between traps to ensure equal probability of having a capture. NOTE: The collector must have a valid Washington State scientific collection permit to conduct small mammal trapping in Washington State. A flag should be placed at the beginning of each trap line that identifies the Washington State scientific collection permit number (specific contact information is provided on the investigation area sign), contact name, and phone number.

<u>Field Trapping Equipment List:</u>

1. Plastic bags.
2. High-efficiency particulate air (HEPA) mask.

3. Lysol® solution and spray bottle.
4. Rubber gloves (gardening or thicker) or leather gloves.
5. Field logbook.
6. Nontoxic permanent marker.
7. Ice and cooler (preferably two coolers).
8. Scientific collection permit.
9. Live traps (small mammal sizes).
10. Trap shades (one for each trap where vegetation or cover/shade is limited).

Small Mammal Trapping Instructions:

1. Set traps in accordance with specification in Section B3.2.1.1.
2. Traps should be spaced systematically 25 m (~82 ft) apart along each transect.
3. Place traps nearby or underneath vegetation/rocks to reduce likelihood of heat-stress/ cold-stress. If natural cover is insufficient to prevent heat/cold stress to animals, then a trap shade should be placed over the top of the trap and secured to the ground with stakes or heavy objects.
4. Set trap trigger sensitivity to ensure consistent trapping success efforts between areas.
5. Bait traps with an oatmeal-peanut butter mixture [~30 mL (2 tbsp) of peanut butter and 2.7 L (0.7 gal) of oatmeal in a 4-L (1-gal) zippered plastic bag].
6. Check traps daily, preferably before ambient temperatures exceed ~90°F.
7. If samples are abundant, use only reproductively active specimens for contaminant analysis.
8. When traps have been tripped and a small mammal is captured, don a HEPA mask (optional) and gloves, and position yourself in a generally upwind direction from the trapped animal.
9. Empty trap contents (small mammal, bait, and feces) into a new plastic bag. If animal is not selected for collection, mark the ventral portion of its tail with a black, blue, or red nontoxic permanent marker to ensure all marked animals can be identified later if recaptured.
10. Record species, age, sex, and reproductive status, and note any abnormalities of condition in the field logbook. (Do not record this information if the animal has been previously captured and recorded.)

® Lysol is a registered trademark of Rickitt Benckiser, Inc., Richmond, Virginia.

11. If animal is selected for collection, euthanize selected small mammals by American Veterinary Medical Association ("1986 Report of the AVMA Panel on Euthanasia," AVMA 1986) approved cervical dislocation technique.

12. Place each euthanized specimen in a new plastic bag, labeled with the date, trap grid, trap number, sample number (e.g., 1 of 6), collection permit number, and collector's initials, and store in an iced cooler until samples can be transferred to the laboratory for sample preparation process.

13. Reset the trap, checking the sensitivity, and re-bait the trap.

14. Spray hands (with gloves donned) with Lysol solution, doff the HEPA mask, and then gloves.

15. Record all trapping efforts in small mammal field logbook.

16. Freeze the collected specimens until sufficient number of specimens is obtained to prepare each of the desired samples.

B3.2.1.2 Small Mammal Condition Inspections and Tissue Sample Preparations at the Laboratory

Small Mammal Laboratory Equipment List:

1. Appropriate sample containers (see Table B-3).
2. Autoclave.
3. Stainless steel forceps.
4. Blunt scissors.
5. Surgical (nitrile) gloves.
6. Liqui-nox®[1] solution.
7. Deionized water (Teflon®[2] squeeze bottle).
8. Teflon weighing and wash tray.
9. Calibrated balance (±0.01 g).
10. Laboratory-grade blender.
11. Absorbent paper and aluminum weigh boats.
12. Lysol solution (5% Lysol) and spray bottle.

[1] Liqui-nox® is a registered trademark of Alconox, Inc., White Plains, New York.
[2] Teflon® is a registered trademark of E. I. du Pont de Nemours and Company, Wilmington, Delaware.

13. Animal necropsy/gross external observations form.
14. Chain-of-custody seals.
15. Chain-of-custody form.
16. Dry ice.
17. Laboratory grade blend and stainless steel 500-mL cup.

Table B-3. Sample Collection and Packaging Requirements (per sample basis)

Sample Type	Target Biota Sample Mass Per Transect[a]	Pre-Processing Sample Container Requirements	Post-Processing Sample Container Requirements	Analyte Group
Mammal carcass	100 g[b]	Plastic bag	Amber glass bottle or polyethylene bottle with polyethylene cap	Inorganic chemicals, Radionuclides
	75 g[c]	Plastic bag	Amber glass bottles with Teflon-lined cap	Organic compounds
Mammal liver/kidney	1 g[d]	Not applicable	Amber glass bottle or polyethylene bottle with polyethylene cap	Inorganic chemicals only

[a] The information contained in this table is based on laboratory estimates and is subject to change if alternative laboratories are used or laboratory requirements are modified.
[b] One (1) sample container with ~100 g of processed mammal carcass composite in 500 ml total digestate. Mixture must remain in solution and not precipitate out. (Tissue settling from digestate may result in inaccurate results.)
[c] A minimum of 25 g of biota sample mass is required to complete the analyses for organic compounds; however, additional mass may be collected to support preparation of laboratory quality control samples (matrix spike/matrix spike duplicate). Collection of a small amount of additional sample mass will also be required to support the possible need to perform polychlorinated biphenyl congener analysis.
[d] One (1) sample container with ~1 g of processed mammal liver/kidney composite in 50 ml total digestate.

