Data Quality Objectives Report Phase 2 Characterization for Waste Management Area C RCRA Field Investigation/Corrective Measures Study

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Abstract: The U. S. Department of Energy developed this data quality objectives (DQO) report for WMA C to identify the data required to support the evaluation of alternative corrective measures and subsequent decision-making for the RCRA corrective action process. This DQO report directs the vadose zone (soil) characterization efforts and defines other data needs that will be used in the Phase 2 RCRA Facility Investigation/Corrective Measures Study (RFI/CMS) work plan for WMA C (Hanford Federal Facility Agreement and Consent Order Milestone M-45-60) that is required to complete the Phase 2 RFI/CMS at WMA C. The objective is to ensure adequate data are collected to support the evaluation of corrective action alternatives that are protective of human health and the environment in the Phase 2 RFI/CMS.

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TABLE OF CONTENTS

1. INTRODUCTION 1-1
1.1 WASTE MANAGEMENT AREA C BACKGROUND 1-2
1.1.1 Metal Waste Retrieval 1-2
1.1.2 Ferrocyanide Treatment of Tank Wastes 1-5
1.1.3 Strontium/Rare Earth Fission Products Processing 1-5
1.1.4 PUREX Acidified Sludge Processing 1-6
1.1.5 241-A Tank Farm Process Condensate Treatment Testing 1-6
1.1.6 241-C-801 Cask Loading Building 1-6
1.2 DATA QUALITY OBJECTIVE TEAM MEMBERS AND STAKEHOLDERS PARTICIPATING IN DATA QUALITY OBJECTIVE PROCESS 1-7
1.3 PROJECT ISSUES 1-8
1.4 PROJECT ASSUMPTIONS 1-11

2. STEP 1 – PROBLEM STATEMENT 2-1
2.1 PROBLEM STATEMENT 2-1
2.2 PRINCIPAL STUDY QUESTION 2-1
2.3 BASIS FOR PROBLEM STATEMENT - ASSESSMENT OF WASTE LOSS EVENTS IN WASTE MANAGEMENT AREA C 2-1
2.3.1 Assessment of Known or Suspected Leakers at WMA C 2-2
2.3.2 Waste Management Area C Unplanned Releases 2-6
2.3.3 Waste Losses from Spare Inlet Nozzles and Cascade Lines 2-9

3. STEP 2 - DECISION STATEMENTS 3-1

4. STEP 3 - DATA INPUTS 4-1
4.1 DATA NEEDS 4-1
4.2 REGULATORY BASIS FOR CHARACTERIZATION 4-1
4.2.1 HFFACO Milestones 4-3
4.2.2 RCRA and Hazardous Waste Management Act 4-3
4.2.3 RCRA TSD Closure Requirements 4-4
4.2.4 RCRA Corrective Action Requirements 4-4
4.2.5 CERCLA Remedial Action Requirements for Groundwater and the 200-IS-1 OU 4-6
4.2.6 AEA and DOE O 435.1 Requirements 4-6
4.3 DATA NEEDS 4-7
4.3.1 An Evaluation of Hanford Site Tank Farm Subsurface Contamination, FY 2007 (RPP-33441) (Gaps Report) 4-7
4.3.2 Performance Assessment for WMA C 4-10
4.3.3 Risk Assessment 4-11
4.3.4 Additional Data Needs 4-14
4.4 INTEGRATION WITH CENTRAL PLATEAU OPERABLE UNITS 4-15
4.4.1 200-BP-5 DQO 4-16
4.4.2 200-IS-1 DQO 4-17
4.5 ANALYTICAL PARAMETERS 4-19

4.6 INORGANIC CHEMICALS 4-20
4.7 ORGANIC CHEMICALS 4-20
4.8 RADIOLOGICAL PARAMETERS 4-29
4.9 QUALITY CONTROL FOR FIELD SAMPLING 4-29
4.9.1 Field Duplicates 4-29
4.9.2 Equipment Rinsate Blanks 4-32
4.9.3 Trip Blanks 4-32
4.9.4 Prevention of Cross-Contamination 4-32
4.10 REQUIRED QUALITY CONTROL FOR ANALYSIS 4-33
4.11 REQUIRED METHOD DETECTION LIMITS 4-35

5. STEP 4 – STUDY BOUNDARIES 5-1
5.1 SPATIAL AND TEMPORAL BOUNDARIES 5-1
5.2 POTENTIAL SAMPLE DESIGN LIMITATIONS 5-1

6. STEP 5 – DECISION RULES 6-1

7. STEP 6 – SPECIFY TOLERABLE LIMITS ON DECISION ERRORS 7-1
7.1 INVENTORY LEAK ESTIMATE UNCERTAINTIES 7-1
7.2 REDUCING UNCERTAINTY IN CHARACTERIZATION THROUGH TECHNOLOGY DEVELOPMENT 7-3

8. STEP 7 – OPTIMIZE THE SAMPLING DESIGN 8-1
8.1 PURPOSE 8-1
8.1.1 Alternative 1: Phase 1 Conceptual Model 8-2
8.1.2 Alternative 2: Movement of Contaminants down Stratigraphic Dip Conceptual Model 8-6
8.1.3 Alternative 3: Preferential Pathways Conceptual Model 8-7
8.1.4 Alternative 3: Unknown Leak Event Conceptual Model 8-9
8.1.5 Conceptual Models of WMA C 8-9
8.1.6 Conceptual Site Models and Contaminant Distribution 8-12
8.2 GENERAL SAMPLE DESIGN PROCESS 8-13
8.2.1 Candidate Sample Site Locations 8-13
8.2.2 Characterization Field Activities 8-20
8.2.3 Optimizing Characterization of WMA C 8-23
8.2.4 Surface Geophysical Exploration 8-28

9. REFERENCES 9-1

LIST OF FIGURES

Figure 1-1. Location Map of WMA C in the 200 East Area of the Hanford Site 1-3
Figure 1-2. Location Map of WMA C and Surrounding Area. 1-4
Figure 2-1. Drywell Locations WMA C 2-3
Figure 2-2. Areas of Low Resistivity WMA C 2-4
Figure 5-1. Aerial Boundary of WMA C 5-2
Figure 8-1. Alternative 1: Phase 1 Conceptual Model 8-4
Figure 8-2. Expanded Phase 1 Conceptual Model (Accounting for Artificial Recharge due to Pipeline Leak) 8-6
Figure 8-3. Alternative 2: Movement of Contaminants down Stratigraphic Dip Conceptual Model 8-7
Figure 8-4. Alternative 3: Preferential Pathways (Clastic Dikes) Conceptual Model 8-9
Figure 8-5. Alternative 4: Unknown Leak Conceptual Model 8-10
Figure 8-8. Candidate Sample Locations and Infrastructure Constraints 8-16
Figure 8-9. Optimization of Sample Analysis (2 sheets) 8-25

LIST OF TABLES

Table 1-1. DQO Team 1-8
Table 1-2. Global and Technical Issues (3 sheets) 1-9
Table 2-1. Potential Waste Losses Through Spare Inlets on WMA C SSTs 2-10
Table 2-2. Failed Pipelines in WMA C (2 sheets) 2-11
Table 4-1. Summary of Milestones 4-3
Table 4-2. Data Gap Summary. 4-8
Table 4-3. Current Data Needs for Corrective Measures Study (2 sheets) 4-9
Table 5-1. Practical Constraints on Data Collection 5-3
Table 7-1. Tolerable Limits on Decision Errors 7-1
Table 8-1. Sample Plan WMA C Phase 2 Characterization for CMS (3 sheets) 8-17
Table 8-2. Sampling Design Elements 8-21

ABBREVIATIONS AND ACRONYMS

3-D	three-dimensional
AEA	*Atomic Energy Act of 1954*
BCG	biota concentration guide
bgs	below ground surface
CAS	Chemical Abstracts Service
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act*
CFR	*Code of Federal Regulations*
CMS	Corrective Measures Study
COC	contaminants of concern
COPC	contaminants of potential concern
CPERA	Central Plateau ecological risk assessment
CSM	conceptual site model
CVAA	cold vapor atomic absorption
DOE	U.S. Department of Energy
DOECAP	U. S. Department of Energy Consolidated Audit Program
DQO	data quality objective
Ecology	Washington State Department of Ecology
EIS	Environmental Impact Statement
EM	U.S. Department of Energy, Office of Environmental Management ()
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
FIR	field investigation report
GC/ECD	gas chromatography/electron capture detection
GC/FID	gas chromatography/flame ionization detection
GC/MS	gas chromatography/mass spectrometry
GEA	gamma energy analysis
HASQARD	*Hanford Analytical Services Quality Assurance Requirements Documents*