<u>Small Mammal Sample Inspection Instructions:</u>

1. Remove samples to be processed from refrigerated locked storage. Keep animal sealed in plastic bag until transported to the biological hood in the laboratory.
2. Don latex/rubber gloves, open the bag under the biological hood, remove the specimen from the bag, and observe animal's general external condition.
3. Weigh animal using a pre-cleaned aluminum or Teflon tared weighing tray and calibrated scale (±0.01 g), and record whole animal weight (0.01 g) on the animal sample processing form.
4. Thoroughly rinse specimen for ~30 seconds in the pre-cleaned aluminum or Teflon wash tray containing deionized water. (Thoroughly clean the wash tray with Liqui-nox solution and rinse with deionized water between each small mammal sample rinsing event.)
5. Place specimen on new absorbent towel or a pre-cleaned sheet of aluminum foil (still in biological hood).

6. Thoroughly wash gloves and dissection instruments with Liqui-nox solution and rinse with deionized water.

7. Conduct general animal condition inspection, looking for abnormalities, and record species, age, sex, weight, and reproductive status on the animal sample processing form or in the laboratory record book.

8. Dissect animal with pre-cleaned stainless steel scissors and forceps to remove kidneys and liver for composite analysis. Note any unusual coloration or appearance of organs, internal parasites, etc. on the sample processing form.

9. Briefly rinse the target organs with deionized water and place organs on pre-cleaned aluminum or Teflon tared weighing tray (or tared sample bottle) and record organ weights on the animal sample processing form using a calibrated scale (±0.01 g).

10. Place carcass (whole animal minus kidney and liver tissues) in appropriate sample container(s) according to analytes and sample mass requirements prescribed in the sample authorization form.

11. Tissue subsamples for carcass and organs will be prepared separately by blending tissues in a laboratory-grade blender with dry ice for ~30 sec to 1 minute to allow homogenization. (NOTE: The tissue should be partly frozen before attempting to homogenize with blender.) (NOTE: A minimum of one equipment blank will be performed on the laboratory grade blender to ensure equipment cleaning procedures are adequate. An equipment blank will be provided to each lab performing analytical work.)

12. Small mammal samples analyzed for non-organic analyses will be autoclaved at 121ºC for at least 90 minutes or digested in nitric acid to eliminate hantavirus concerns prior to submitting samples to the analytical laboratories. Samples analyzed for semi-volatile organic compounds, PCBs, and pesticides will not be sterilized prior to submission to the analytical laboratory because these samples cannot be digested or autoclaved prior to analyses.

13. Label sample containers consistent with the sample analysis report.

14. Place non-digested samples in the freezer for temporary storage prior to shipment to the analytical laboratories.

15. After all small mammal samples are prepared, thoroughly clean fume hood and all sample processing tools using a disinfectant solution (1% bleach or 5% Lysol). Let solution stand on all surfaces for at least 1 minute before wiping clean.

16. Record pertinent sample preparation activities (deionized water, purity, etc.) in the laboratory record book.

B3.2.2 SAMPLE HANDLING, SHIPPING, AND CUSTODY REQUIREMENTS

All sample handling, shipping, and custody requirements will be consistent with established WRPS procedures and HASQARD (DOE/RL-96-68). Sample transportation shall be in

compliance with the applicable regulations for packaging, marking, labeling, and shipping hazardous materials, hazardous substances, and hazardous waste that are mandated by the U.S. Department of Transportation [Title 49 *Code of Federal Regulations* (CFR) 171-177, Chapter 1, "Research and Special Programs Administration, Department of Transportation;" Part 171, "General Information, Regulations, and Definitions," through Part 177, "Carriage by Public Highway"] in association with the International Air Transportation Authority, DOE requirements, and applicable program-specific implementing procedures.

B3.2.3 QUALITY CONTROL REQUIREMENTS

The quality control procedures must be followed in the field and laboratory to ensure that reliable data are obtained. When performing this field sampling effort, care shall be taken to prevent the cross-contamination of sampling equipment, sample bottles, and other equipment that could compromise sample integrity. Each specimen will be thoroughly rinsed for ~30 seconds in a pre-cleaned aluminum or Teflon wash tray containing deionized water. Rinsing is intended to remove most exterior soil per HASQARD (DOE/RL-96-68). A minimum of one equipment blank will be performed on the laboratory grade blender to ensure equipment cleaning procedures are adequate. An equipment blank will be provided to each lab performing analytical work. Other typical field quality control (i.e., duplicates, splits, etc.) are not applicable to the small mammal sampling. The WRPS or subcontractor QA plan will be reviewed for consistency with HASQARD (DOE/RL-96-68).

B3.2.4 INSTRUMENT CALIBRATION AND MAINTENANCE

All field screening and analytical instruments shall be calibrated and maintained in accordance with HASQARD (DOE/RL-96-68). The results from all instrument calibration and maintenance activities shall be recorded in a bound logbook in accordance with procedures outlined in the most recent WRPS procedure for maintenance of field logbooks.

B3.2.5 FIELD DOCUMENTATION

Project documentation and records include field logbooks, field measurement records, chain-of-custody records, analytical data packages, and validation reports. At the direction of the task lead, all data packages and/or validation reports shall be subject to technical review before submittal to regulatory agencies or inclusion in reports/technical memoranda. When appropriate, electronic access shall be through computerized databases (e.g., Hanford Environmental Information System). Where electronic data are not available, hard copies will be provided in accordance with Section 9.6 of the HFFACO (Ecology et al. 1989).

Field documentation shall be kept in accordance with the most recent WRPS procedures for

1. Field logbooks.
2. Environmental site identification and information reporting.
3. Chain of custody.

B4.0 ASSESSMENTS AND RESPONSE ACTIONS

Random surveillance and assessments may be conducted in accordance with the most recent QA plan or its equivalent, TFC-PLN-02, "Quality Assurance Program Description," for the RCRA corrective action process. Deficiencies identified by one of these assessments shall be reported in accordance with TFC-ESHQ-Q_PP-P-02, "Quality Assurance Surveillances." When appropriate, corrective actions will be taken by the project engineer in accordance with HASQARD Volume 1, Section 4.0, to minimize recurrence.

B5.0 DATA VERIFICATION AND VALIDATION REQUIREMENTS

Data verification and validation are performed on analytical data sets primarily to confirm that sampling and chain-of-custody documentation is complete, sample numbers can be tied to the specific sampling location, samples were analyzed within the required holding times, and analyses met the data quality requirements specified in this SAI. All data verification and validation shall be performed in accordance with Attachment 3 of the main document and the current TFC-PLN-17, "Document Control and Records Management Program."

B6.0 MANAGEMENT OF INVESTIGATION-DERIVED WASTE

Waste generated by sampling activities will be managed consistent with the most recent waste management plan or its equivalent, TFC-PLN-33, "Waste Management Basis," for the RCRA corrective action process.

Unused samples and associated laboratory waste for analysis will be dispositioned in accordance with the laboratory contract and agreements. In accordance with 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," Subpart E--Hazardous Substance Response, §300.440, "Procedures for planning and implementing off-site response actions," Remedial Project Manager approval is required before unused samples or waste is returned from offsite laboratories.

B7.0 HEALTH AND SAFETY

All field operations will be performed in accordance with the most recent TFC-PLN-43, "Treatment, Storage and Disposal Facility Hazardous Waste Operations," and TFC-PLN-47, "Worker Safety and Health Program," or their equivalent, for the RCRA Corrective Action Program.

B8.0 REFERENCES

40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," Subpart E--Hazardous Substance Response, §300.440, "Procedures for planning and implementing off-site response actions," *Code of Federal Regulations*, as amended.

49 CFR, "Transportation," Parts 171 through 177, *Code of Federal Regulations*, as amended.

AVMA, 1986, "1986 Report of the AVMA Panel on Euthanasia," *Journal of the American Veterinary Medical Association*, Vol. 188, No. 3, pp. 252-268.

DOE/RL-96-68, 2007, *Hanford Analytical Services Quality Assurance Requirements Documents (HASQARD)*, Rev. 3, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2005-22, 2005, *100-NR-2 Study Area Ecological Risk Assessment Sampling and Analysis Plan*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, 2 vols., as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

EPA/600/R-93/187, 1993, *Wildlife Exposure Factors Handbook*, Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C. Available on the Internet at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=2799

Resource Conservation and Recovery Act of 1976, 42 USC 6901, et seq.

RPP-35484, 2008, *Field Investigation Report for Waste Management Areas C and A-AX*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-PLAN-39114, 2011, *Phase 2 RCRA Facility Investigation/Corrective Measures Study Work Plan for Waste Management Area C*, Rev. 1B, Washington River Protection Solutions, Richland, Washington.

RPP-RPT-38152, 2008, *Data Quality Objectives Report Phase 2 Characterization for Waste Management Area C RCRA Field Investigation/Corrective Measures Study*, Rev. 0, Cenibark International, Inc., Richland, Washington.

SW-846, 1986, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, Third Edition, as amended, http://www.epa.gov/epaoswer/hazwaste/test/main.htm, U.S. Environmental Protection Agency, Washington, D.C..

TFC-ESHQ-Q_PP-P-02, Rev. E, "Quality Assurance Surveillances," Washington River Protection Solutions, LLC, Richland, Washington.

TFC-PLN-02, Rev. G-3, "Quality Assurance Program Description," Washington River Protection Solutions, LLC, Richland, Washington.

TFC-PLN-17, Rev. C, "Document Control and Records Management Program Description," Washington River Protection Solutions, LLC, Richland, Washington.

TFC-PLN-33, Rev. C-5, "Waste Management Basis," Washington River Protection Solutions, LLC, Richland, Washington.

TFC-PLN-43, Rev. B-3, "Treatment, Storage and Disposal Facility Hazardous Waste Operations," Washington River Protection Solutions, LLC, Richland, Washington.

TFC-PLN-47, Rev. B-7, "Worker Safety and Health Program," Washington River Protection Solutions, LLC, Richland, Washington.

WAC 173-340-7493, "Site-Specific Terrestrial Ecological Evaluation Procedures," *Washington Administrative Code*, as amended.

WHC-SD-EN-TI-122, 1993, *Biological Uptake of 300-FF-5 Operable Unit Contaminants*, Westinghouse Hanford Company, Richland, Washington.

WMP-20570, 2004, *Central Plateau Terrestrial Ecological Risk Assessment Data Quality Objectives Summary Report - Phase I*, Rev. 0, Fluor Hanford, Richland, Washington.

WMP-23141, 2005, *100-NR-2 Groundwater Operable Unit Ecological Risk Assessment Data Quality Objectives Summary Report*, Rev. 0, Fluor Hanford, Inc., Richland, Washington.