HFFACO	*Hanford Federal Facility Agreement and Consent Order*
HLW	high-level waste
HRGC/HRMS	high resolution gas chromatography/high resolution mass spectrometry
HWMA	*Hazardous Waste Management Act of 1976*
HSWA	*Hazardous and Solid Waste Amendment of 1984*
IC	ion chromatography
ICP/AES	inductively coupled plasma/atomic emissions spectroscopy
LCS	laboratory control sample
MCL	maximum contaminant level
MDL	Method detection limit
MTCA	*Model Toxics Control Act*
NEPA	*National Environmental Policy Act of 1969*
NIST	National Institute of Standards and Technology
ORP	U.S. Department of Energy, Office of River Protection
OU	operable unit
PA	performance assessment
PAS	PUREX acidified sludge
PCB	polychlorinated biphenyl
QA	quality assurance
QC	quality control
RCRA	*Resource Conservation and Recovery Act of 1976*
RCW	Revised Code of Washington
RFI	RCRA Field Investigation
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RL	U.S. Department of Energy, Richland Operations Office
ROD	Record of Decision
SAP	sampling and analysis plan

SEPA	*State Environmental Policy Act of 1971*
SGE	surface geophysical exploration
SST	single-shell tank
TBP	tributyl phosphate
SVOC	semivolatile organic compounds
TC&WM	Tank Closure and Waste Management
TIC	tentatively identified compounds
TOC	Tank Operations Contractor
TSD	treatment, storage, and disposal unit
UCL	upper confidence limit
UPR	unplanned release
VOA	volatile organic analysis
VOC	volatile organic compounds
WAC	*Washington Administrative Code*
WIDS	Waste Information Data System
WMA	Waste Management Area

1. INTRODUCTION

The single-shell tank (SST) waste management area (WMA) *Resource Conservation and Recovery Act of 1976* (RCRA) corrective action program is divided into two phases. The Phase 1 RCRA Facility Investigation (RFI) report was completed and includes a detailed description of the state of knowledge gained in the last 10 years by the Tank Farm Vadose Zone Program and needs for tank farm risk assessments (DOE/ORP-2008-01, *RCRA Facility Investigation Report for Hanford Single-Shell Tank Waste Areas*). Phase 2 includes the remaining elements of the corrective action process including additional characterization and the identification, evaluation, selection, and implementation of corrective measures for soil to support final soil corrective actions in support of closure decisions for the SST WMAs. The U.S. Department of Energy (DOE) developed this data quality objectives (DQO) report for WMA C to identify the data required to support the evaluation of alternative corrective measures and subsequent decision-making for the RCRA corrective action process. This DQO report directs the vadose zone (soil) characterization efforts and defines other data needs that will be used in the Phase 2 RFI/Corrective Measures Study (CMS) work plan for WMA C [*Hanford Federal Facility Agreement and Consent Order* (HFFACO) Milestone M-45-60] that is required to complete the Phase 2 RFI/CMS at WMA C. The objective is to ensure adequate data are collected to support the evaluation of corrective action alternatives that are protective of human health and the environment in the Phase 2 RFI/CMS. This objective can be achieved through the evaluation of existing data and process knowledge and implementation of data gathering efforts that are directed by this DQO. Meeting this objective also involves coordination of information needs with tank waste retrieval (monitoring for any waste released during waste retrieval from the SSTs), WMA C tank system closure, and the groundwater under WMA C that is part of the groundwater Operable Unit (OU) 200-BP-5.

This Phase 2 DQO report assembles and evaluates existing data to identify areas where there have been known or suspected releases in and immediately adjacent to WMA C. The evaluation of existing information also aids in the identification of contaminants of potential concern (COPC) and contaminants of concern (COC), aids in the development of the conceptual site models (CSM), and identifies data gaps and potentially applicable corrective measures technologies.

RPP-35169, *Near Term Data Quality Objectives for Vadose Zone Characterization Waste Management Area C*, was issued in October 2007. RPP-35169 was used to support characterization efforts that were conducted at unplanned release site (UPR) –86 and partially completed at UPR-81 at WMA C. In addition, RPP-35169 identified additional areas of concern in and around WMA C that would require characterization; however, it did not identify all of the characterization data required to support the Phase 2 RFI/CMS. Subsequent to the release of RPP-35169, additional data needs to support the Phase 2 RFI/CMS were identified and are addressed in this DQO process. The balance of the characterization work at WMA C will be accomplished under this DQO, which supersedes RPP-35169.

1.1 WASTE MANAGEMENT AREA C BACKGROUND

WMA C is located in the 200 East Area of the Central Plateau of the Hanford Site (Figure 1-1). WMA 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. The general layout of WMA C tank and diversion boxes is shown in Figure 1-2.

WMA 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. Additional infrastructure added afterwards include diversion boxes CR-151, CR-152, CR-153, and the 244-CR vault in the southern part of WMA C and the C-801 loadout building in the eastern part of the tank farm. More recently tank waste retrieval activities have added an extensive array of surface facilities that include skids, transfer piping, and ventilation systems along with supporting trailers and associated utility infrastructure.

To utilize the tanks in the WMA C, diversion box 241-B-154 was installed to enable connections from the 221-B Bismuth Phosphate Plant to either the 241-B or 241-C tank farms (HW-10475-C, p 906-910). 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 was conducted on February 10, 1945 (HW-7-1388-DEL, *Hanford Engineer Works Monthly Report, February 1945*, page 16, and INDC-356-VOL3, *Construction Hanford Engineer Works, U.S. Contract No. W-7412-ENG-1, du Pont Project 9536, History of the Project*, page 840).

Following completion of construction, the tanks in the WMA C were not put into service until March 1946, beginning with receipt of waste into the 100-series tanks, and receipt of waste in the 200-series tanks in September 1947. Additional facilities were constructed in WMA C in 1951-1952.

1.1.1 Metal Waste Retrieval

The 244-CR vault, diversion boxes 241-CR-151, -152, and 153, concrete-encased pipelines, and concrete pits atop tanks 241-C-101 (C-101) through 241-C-106 (C-106) (heel jet, pump, and sluicing pits) were constructed from 1951-1952 in WMA C. These WMA C facilities were part of other facilities constructed in 241-U, 241-T, 241-TX, 241-B, 241-BX, and 241-BY tank farms, as well as major modifications of the 221-U Plant, that were used to retrieve and process metal wastes to recover uranium (HW-19140, *Uranium Recovery Technical Manual*). 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. The 241-CR-151 master diversion box has concrete-encased underground pipelines connecting to the 244-CR vault.