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APPENDIX C

THREE DIMENSIONAL REPRESENTATION OF WASTE MANAGEMENT AREA C

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C1.0 WMA C 3-D MODEL VISUAL AID

This appendix contains a three-dimensional model of WMA C on the following page. Adobe has provided a 3-D tool within Adobe Reader that allows the user to rotate, pan, zoom, cut cross-sections through the model, and turn on and off different 3-D objects that are included in the model. A brief tutorial is provided.

C2.0 BRIEF TUTORIAL

Step 1) Set the correct Adobe preferences, this is done by choosing by going to the Adobe Reader's Edit menu and selecting preferences. Choose 3-D under categories. On that menu, toggle on "Enable Double-Sided Rendering". See page G-4 for additional information on setting preferences

Step 2) Return to 3-D model

Step 3) Click on the gray color box in the stratigraphy legend that says Basalt, then blue box for the unconfined aquifer, etc.

Step 4) Until the model has all the layers except the Backfill at that point, click on the Retrieved/Unretrieved buttons, and then on any of the side buttons (i.e. uprs, pipelines, etc.)

Step 5) Click on the Backfill color in the legend (orange) to fill in the backfill

Step 6) Click on all the buttons you used to turn on the additional features and turn them off (undo step 4)

Step 7) Click on the word Stratigraphy (that should remove the geology)

Step 8) Select C-105 View from Adobes 3-D Toolbar Dropdown box

Step 9) Now click on the color boxes in the contaminant legends, starting with the highest value, and working your way down the legend, you should see the boreholes get populated with boxes showing the contaminant levels. The boxes are based on the measured value at that location

Step 10) Click on the title of the contaminant legend (that should remove the boxes contaminant samples)

Step 11) On the view list click on the WIDS:Tank view when that view comes up click on the paperclip icons located on the tanks and pdf file will open giving the WIDS report for that tank

Step 12) On the view list click on the Water Table view when that view comes up click on the graph icons located by the wells and pdf file will open giving a time-history of Tc-99, Nitrate, Cyanide, and water levels at that well

If you wish to use Adobe's 3-D tool to manipulate the model, see page G-3 for the user guide.

Known Bugs: Sometimes the model does not perform as expected, if you click on an item and nothing happens, click on the Animation Tool on the Adobe's 3-D menu (blue triangle pointed to the right).

Stratigraphy

- Back Fill
- Hanford Gravels (H1)
- Hanford Sands (H2)
- Hanford Gravels (H3) (Vadose)
- Hanford Gravels (H3) (Sat.)
- Basalt

Cs-137 (pCi/g)
(Max = 25,070,920)

10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
0.1
0.01

Co-60 (pCi/g)
(Max = 9.89)

5
1
0.5
0.1
0.05
0.01

Tc-99 (pCi/g)
(Max = 28.6)

15.0
10.0
5.0
1.0
0.5
0.1
0.05
Non-Detects

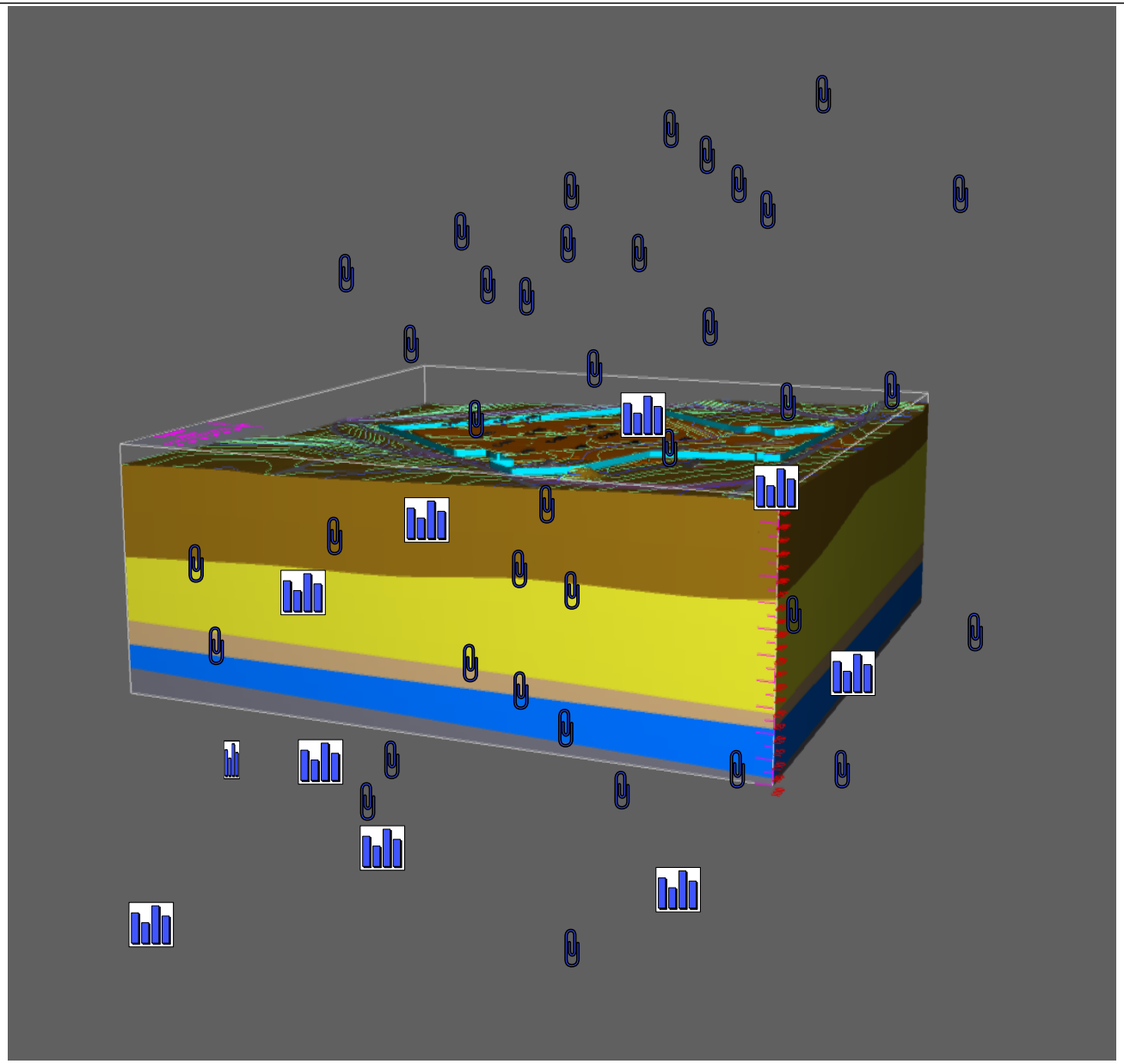
Nitrate (µg/g)
(Max = 29.3)

20.0
15.0
10.0
5.0
1.0
0.5
Non-Detects

Note Blue Tanks are Assummed Leakers

UPRs | Wells
Topography | Roads and Boundaries
Tank Labels | Pipe Lines and D/Bs

Click Here for Instructions



Defined Views

- Default
- Geology

Looking

- West
- South
- East
- North
- Down

C-105
Cross-Section
Reset
WIDS: Tanks
WIDS: Anc. Eq
WIDS: UPR
Water Table

Retrieved Tanks | Hide Leakers

C-103 | C-201 | C-202
C-106 | C-203 | C-204

Unretrieved Tanks | Hide Leakers

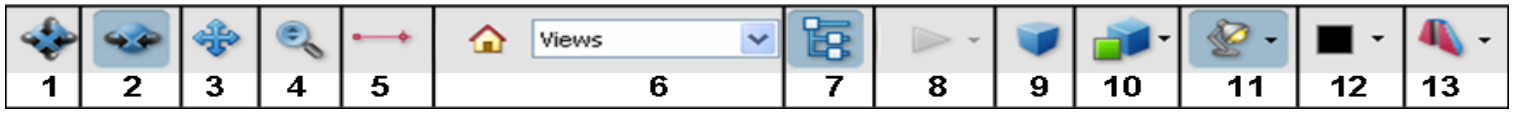
C-102 | C-104 | C-105 | C-107 | C-108
C-109 | C-112 | C-101 | C-110 | C-111

Reset

3-D Preferences Instructions (click here if model is not solid)

Instructions for using Acrobat's 3-D tool and WMA C Geologic Model (return to model →)

a) Click on the 3-D Graphic to activate Acrobat's 3-D tool
b) Use Acrobat's 3-D Tool Bar and Model Tree to manipulate the WMA C Geologic Model (3-D Tool Bar Description is given below)
c) Use Model Tree on the left to: **1)** expand layers, **2)** turn on/off layers, **3)** turn layers transparent (right click on the layer) and **4)** go to set views