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

Figure 1-1. Location Map of WMA C in the 200 East Area of the Hanford Site

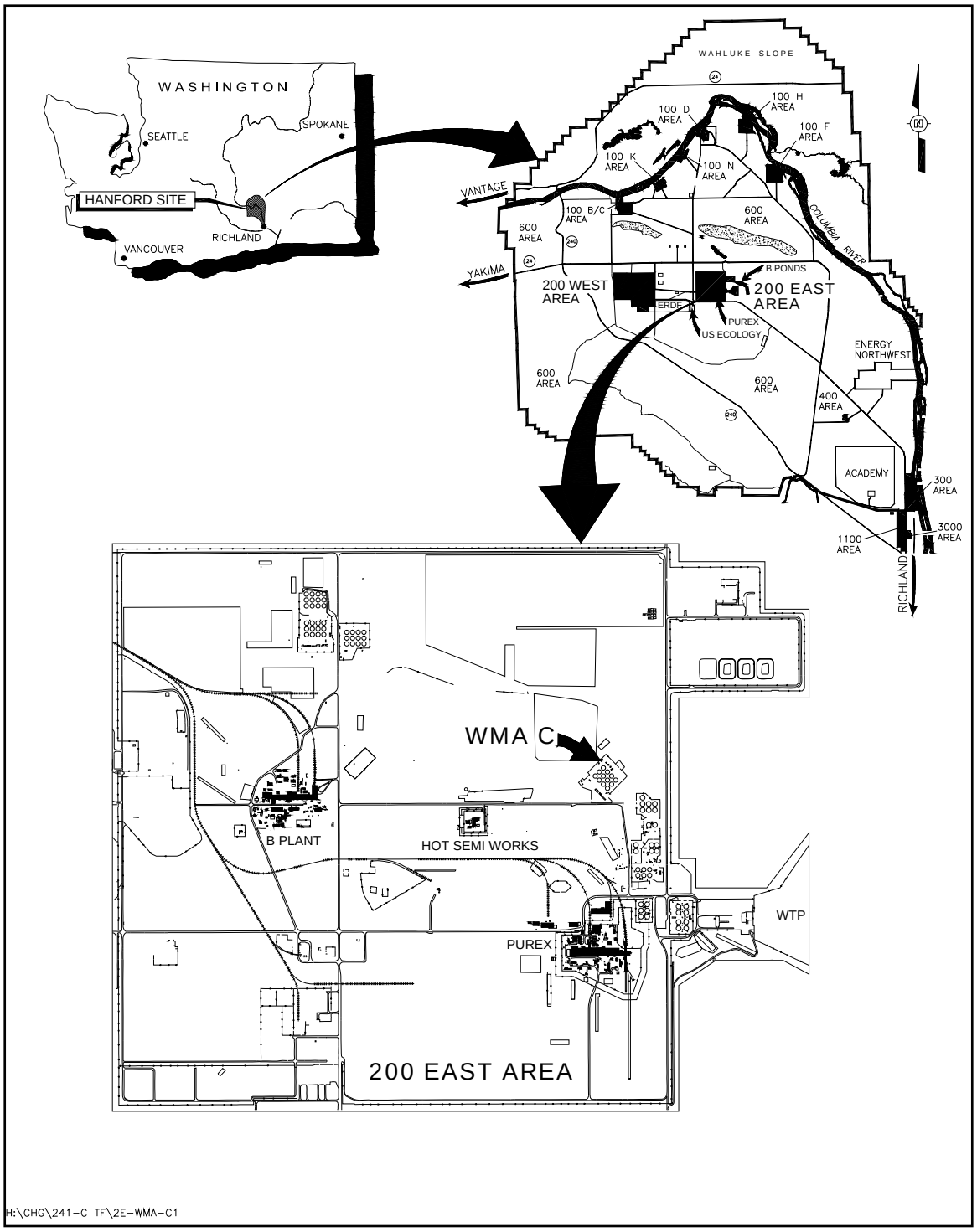
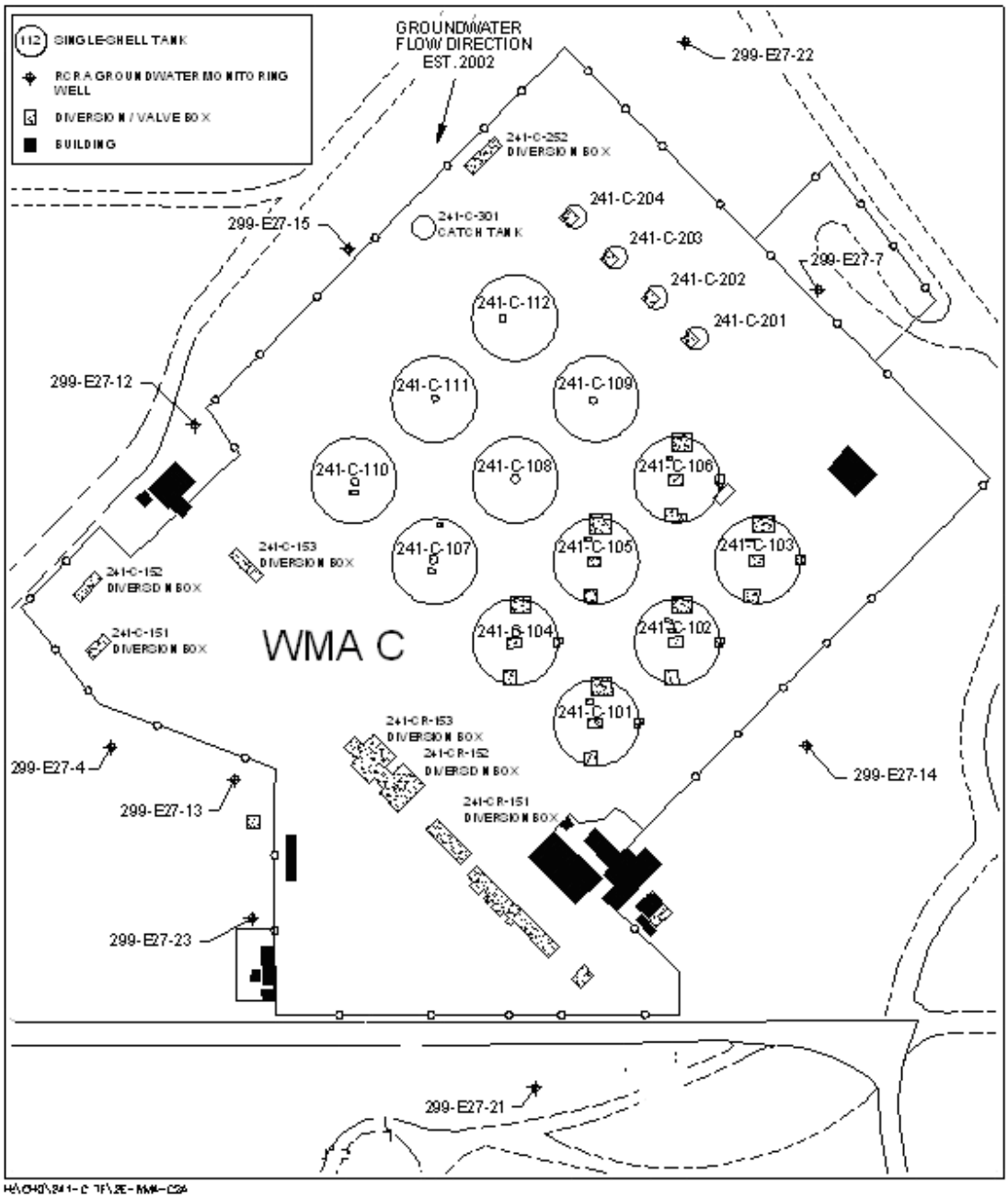


Figure 1-2. Location Map of WMA C and Surrounding Area.



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.

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 241-C tank farm began in October 1952 and was completed in April 1955. All waste transfers used the installed underground pipelines and the three diversion boxes, 241-CR-151, -152, and -153.

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 supernatant and sludges present in tanks 241-C-201 (C-201) through 241-C-204 (C-204) were intermittently retrieved and transferred to 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.

1.1.2 Ferrocyanide Treatment of Tank Wastes

The 244-CR vault, previously used for metal waste recovery, was reused for precipitation of ^{137}Cs, ^{90}Sr, and ^{60}Co from tributyl phosphate (TBP) wastes. A new chemical make-up facility, 241-C-601 building, was constructed adjacent to the 241-CR-271 control room building, underground transfer piping installed to the 244-CR vault, and necessary jumpers in diversion boxes (HW-34487, *Scavenging of Stored TBP Waste*). The 241-C-601 building has since been removed from WMA C.

Ferrocyanide precipitation processing in the 244-CR vault is reported to have started on November 9, 1955 (HW-38955-REV, *"In-Farm Scavenging" Operating Procedure and Control Data*) and completed in January 1958. The ferrocyanide treated TBP waste, referred to as TFeCN waste, was transferred from 244-CR vault to tanks 241-C-108 (C-108), 241-C-109 (C-109), 241-C-111 (C-111), and 241-C-112 (C-112) for settling of the precipitates before discharge to the 216-BC trenches and cribs.

1.1.3 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 high-level waste (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 strontium and rare earth 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 241-C Farm received wastes from the strontium/rare earth processing conducted in PUREX and B Plant. However, tanks 241-C-107 (C-107), C-108, C-109, C-111, and C-112 did receive waste from the strontium and rare earth processing purification processing conducted in the 201-C Strontium Semiworks building.

Processing of strontium and rare earth solutions within B-Plant continued until June 1966 (HAN-95105-DEL, *Monthly Status and Progress Report*, 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*, 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.

1.1.4 PUREX Acidified Sludge Processing

The sludges stored in the 241-A and 241-AX tank 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 (WHC-SD-WM-TI-302, *Hanford Waste Tank Sluicing History*, 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 and then dissolved in nitric acid in the 244-AR vault. The dissolved sludge, designated as PUREX acidified sludge (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*).