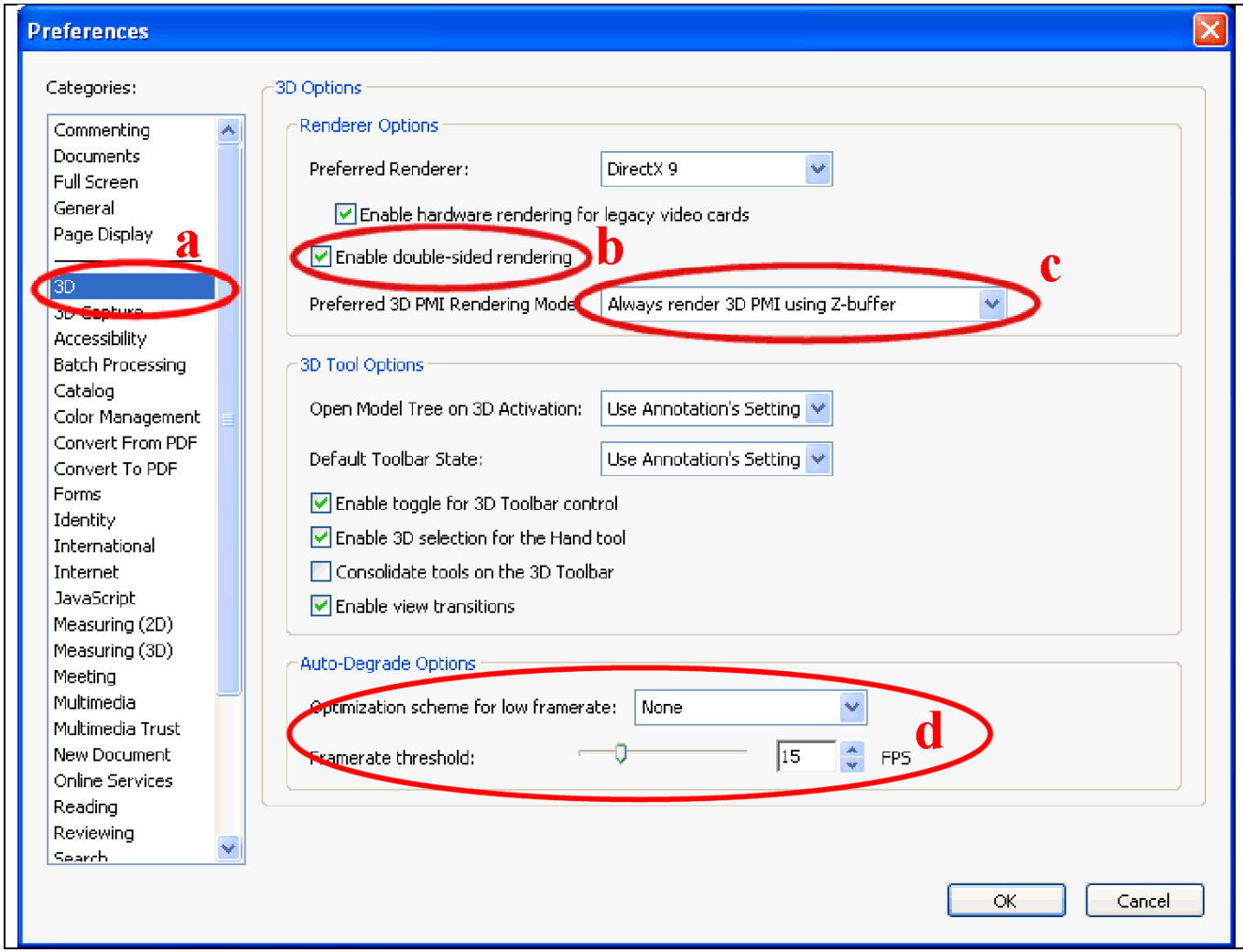
Item	Image	Tool	Description
1		Roller Ball	Use mouse* to roll the model around a pivot point
2		Spin	Use mouse* to spins the model around a pivot point (I prefer this tool for rotating model)
3		Translate	Use mouse* to move model from it's present location
4		Magnify	Use mouse* to magnify model (this can also be accomplished by holding the right mouse button)
5		Measure	Use the mouse to measure distance between objects
6	Views	View	Click on the picture of the house to return to the default view or select a view by clicking the down arrow
7		Model Tree	This opens and closes Acrobat's "Model Tree" which controls the display of each individual item (click on the plus signs in the model tree to see all of the items under the different model groups (i.e. topography, boundaries, tanks and UPRs, etc.). These individual items can be turned on/off by clicking in the check box, furthermore right clicking with the mouse on individual item brings up more controls such as transparency, so an individual part can be made transparent
8		Animate	If an animation is present use this arrow to play the animation or to bring up the animation's controls
9		Orthographic/ Perspective	Toggle between orthographic and perspective views of the model
10		Model	Click on the down triangle and select the type of model (i.e. solid, wireframe, illustration, etc.) being displayed (default is solid). Those of you with a poor graphics card will see bounding box displayed when model is moved.
11		Lights	Click on the down triangle and select the type of lights model uses (default is CAD Optimized Lights)
12		Background Color	Click on the down triangle and select background color (black is better when displaying on light box, while white is better for printing.
13		Cross-Section	Use this tool to turn on and manipulate the clipping plane (this allows you to make cross-sections through the model

* note mouse moves are done by holding down the left mouse button while moving the mouse

Return to model →

If the model being displayed is not solid (i.e. you can see through the layers and the geology is not properly displayed), you will need to set Adobe's 3-D preferences. To do this follow these instructions

1) Go to the Edit Menu and Select Preferences or hit Crtl-K on the key board that will bring up the following menu



Preferences to Set
a) Select 3D Category
b) Enable double-sided rendering
c) Select "Always render 3D PMI using Z-Buffer
d) If you do not have a good graphics card (i.e. moving model is slug-gish), play around with these settings, until you get something you can live with.

Return to model →

ATTACHMENT 1

TANK FARM CONTRACTOR
QUALITY ASSURANCE PROGRAM DESCRIPTION

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This attachment references the most recent quality assurance plan or its equivalent, TFC-PLN-02, "Quality Assurance Program Description," for the RCRA corrective action program.

Reference

TFC-PLN-02, Rev. G, "Quality Assurance Program Description," Washington River Protection Solutions LLC, Richland, Washington.

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ATTACHMENT 2

GENERAL HEALTH AND SAFETY PLAN

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This attachment references the most recent health and safety plans, TFC-PLN-43, "Treatment, Storage and Disposal Facility Hazardous Waste Operations" and TFC-PLN-47, "Worker Safety and Health Program," or their equivalent, for the RCRA corrective action program.

References

TFC-PLN-43, Rev. B-3, "Treatment, Storage and Disposal Facility Hazardous Waste Operations," Washington River Protection Solutions LLC, Richland, Washington.

TFC-PLN-47, Rev. B-7, "Worker Safety and Health Program," Washington River Protection Solutions LLC, Richland, Washington.

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ATTACHMENT 3

INFORMATION MANAGEMENT OVERVIEW

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This information management overview attachment references the most recent plan or its equivalent that addresses information management, TFC-PLN-17, "Document Control and Records Management Program Description," for the RCRA corrective action program.

Reference

TFC-PLN-17, Rev. C, "Document Control and Records Management Program Description," Washington River Protection Solutions LLC, Richland, Washington.