1.1.5 241-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 ion exchange materials for separating organics and fission products from the 241-A Tank Farm Process Condensate. 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 (RPP-RPT-29191, *Supplemental Information Hanford Tank Waste Leaks*).

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. RPP-RPT-29191 summarizes the analyses of the 241-A Tank Farm Process Condensate 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 241-A Tank Farm Process Condensate was discharged to the crib 216-C-8 from January 1960 through March 1965.

1.1.6 241-C-801 Cask Loading Building

In 1962, building 241-C-801 (or 801-C) 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 ion exchange material (interoffice memo 7G400-03-SMM-003, “Shipment 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 P1 and P2 waste types) was transferred from tank 241-C-103 (C-103) through underground piping to a valve pit located inside 241-C-801. The tank waste would then flow into the cask, the target radionuclide would

be absorbed by the ion exchange material (Decalso®[1]), and then waste would flow back to tank 241-C-102 (C-102).

The 201-C Strontium Semiworks building was also used in conjunction with the 801-C cask station to demonstrate the separation of ^{99}Tc from alkaline high-level waste solutions. Approximately 1 kg of ^{99}Tc was separated from HLW that was stored in C-Farm SSTs in October 1963 (HW-79377, *Hanford Laboratories Monthly Activities Report*, 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 801-C 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 801-C building that contained IRA-401®[2] ion exchange material, which adsorbed technetium from the waste solution. The Strontium Semiworks received the cask that was loaded with technetium in November 1963, 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 801-C building has a drain line connecting to the valve pit. The valve pit and cask loading area have separate drains lines connecting to a drywell located outside of the tank farm fence (H-2-4573, *Engineering Flow Diagram, C-Farm Cesium Loadout Facility*, and H-2-4554, *Vent Filter VF-E1 Strontium Storage and Loadout Facility*). This drywell is located approximately 23 m (75 ft) north of the 801-C building, outside the tank farm fence (DOE/RL-88-30, *Hanford Site Waste Management Units Report*, 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 <u>may</u> have been discharged to this drywell as a result of operations conducted at the 801-C building.

There are 14 UPR sites within or adjacent to WMA C. In addition, there are planned release sites associated with some of the facilities at WMA C. Uncertainties exist in the volume and content of releases in and around WMA C. These release sites are the principal focus of the vadose zone characterization efforts of this DQO.

1.2 DATA QUALITY OBJECTIVE TEAM MEMBERS AND STAKEHOLDERS PARTICIPATING IN DATA QUALITY OBJECTIVE PROCESS

Table 1-1 identifies the DQO team members that participated in the seven-step DQO process. The development of this DQO is based on input from the DQO team.

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[1] Decalso® is a synthetic, sodium aluminosilicate gel manufactured by the Permutit Company, Paramus, New Jersey.
[2] IRA-401® is a styrene, di-butyl benzene ion exchange bead manufactured by the Rohm and Haas Company, Philadelphia, Pennsylvania.

Table 1-1. DQO Team

Organization	Name	Function/Decision Authority
U.S. Department of Energy – Office of River Protection (ORP)	Robert Lober	ORP Project Lead
U.S. Department of Energy – Richland Operations Office (RL)	John Morse Doug Hildebrand	RL Lead - Integration with Groundwater OUs
Washington State Department of Ecology (Ecology)	Mike Barnes Jeff Lyon Joe Caggiano Elizabeth Rochette	Lead WMA C DQO Tank Farms Project Manager Technical Support Technical Support
DOE Tank Operations Contractor (TOC)	Susan Eberlein Jim Field Janet Badden Mike Connelly Fred Mann David Myer Harold Sydnor Duc Nguyen David Banning	Vadose Zone Project Director Project Lead Regulatory Compliance Risk Assessment Risk Assessment Field Characterization Field Characterization Sampling and Analysis DQO Oversight
Cenibark International, Inc.	Paul Seeley	Principal Author
Fluor Hanford, Inc.	Greg Thomas Marcus Wood	Project Lead OU 200-BP-5 Risk Assessment

Stakeholder input was solicited to help define the type of data the vadose zone characterization effort at WMA C will need to collect to help make decisions for the corrective action process. The process included meeting with the following stakeholders: Nez Perce Tribe, Oregon Department of Energy, and the Hanford Advisory Board. The process resulted in identifying WMA C vadose zone characterization issues. These issues are incorporated into the global and technical issues described in Section 1.3.

1.3 PROJECT ISSUES

Project issues include global issues that transcend the specific DQO process and the technical issues that are unique to the project. Both global and project technical issues have the potential to impact the DQO, the work plan, and the CMS. Table 1-2 presents the global and technical issues that were identified throughout the development of this DQO through meetings, and workshops.

Table 1-2. Global and Technical Issues (3 sheets)

Global/Technical Issues	Elements of Issue	Obstacles to Resolving Issue	Actions that can be taken to Resolve Issues	Where Issue will be Dispositioned in the CMS Process
Can the nature and extent of vadose zone contamination be adequately characterized sufficiently to evaluate and select a remedy?	Characterize plumes from known or suspected past releases Characterize documented unplanned releases Characterize vadose zone around facilities without logged boreholes or other vadose zone characterization (such as C-200 tanks, C-301 catch tank, drains, tanks/vaults outside of farm, other facilities away from 100-series tanks and previous Vadose Zone Program investigations) Define contaminantion boundaries – spatial (vertical and lateral) and temporal Define gaps/unknowns	Field investigations – interferences both above and below ground surface limit locations sampling can occur	Place surface geophysical exploration (SGE) electrodes deep into vadose zone to support three dimensional SGE mapping. Place SGE electrodes to support C Tank retrievals Characterize nature and extent of surface and near surface releases Collect samples outside of fenceline/expand lateral extent of study boundary Integrate with CP OU 200-IS-1 and 200-BP-5 on characterization efforts	WMA C DQO and work plan define data requirements and how they will be obtained
Can field investigations provide the necessary data?	Confirm nature and extent of releases Define the inventory in the vadose zone	Based on existing characterization efforts the potential exists that field conditions constrain additional sampling and analysis such that less than optimal information can be generated to quantify the nature and extent of contamination at WMA C (e.g., uncertain contaminated soil volume and contaminant concentrations within that volume)	Characterize to the extent possible (based on historical knowledge, field sampling constraints, available resources) and incorporate residual uncertainty in the remedial action decision making process.	WMA C DQO, work plan, and Phase 2 RFI/CMS

Table 1-2. Global and Technical Issues (3 sheets)

Global/Technical Issues	Elements of Issue	Obstacles to Resolving Issue	Actions that can be taken to Resolve Issues	Where Issue will be Dispositioned in the CMS Process
Integration and timing between programs – RCRA and *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA), ORP and RL to mutually support processes	Integrate with Central Plateau OUs 200-IS-1 and 200-BP-5 on characterization efforts and deep vadose zone treatability testing Why is groundwater remedy selection process proceeding ahead of the understanding of the vadose zone contamination?	ORP funding to support 200-IS-1 remedial investigation and feasibility study does not align with RL milestones 200-BP-5 OU FS is due at the same time (1st quarter FY-11) WMA C RFI/CMS but B/BX/BY characterization is later in schedule WMA C RFI/CMS will precede deep vadose zone technology treatability testing	Align ORP milestones and funding to support 200-IS-1 needs Scope WMA C RFI CMS to evaluate corrective measures for shallow vadose zone only with follow-on study to be performed after deep vadose zone work is completed	WMA C DQO, work plan, and Phase 2 RFI/CMS Funding and milestones are beyond the scope of the WMA C RFI/CMS
Lack of consensus on the Conceptual Site Model(s) that apply to WMA C leading to lack of confidence in the reliability of remedy evaluation and implementation	Determine the most plausible conceptual site model for WMA C using field contaminant characterization Transitioning to numeric, inputs Integration of vadose zone and groundwater conceptual models Establish threshold to define where modeling applies and where it does not Ability to determine potential impacts	Data may be insufficient to determine the most plausible conceptual model	Develop multiple conceptual models, including Tribal input, that will contribute to defining the characterization efforts and support defining an plausible conceptual site model for WMA C in the CMS Test validity of various models against expanded data base and widely accepted scientific concepts of contaminant behavior in the natural environment. .	WMA C DQO, work plan, and Phase 2 RFI/CMS
Risk Assessment	Determine the acceptable level of uncertainty in determining risk and decision making	How to resolve the use of null values in the risk assessments and decision making	Collect samples outside of fenceline/expand lateral extent of study boundary Integrate with CP ecological risk assessment to ensure continuity in approach and that interfaces are defined Integrate data needs for surface (direct contact and ecological risk) and deep vadose zone characterization	WMA C DQO, work plan and Phase 2 RFI/CMS

Table 1-2. Global and Technical Issues (3 sheets)

Global/Technical Issues	Elements of Issue	Obstacles to Resolving Issue	Actions that can be taken to Resolve Issues	Where Issue will be Dispositioned in the CMS Process
Identification and evaluation of corrective measures	Assessment of their effectiveness Interface with groundwater treatability studies and out comes Will waste determination be considered in Implementability?	Phase 2 RFI/CMS milestone may not be achievable because data collection to meet DQO requirements may extend beyond the completion date	Define corrective measures in DQO process and data needs that support the balancing criteria of the CMS (long-term protection, short-term protection, implementability, reduction of mobility/toxicity/volume through treatment, and cost Waste determination is not an element of implementability	WMA C DQO, work plan and Phase 2 RFI/CMS
Will characterization data be sufficient to implement corrective action and support data needs for WMA C closure of tank and ancillary equipment	Are corrective measure design data requirements meet by this DQO? Can the effective depth of a barrier at WMA C be established with this DQO?			Design data requirements will be defined once a corrective action(s) is selected which is a post-CMS activity and not part of this DQO.
Decisions on full removal of WMA tanks, ancillary equipment, and associated soil	Full removal of systems would require huge layback area and unknown depth High cost, high worker risk, and implementability challenges will contribute to feasibility of this option.	Data needs to support analysis of full removal in CMS would need to be defined prior to decisions being made on full removal in the Tank Closure and Waste Management (TC&WM) Environmental Impact Statement (EIS)	DQO assumes full removal will not be included in scope of characterization and that further characterization may be required should the EIS select this alternative	Post-EIS ROD supplemental DQO and work plan (as needed should full removal be required) and WMA C Closure Plan

1.4 PROJECT ASSUMPTIONS

General project assumptions associated with this DQO include the following:

- The DQO process will be conducted in accordance with EPA 2006 EPA/240/B-06/001:EPA QA/G-4, *Guidance on Systematic Planning Using the Data Quality Objectives Process*, and the Tank Operations Contractor (TOC) procedures (TFC-ENG-CHEM-C-16, “Data Quality Objectives for Sampling and Analysis”).
- The DQO will be used to prepare a WMA C work plan and sampling and analysis plan (SAP) for Phase 2 characterization.

- The DQO supersedes the near-term DQO and will be used for the remaining vadose zone characterization work to be conducted at WMA C.
- Characterization data will be collected from the vadose zone associated with the WMA C. The data will be used to prepare a corrective measures study and support corrective measure decision-making. The DQO effort will focus on WMA C and the associated waste sites.
- Existing characterization data from the Phase 1 RFI and the ongoing characterization work in and around WMA C will be used to support the DQO process and to prepare the work plan. Based on process knowledge and existing characterization data, it is expected that waste site COCs will exceed action levels and that corrective action will be required.
- The characterization of waste sites at WMA C will support the data needs of other closure actions and the 200-BP-5 groundwater OU remedial investigation/feasibility study (RI/FS). Integration of characterization efforts will promote more efficient and cost-effective use of resources while still obtaining the necessary data to support the objectives for the work plan as a whole. Active participation by these other projects was solicited to provide input to the DQO process.
- The investigations directed under this DQO will focus on vadose zone soil contamination.
- An ecological risk assessment (ERA) will be prepared to support the CMS. The ERA will be performed in accordance with two guidance documents for ecological risk assessment: The *Washington Administrative Code* (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*. Data requirements for the ERA are included in this Phase 2 DQO.
- Data uses that are considered in the development of this DQO include refining the preliminary conceptual contaminant distribution model(s), risk assessments, corrective action alternatives, corrective action decisions, closure, maintaining worker health and safety, and protecting the environment.
- Groundwater may have been impacted in the past by some waste releases in WMA C. However, evaluations of groundwater contamination and remediation are not in the scope of this Phase 2 DQO or the subsequent work plan. Investigating groundwater contamination under WMA C is part of the 200-BP-5 groundwater OU RI/FS conducted by DOE-RL.

2. STEP 1 – PROBLEM STATEMENT

The objective of a problem statement is to clearly define the problem (the reason data are required) so the focus of the project (completing a CMS for WMA C) will be unambiguous. With the objective of the problem statement in mind, the scope of this DQO is outlined in the following:

- The DQO process will address vadose zone contamination in and around WMA C.
- Data will be used in the evaluation of alternatives in a CMS and in the selection of a proposed remedy.
- The corrective action decisions supported by the data collected under this DQO will be consistent with and support final closure of WMA C.
- This DQO will not address data requirements of SST residual waste sampling and analysis or other data required to address closure associated with ancillary equipment in the tank farm. These data requirements are/or will be addressed in separate DQOs for the closure of the SST system.

2.1 PROBLEM STATEMENT

Considering the purpose and scope of this DQO and a review of available information, a concise statement of the problem is as follows:

Based on DOE/ORP-2008-01, ***RCRA Facility Investigation Report for Hanford Single-Shell Tank Waste Areas,*** **contamination identified in WMA C has caused a need for corrective action.**

2.2 PRINCIPAL STUDY QUESTION

The principal study question identifies key unknown conditions that reveal the solution to the problem. Generally, the principal study question requires data to be resolved. The principal study question that addresses the problem statement in Section 2.1 is the following:

Do contaminants in soil have a significant environmental impact that may require corrective action?

2.3 BASIS FOR PROBLEM STATEMENT - ASSESSMENT OF WASTE LOSS EVENTS IN WASTE MANAGEMENT AREA C

Approximately 53 million gal of radioactive waste from chemical processing and plutonium processing operations are stored in 177 underground storage tanks on the Hanford Site. Of these,

149 are SSTs, which consist of a single steel liner inside a concrete shell. Nominal capacities of these tanks range from 55,000 to 1,000,000 gal. Sixty-seven of the 149 SSTs have been identified as "confirmed or suspected leakers" over the operational lifetime (1945-1980) of the SST farms (HNF-EP-0182, *Tank Waste Summary Report for Month Ending February 29, 2008*).

There have been numerous studies and investigations in an attempt to estimate the inventory of contaminants in the tank farms vadose zone. Most efforts to date have focused on leak volume estimates. Vadose zone inventories are then estimated based on process knowledge of the composition of waste in the tank at the time the release occurred. For some major tank leaks and UPRs, historical records confirm the waste loss event and provide a strong technical basis for leak volume and inventory estimates. However, for many tank leaks and UPRs little data are available to support the estimates of loss.

HNF-EP-0182 provides the commonly accepted basis for tank leak volume estimates, but it does not provide associated inventory estimates or UPR volumes. RPP-23405, *Tank Farm Vadose Zone Contamination Estimates*, summarizes many of the tank leak volume estimates listed in HNF-EP-0182 and additionally provides UPR volume estimates. However, RPP-23405 shows large differences in estimated leak volumes, both higher and lower, compared to some tank leak volume estimates in HNF-EP-0182.