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ATTACHMENT 4

WASTE MANAGEMENT FOR THE RCRA CORRECTIVE ACTION PROGRAM

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Waste generated by sampling activities will be managed consistent with the most recent waste management plan or its equivalent, TFC-PLN-33, "Waste Management Basis," for the RCRA corrective action process.

Unused samples and associated laboratory waste for analysis will be dispositioned in accordance with the laboratory contract and agreements. In accordance with Title 40 Code of Federal Regulations, Part 300.440, "Procedures for planning and implementing off-site response actions," Remedial Project Manager approval is required before unused samples or waste is returned from offsite laboratories.

Reference

40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," Subpart E—Hazardous Substance Response, § 300.440, "Procedures for planning and implementing off-site response actions," *Code of Federal Regulations*, as amended.

TFC-PLN-33, Rev. C-9, "Waste Management Basis," Washington River Protection Solutions LLC, Richland, Washington.

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ATTACHMENT 5

OFFICE OF RIVER PROTECTION,
STATE OF WASHINGTON DEPARTMENT OF ECOLOGY
CHANGE NOTICE
(PER HANFORD FEDERAL FACILITY AGREEMENT AND CONSENT ORDER SECTION 9.3)

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STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
3100 Port of Benton Blvd • Richland, WA 99354 • (509) 372-7950
711 for Washington Relay Service • Persons with a speech disability can call 877-833-6341

May 8, 2012 12-NWP-071

Mr. Christopher Kemp
United States Department of Energy
Office of River Protection
P.O. Box 450, MSIN: H6-60
Richland, Washington 99352

Re: Proposed Changes to RPP-PLAN-39114 and RPP-PLAN-38777

Dear Mr. Kemp:

The Department of Ecology (Ecology) has reviewed the proposed changes for both the *Phase 2 Resource Conservation and Recovery Act (RCRA) Facility Investigation/Corrective Measures Study (RFI/CMS) Work Plan for Waste Management Area C* (RPP-PLAN-39114) and the *Sample and Analysis Plan for Phase 2 Characterization of Vadose Zone in Waste Management Area C* (RPP-PLAN-38777). We approve the proposed changes in both documents. The information obtained from these RFI/CMS activities is important in the completion of the Waste Management Area (WMA) C Performance Assessment.

Ecology appreciates the cooperative and collaborative development for these documents. However, we remain concerned that the United States Department of Energy (USDOE) has suspended the discussions on development of the RFI/CMS Report identified in Milestone M-045-61, which is due 12/31/2014. Continuing that collaboration, to ensure that the agencies are in agreement on content, would provide a more efficient review period. Our hope is to be able to respond and resolve comments in a timely manner so that we can support Hanford Federal Facility Agreement and Consent Order Milestones, M-045-62, "*Submit a Phase 2 Corrective Measures Implementation Plan for WMA-C*", due 06/30/2015 and M-045-82, "Submit a permit modification to support final closure requirements for WMA-C", due 9/30/2015.

Ecology acknowledges that the field work and laboratory analysis work for the RFI/CMS has been stopped and some analytical activities were left incomplete. We want to emphasize the importance of completing the validation, documentation, and evaluation of the field work data (RPP-39114, Section 5). We strongly urge its completion. These efforts will enable all parties to understand the purpose and importance of the remaining work that is planned (RPP-39114, Section 4.5).

Ecology anticipates that the following actions are necessary to support the completion of the RCRA RFI/CMS Study work:

1) USDOE Office of River Protection (ORP) will release a final revision of these two documents as approved
2) Complete work identified in work plan

3) Provide the date for submittal and completion of:
   a) The validation, documentation, and evaluation of the analytical data from FY2010 and FY2011
   b) The following reports:
      i) Tc-99 laboratory interferences
      ii) Evaluation of the organic detects in WMA C groundwater wells
      iii) Latest trending of groundwater contaminants at WMA C groundwater wells
      iv) Evaluation of the Quality Assurance/Quality Control and holding time issues associated with the 222-S shutdown in summer of 2011
4) Submit the revised *Hanford C-Farm Leak Assessment Report* (RPP-ENV-33418)

With the completion of these actions, USDOE-ORP and Ecology can discuss the information and agree to any needed changes or actions to complete the field work, or determine that USDOE-ORP has completed the necessary field work for the work plan. These actions will allow for immediate and final implementation of the work plan when available funding can be obtained to support Milestone M-045-61, which is due 12/31/2014.

If there are any questions, please contact Michael Barnes at 509-372-7927.

Sincerely,

Jeffery J. Lyon
Project Manager
Tank System Operations and Closure

mb/dbm

cc:

Dennis Faulk, EPA	Gabriel Bohnee, NPT
Scott Samuelson, USDOE	Russell Jim, YN
Bruce Sullivan, LMSI	Isabelle Wilder, Wanapum
Jennifer Ollero, MSA	Susan Leckband, HAB
Rob Piippo, MSA	Ken Niles, ODOE
Judy Vance, MSA	John Martell, DOH
Janet Badden, WRPS	Administrative Record: Tank Waste Storage M-45-101
Susan Eberlein, WRPS	Environmental Portal
Steve Killoy, WRPS	USDOE-ORP Correspondence Control
Jeff Luke, WRPS	WRPS Correspondence Control
Stuart Harris, CTUIR	

Office of River Protection, State of Washington Department of Ecology
Change Notice
(Per Hanford Federal Facility Agreement and Consent Order Section 9.3)