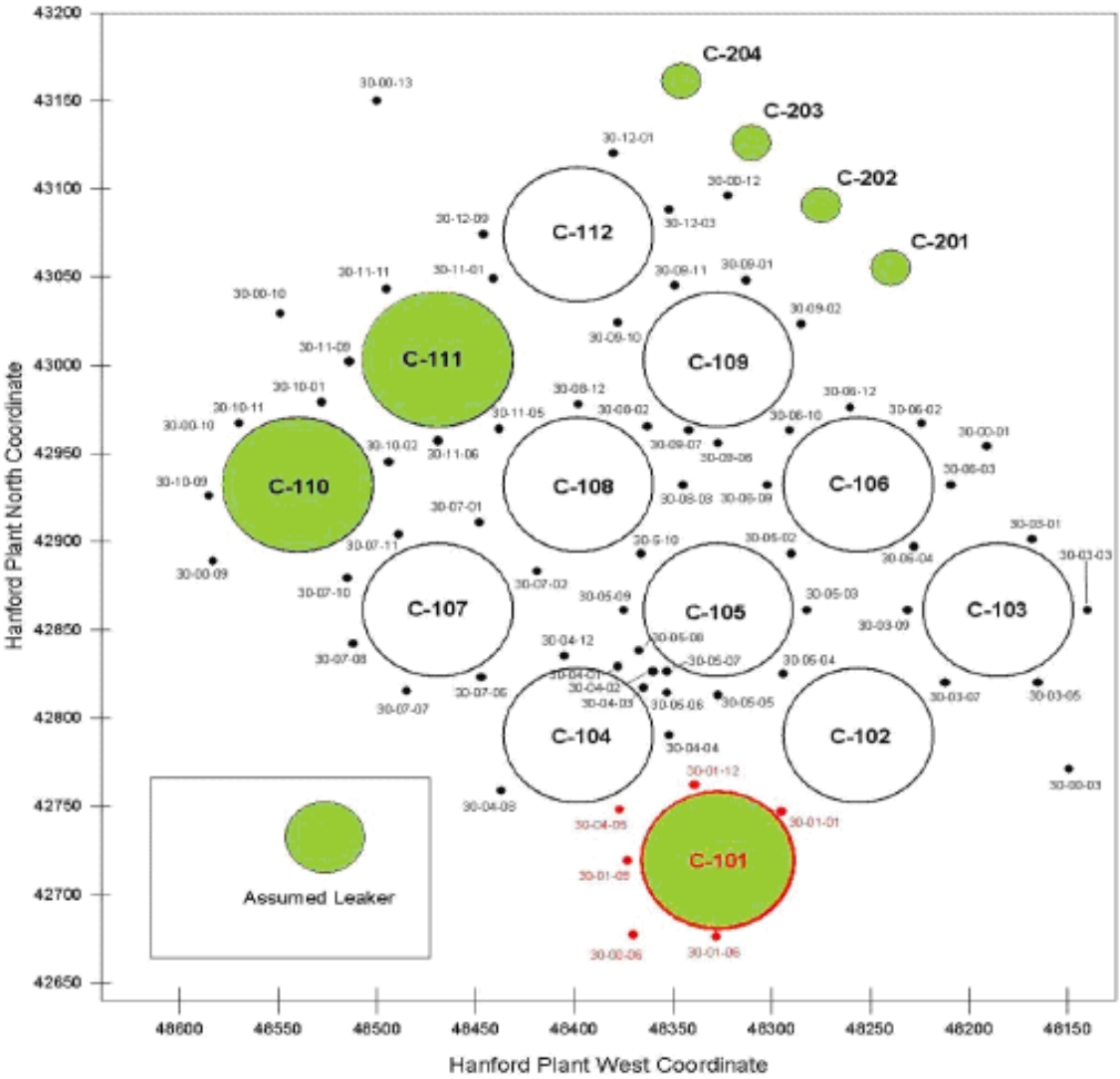
DOE's TOC with U.S. Department of Energy, Office of River Protection (ORP) and Washington Department of Ecology (Ecology) have applied a process to reassess selected tank leak estimates (volumes and inventories) and to update release estimates and UPR volumes, and inventory estimates as emergent field data are obtained (RPP-32681, *Process to Assess Tank Farm Leaks in Support of Retrieval and Closure Planning*). 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*, documents the results of applying the process described in RPP-32681 for reassessing UPRs and tank leak estimates for SSTs in the 241-C tank farm.

The information gathered and the reassessment results for each of the SSTs and UPRs in the 241-C tank farm are discussed in Sections 2.3.1 and 2.3.2.

2.3.1 Assessment of Known or Suspected Leakers at WMA C

The 241-C tank farm consists of twelve100-series SSTs and four 200-series SSTs. Indications of tank waste losses at WMA C are derived from historical operations records (e.g., in-tank liquid level measurements) and subsurface monitoring data, mostly from drywells installed around the 100-series SSTs (Figure 2-1) to measure radiation from gamma-emitting radionuclides dissolved in leaked tank waste fluids. No drywells are installed adjacent to the 200-series SSTs. Unexplainable liquid level drops in tanks and the occurrence of high radiation readings were indicators of liquid loss events.

Figure 2-1. Drywell Locations WMA C

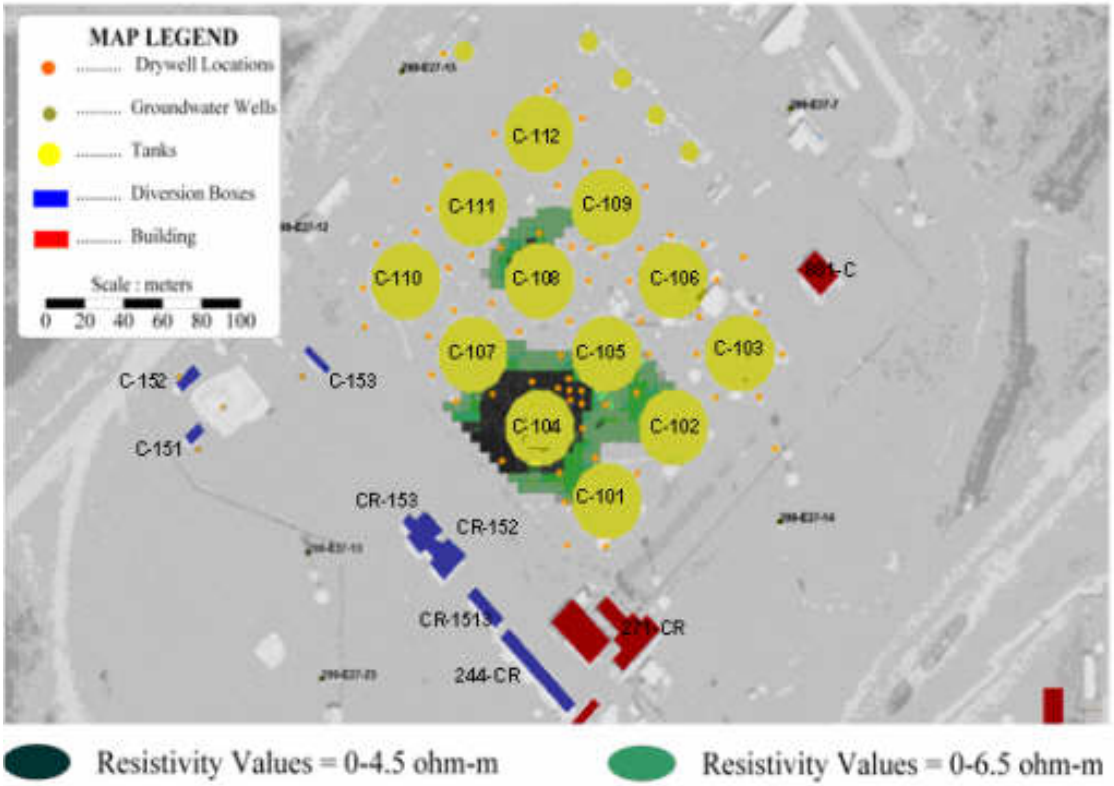


An earth resistivity was used between August and December 2006 to collect information within the 241-C tank farm (RPP-RPT-31558, *Surface Geophysical Exploration of C Tank Farm at the Hanford Site*). The resistivity data were collected using 69 drywells within the tank farm and with a set of eight monitoring boreholes (e.g., groundwater wells), one buried electrode, 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 2-2 for the 241-C tank farm. Areas with low resistivity are most likely associated with increased soil moisture or inorganic salt concentration, which could be due to waste loss events. Specific areas of low-resistivity values within the

241-C tank farm are a region near tanks C-101, C-102, 241-C-104 (C-104), 241-C-105 (C-105), and C-107, along with a smaller low-resistivity zone near tanks C-108 and C-109.

Figure 2-2. Areas of Low Resistivity WMA C



2.3.1.1 Single-shell Tank 241-C-101

C-101 has a capacity of 2,006,000 L (530,000 gal) and a diameter of 22.9 m (75 ft). C-101 is presently passively ventilated and is the first tank in a three-tank cascade that includes C-102 and C-103. The base of C-101 is approximately 38 ft below grade. The inlet nozzles on the tank side wall are approximately 20.5 ft below grade; the cascade overflow pipeline to C-102 is approximately 21 ft below grade.

Based on the reassessment of C-101, it was concluded that available data are insufficient to establish a minimum range or leak mass for C-101. The upper range is estimated to be 36,000 gal. The mass of the C-101 leak is in question because of inconsistencies in low-activity measurements in surrounding drywells and expected drywell radioactivity for a large leak of HLW. As a result, the liquid level decrease may be a dilute condensate loss through spare inlet nozzles rather than a HLW PUREX leak. It was agreed during the reassessment process that a 1000-gal release, as contained in RPP-23405, is possible but indefensible and in the absence of better supporting evidence, to leave the estimated leak volume at 20,000 gal as reported in HNF--EP-0182, *Waste Tank Summary Report for Month August 31, 2006*. The 20,000-gal leak

volume estimate apparently represents a compromise estimate reached in 1980 and is based on unspecified evidence or evaluation that is not documented in the record.

As a result of the reassessment, it is recommended that (1) The area in the vicinity of C-101, C-104, and C-105 require further soil investigation directed by a DQO, (2) further tank assessments are necessary to establish if there is a relationship to nearby plume (C-104/105) to C-101, and (3) maintain HNF-EP-0182 volume estimate and notes related to C-101.

2.3.1.2 SST 241-C-110

The tank 241-C-110 (C-110) release appears to be the result of a tank overflow (RPP-ENV-33418), 17 ft 4 in. (208 in.) above the tank bottom.

Because no liquid level decrease was observed based on liquid level accuracy for the manual tape and electrode instrumentation in the tank in 1971-72, the volume of the loss was previously determined to be less than 2000 gal. Rough calculations of the gamma activity observed in drywells indicate that the volume could have been significantly smaller. The supernatant was predominantly cesium removal waste. Supernatant samples of this waste obtained in 1975 provide waste composition measurements. The measured 1975 C-110 supernatant composition appears to be consistent with the measured ^{106}Ru drywell activity.

2.3.1.3 SST 241-C-111

Tank 241-C-111 (C-111) has a capacity of 2,006,000 L (530,000 gal) and a diameter of 22.9 m (75 ft) (HNF-EP-0182). C-111 is passively ventilated and is the second tank in a three-tank cascade that includes C-110 and C-112. A manual tape with an electrode was used for many of the liquid level measurements reported in the 1950s through the 1970s. The statistical accuracy of the manual tape and electrode measurement technique was 0.75 in. (~2,060 gal), as determined in July 1955 (HW-51026, *Leak Detection – Underground Storage Tanks*).

Evaporation calculations and plotted liquid level and evaporation rates clearly indicate that the liquid level decrease can be attributed to evaporation and suggest that high tank waste temperature information was apparently not available for previous assessments. A recent assessment (RPP-ENV-33418) concludes that data supports the potential to reclassify C-111 as sound. Therefore, no leak volume or inventory is assigned for C-111.

2.3.1.4 SST 241-C-105

Tank C-105 was constructed in 1944 through early 1945 and has a capacity of 530,000 gal and a diameter of 75 ft. A cascade overflow line connects C-105 as second in a cascade series of three tanks continuing through C-104 and C-106. The cascade overflow line consists of a 3-in.-diameter schedule 80 steel pipe contained within an 8-in.-diameter schedule 40 steel pipe (W-72743, *Hanford Engineer Works – Bld. 241, 75'-0"Dia. Storage Tanks T-U-B&C Arrangement*"). The 3-in.-diameter cascade pipeline extends into the pipe sleeves on both SSTs. The pipe sleeves consist of an outer 6-in.-diameter schedule 40 steel pipe and an inner 4-in.-diameter schedule 40 steel pipe. The pipe sleeves protrude from the SST, and the ends of the outer 8-in.-diameter pipe are welded to the pipe sleeve, external to the SST. C-105 is

categorized as a sound tank (HNF-EP-0182, rev. 229, page 16). The operational history for C-105 for 1947 through 1980 is presented in WHC-MR-0132, *A History of the 200 Area Tank Farms*, and summarized in the following discussion.

The radioactivity detected in drywells around SST C-105 suggests there may be several waste loss events. The pipeline, C-104 to C-105 cascade line, and spare inlet nozzle waste loss events are thought to be responsible for the radioactivity detected at one or more depth intervals in drywells 30-04-02, 30-04-03, 30-04-04, 30-04-05, 30-04- 08, 30-05-06, 30-05-09, and decommissioned borehole C4297. Potential sources of the waste losses include the tank, nearby transfer pipelines, the cascade line from C-104, leakage from the C-104 atmospheric condenser, and/or the spare inlet lines to C-105. The peak radioactivity detected in drywell 30-05-07 is approximately at the same elevation as the base of tank C-105. Therefore, waste loss from C-105 may have occurred. Data recently collected from a nearby characterization borehole (C4297) reveal nitrate and ^{99}Tc at greater depths that further support the plausibility of a leak event. Based on drywell calculations scenarios presented and the absence of ^{137}Cs contamination in drywell C4297 (within 9 ft of 30-05-07), contamination below the tank base was estimated to range from 40 gal to 2000 gal. The waste type for the leak is assumed to be PUREX (PSN-IX or P1) supernatant with a measured ^{137}Cs concentration of 4.34 Ci/gal (ARH-1945, *B Plant Ion Exchange Feed Line Leak*) for these calculations. On the other hand, no increase in gamma activity has occurred in drywells since 1974, during which 2.8 million gal of supernatant was cycled through C-105. A formal tank leak assessment has not been conducted and therefore a definitive statement concerning the integrity of this tank cannot be made at this time.

2.3.2 Waste Management Area C Unplanned Releases

Fourteen UPRs have occurred within or adjacent to WMA C. The following brief descriptions of these UPRs are summarized from the Waste Information Data System (WIDS) General Summary Reports (DOE/RL-88-30) and represent the best information available on the nature and extent of releases. Substantial uncertainty exists in the volume and content of UPRs from components within the WMA C.

- Unplanned release UN-200-E-16 is a surface spill associated with an overground transfer pipeline between C-105 and C-108. The surface spill associated with this release is located approximately 18 m (60 ft) northeast of C-105 and occurred in 1959. The spilled liquid was classified as coating waste from the PUREX process and was an estimated 50 gal.
- Unplanned release UN-200-E-27 is located just east of the 244-CR vault and extends east beyond the tank farm fenceline. DOE/RL-92-04, *PUREX Source Aggregate Area Management Study Report*, 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 reports the particulate contamination was due to work in 241-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.

- Unplanned release UN-200-E-68 is wind-borne surface contamination spread from the 241-C-151 (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 C-151 diversion box was opened, flushed, and sprayed with Turco Fabrifilm[3] to physically fix contamination to the structure surface.
- Unplanned release UN-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 contamination 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, and 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 the contamination was not specified.
- Unplanned release UN-200-E-81 is located northeast of the 244 CR vault near the 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.
- Unplanned release UN-200-E-82 occurred in December 1969. The source was determined to be the feed line running between C-105 and the 221-B building. The leak was discovered near the C-152 diversion box. The liquid release, an estimated 2600 gal, flowed from the vicinity of the C-152 diversion box to the northeast, downgrade, until it pooled into an area, measuring approximately 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, 128-129). The WIDS report states that additional decontamination of the area was done in 1985. A gunite cap was subsequently installed on the soil surface above this leak location.
- Unplanned release UN-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 approximately 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 (1300 ft^3). The surface of the release site has been stabilized. 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.
- Unplanned release UN-200-E-91 is located approximately 30 m (100 ft) from the northeast side of the tank farm. It resulted from surface contamination that migrated

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

from WMA C. The date of the occurrence, its aerial 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.

- Unplanned release UN-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.
- Unplanned release UN-200-E-100 is a surface spill of unknown volume and constituents that occurred in 1986. It is located about 60 m (197 feet) south and east of WMA C and surrounds the 244-A lift station.
- Unplanned release UPR-107 is a surface spill. The exact location of this release is unclear. The WIDS General Summary Report for UPR-200-E-107 states the release was reported at the 241-CR-100 tank. The original incident report states it occurred at the 241-CR-110 tank in the 241-CR tank farm. The WIDS states that the location should be the C-110 tank in the 241-C tank farm. 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. "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).
- Unplanned release UPR-200-E-115 is located east of C Farm, south of 8th Street, across an unnamed gravel road. As a result of routine radiological 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 radiological 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 tank farm contractor 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.
- Unplanned release UPR-200-E-118 is located in the northeast portion of the tank farm and extends north up to about 300 m (1000 ft) beyond the fenceline. It was the result of an airborne release from C-107 that occurred in April 1957. The highest exposure rate was estimated at 50 mrem/hr at the ground surface (DOE/RL-92-04).