1. Document Title and Number: *Phase 2 RCRA Facility Investigation/Corrective Measures Study Work Plan for Waste Management Area C*, RPP-PLAN 39114, Rev 1B		
2. Minor Field Change: (Section 12.4 HFFACO Action Plan) ☐ Yes: (WRPS Signature Only – Attach signed form to Primary Document for record purposes) **x** No: Proceed to Box 3	**3.** Document Issue Date: 03/02/2011 **4.** Document Modification Notice Date: 11/28/2011	**5.** Notice Number: **2011-7**
6. Do proposed changes require schedule changes? (Would this extend completion of retrieval beyond 12 months from date of initiation?) ☐ Yes **x** No	**7.** Do proposed changes include specific additions, deletions, or modification to scope and/or requirements which affect the overall intent of the plan? ☐Yes **x** No	**8.** (Check only one box) ☐ Significant Modification (Check if the answer to question in either section 6 or 7 is "yes". Significant modifications require revision of the primary document.) Minor Modification Requires modification of the document **x** Can be accomplished with Change Notice.

9. Description and Justification of Change:

Description: A change is needed to incorporate information gained from the characterization activities already completed in Waste Management Area (WMA) C under this work plan and other characterization tasks, and to modify future characterization activities listed in this work plan accordingly. Text and figures are added with updated information. Proposed changes were discussed and documented in a series of meetings between Office of River Protection and Washington State Department of Ecology, supported by Washington River Protection Solutions. Detailed specific changes and the explanation for the changes are described below.

Explanation:

- Pp i-iii (Executive Summary) are updated to incorporate current status of WMA C characterization
- Pp iv-iX, Table ES-1 is updated to add a status column showing status of sampling through November 2011, to provide current information on Access Availability for sampling locations, to modify plans for Sites C and D based on technology advances, to delete activities deemed no longer necessary based on emerging information, to add analysis of archived soil samples from well 299-E27-20, and to add a new direct push sampling site near tank C-105
- P x, figure ES-1 is revised to match the revisions in Table ES-1
- The table of contents and lists of figures and tables have been updated to reflect changes to document
- Pp xxi-xxii are updated to clarify acronyms
- Pp 1-1, 1-3, 1-4, 1-5 text is updated to reflect the current milestones in the HFFACO
- Pp 1-6 and 1-7 show editorial corrections
- Pp 3-29 and 3-30, Table 3-1 schedule for WMA C performance assessment working sessions is updated to show actual completed and remaining working sessions
- Pp 3-43 – 3-45, the sampling optimization strategy from the DQO and its application are clarified
- Pp 3-45 - 3-49, application of the organic sampling optimization strategy, the results of sampling,

Office of River Protection, State of Washington Department of Ecology
Change Notice
(Per Hanford Federal Facility Agreement and Consent Order Section 9.3)

and decisions made for future sample analysis upon review of those results are discussed

- P 4-7, updated information from the recent leak loss re-assessment is included
- Pp 4-8 -4-10, changes describe modifications to the original plan that have been agreed upon, based on information generated as the characterization effort proceeded
- P 4-11, Figure 4-2 is updated to reflect revised plans
- Pp 4-13, 4-14 describe modified plans to address movement of contaminants down the stratographic dip
- Pp 4-15, 4-15 describe modified plans to address potential unknown leaks
- Pp 4-17 describe advances in surface geophysical exploration (SGE) technology and other results being used to modify future planning
- Table 4-1 is updated to correspond to table ES-1
- Pp 4-22 and 4-23 describe the basis for the changes to table 4-1
- Figures 4-3 through 4-5 are inserted to show comparison between gamma logging sites with different tools
- Figures 4-6 and 4-7 are updated to reflect revised plans
- Pp 4-36, 4-37, Editorial changes are made to clarify text
- P 4-38, a new section 4.5.2 is added to describe plans to analyze archived soil samples
- P 4-39 status and revisions to plans for drywell logging are described
- Pp 4-39 – 4-41, progress in application of SGE is described, and revised plans based on recent results are included
- P 6-1, 6-2 updates to the schedule are described
- Figure 6-1 shows updated schedule with completed work and current plans
- Additional editorial corrections and updates to references are included throughout
- Reference list is updated to include additional reference documents

10. Impact of Change:

Change revises remaining field characterization activities and schedule to reflect information needed to develop the Phase 2 RFI/CMS report for Waste Management Area C. Change documents revisions that have been agreed to in a series of meetings among Ecology, ORP and the tank operations contractor.

11. Additional Requirements and/or Provisions[1]:

Approvals

Washington River Protection Solutions, LLC. for Kent Smith, via email	Office of River Protection	State of Wash., Dept. of Ecology
☐ Provisional Approval[2] Date	☑ Provisional Approval[2] Date	☐ Provisional Approval[2] Date
☒ Final Approval Date 12/21/11	☒ Final Approval Date 1/4/12	☒ Final Approval Date 6/6/12

Notes

Office of River Protection, State of Washington Department of Ecology
Change Notice
(Per Hanford Federal Facility Agreement and Consent Order Section 9.3)

1 - For use by Ecology to identify any additional information needed to make a decision regarding the change notice. In addition, Ecology will identify actions, if any, regarding the change notice that DOE may take pending Ecology's final decision
2 – Provisional approval allows DOE and its contractors to take specific actions identified in section 10, prior to final approval of this change notice.

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