- Unplanned release UPR 200-E-135 is located south and west of WMA C. This site was identified as contaminated vegetation which has subsequently been removed. The source of contamination is suspected to be an underground leaking pipe in the area.
- Unplanned release UPR-200-E-136 was a release in 1969 of 64,345 to 90,840 L (17,000 to 24,000 gal) of waste from C-101. The quantity and type of waste released from C-101 is uncertain (RPP-ENV-33418).
- Unplanned release UPR-200-E-137 occurred when water entered C-203, migrated through the saltcake, and either became entrained in the saltcake or leaked out of the tank, as stated in WIDS. The leak was 1514 L (400 gal) of PUREX HLW. The waste in C-203 was subsequently determined to be sludge and was retrieved to a double-shell tank in 2006.

2.3.3 Waste Losses from Spare Inlet Nozzles and Cascade Lines

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

Tank waste may have been discharged from the spare SST inlet nozzles if the waste elevation in the tank exceeded the elevation of the inlet nozzles. Cascade lines that lie below the spare inlets in elevation are also submerged when the waste level exceeds the spare inlet level. 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 (perhaps where it exits or enters the tank liner), or breach the spare inlet lines. Events are identified when the inlet nozzles on an SST were submerged beneath tank waste. Although the inlet nozzles on several SSTs were submerged, there is no record of the waste volume potentially lost to the soil surrounding the SST.

Tanks C-101, C-103, C-104, C- 105, 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 and cascade lines on several occasions. Waste may have been lost to the ground from these SSTs as a result of overfilling these tanks. The date and waste type present in each SST when the tank was filled with waste above the elevation of the spare inlet nozzles are summarized in Table 2-1.

Several pipelines in the WMA C are known to have failed while transferring tank wastes. Table 2-2 identifies 11 pipelines in WMA C that are known or suspected to have failed. The date the failure was detected, the waste type, and the volume of waste that was leaked to the soil (if known) are listed in Table 2-2. UPRs have been identified for some of the failed pipelines listed in Table 2-2. In some cases, the failed pipeline was contained within a concrete diversion box, vault, or pipeline encasement. The surfaces of the concrete structures were coated with a chemically resistant paint. However, the integrity of the coatings and the concrete structures are unknown. It is not known whether waste leaked from these concrete structures.

Table 2-1. Potential Waste Losses Through Spare Inlets on WMA C SSTs

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 P2 (452 kgal), and Coating Waste (CWP2) (94 kgal).
C-103	October 1953 – March 1957	Tributyl Phosphate Plant (TBP) waste
	June 1961 – December 1961	PUREX CWP2
C-104	August 1958	PUREX CWP1
	June 1965 – March 1966	After receiving 15,000 gal of unknown waste type (likely PUREX CWP2 based on RL-SEP-332, 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 metal waste (MW2)
	December 1965 – March 1966	PUREX P2 HLW supernate
C-109	June 1961 – December 1961	PUREX CWP2
	June 1965 – March 1968	Tank received 19,000 gal from 201-C Strontium Semiworks (HS). Tank contains 112,000 gal of evaporator bottoms (BT-SltCk), 300,000 gal of PUREX CWP2, and 142,000 gal of Strontium Semiworks waste (HS).
C-111	May 1957	TBP waste
	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.

Table 2-2. Failed Pipelines in WMA C (2 sheets)

Date	Waste Type[a]	Waste Discharged (gal)	Event Description	References[b]
6-1964	HS - 201C Strontium Semiworks Waste	No estimate	"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.	RPP-RPT-29191, page 115
11-1964	Cesium Depleted PUREX HLW Supernate (P1)	No estimate	Installation was completed on an alternative effluent return route from the 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 801-C effluent return line to SST C-102 to enable routing waste to SST C-103 or C-102.	RPP-RPT-29191, page 115
2-1965	PUREX CWP2	No estimate	"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."	RPP-RPT-29191, page 116
3-1965	PUREX CWP2	No estimate	"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.	RPP-RPT-29191, page 116

Table 2-2. Failed Pipelines in WMA C (2 sheets)

Date	Waste Type[a]	Waste Discharged (gal)	Event Description	References[b]
5-1966	PUREX CWP2	No estimate	"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.	RPP-RPT-29191, page 118
Pre-1988	PUREX P2 supernate	No estimate	Pipeline V-103 - "Earlier investigations of the extremely high levels of contamination found between Tanks 104-C and 105-C are described in reference (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."	Internal memo 13331-88-088, « Environmental Protection Deviation Report 87-10, Radiation Level Increase in Drywell 30-03-09,) page 4
Unknown	Unknown	No estimate	Line V112 is identified as a leaker adjacent to diversion box 241-C-151. The date and amount of waste leaker from this pipeline is unknown.	RPP-25113,[c] page 7

[a] Waste types are defined in RPP-26744, *Hanford Soil Inventory*.

[b] The UPRs listed have been combined with UPR-200-E-133, Contaminated Soil at C Farm in accordance with DOE/RL-88-30, revision 16, page 665.

[c] RPP-25113, *Residual Waste Inventories in the Plugged and Abandoned Pipelines at the Hanford Site*.

Seven potential tank waste loss events not previously reported in DOE/RL-88-30 are identified in Table 2-2. These potential waste loss events resulted from the following:

- Failure of pipeline V172 (June 1964).
- Possible failure of un-numbered pipeline from 241-C-801 Cesium Loadout Facility to C-103 (November 1964).

- PUREX coating waste transfer pipeline failure in diversion box CR-151 (February 1965); pipeline number was not provided in reference and could not be determined from available information.
- Failure of pipeline 8041 (March 1965).
- Failure of a flexible jumper in diversion box 241-CR-152 (May 1966).
- Failure of pipeline V103 (pre-1988).
- Failure of pipeline V112 (date unknown).

Based on the Phase 1 RFI report and the process knowledge summarized above, it can be concluded that waste has been released into the vadose zone at WMA C and that the known nature of these releases potentially presents a threat to human health and the environment requiring further investigation.

3. STEP 2 - DECISION STATEMENTS

Decision statements link corrective measures alternatives with the principal study question and express a choice between alternative actions. Alternative corrective measures have been identified that may resolve the principal study question, with the exception of No Action. Alternative corrective measures also include an element of institutional controls as part of their implementation. The following categories of candidate alternative corrective measures are identified:

- Take no action [required for consistency with the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA)].
- Remove (excavate), treat, as appropriate, and dispose offsite.
- Treat contaminants to reduce toxicity, mobility, or volume.
- Treat vadose zone to reduce mobility of released contaminants.
- Install surface barrier.
- Combination of any of the above, except for no action.

Decision statements are created by combining the study questions with alternative corrective measures. Using this formula, the decision statement can be expressed as

Determine whether any contaminated soils in WMA C require one or more corrective measures [(1) remove, treat, and dispose or (2) contain and/or treat or immobilize] or require no corrective measures.

4. STEP 3 - DATA INPUTS

This section describes the information required to address the problem statement and the decision statements. The SST WMA RCRA corrective action program is divided into two phases. Phase 1 was completed and included characterization and assessment activities for large releases associated with the SST WMA. Phase 2 will include the remaining elements of the corrective action process including additional characterization (the subject of this DQO), and the identification, evaluation, selection, and implementation of corrective measures to support final closure of SST WMAs. Data on the nature and extent of contamination as well as the fate and transport of the contaminants are required for defining risks and selecting corrective measure alternatives in Phase 2 of the RCRA corrective action process. Nature and extent data includes determining the extent of contamination, chemical constituent concentrations, and radionuclide constituent concentrations. Fate and transport data includes determining the movement and changes that the contaminants may undergo over time through the vadose zone. The extent of contamination data is required to address one of the decision rules (see Chapter 6) and may be used with constituent concentrations to determine estimate constituent inventories in the vadose zone. Concentration data are needed to determine direct contact and ecological risks, and inventory data are needed for groundwater pathway modeling.

In addition, to complete the alternatives analysis in the CMS, engineering data on the vadose zone are also required. Engineering data needed to complete the CMS will be defined once the alternatives are established. The engineering properties of the vadose zone define whether a candidate corrective measures technology will function as anticipated.

4.1 DATA NEEDS

Characterization of the vadose zone is necessary before final decisions can be made on how these sites will be dispositioned for cleanup and closure.

4.2 REGULATORY BASIS FOR CHARACTERIZATION

This section describes the regulatory basis for the DQO. The regulatory framework underlying this DQO was established to satisfy closure of the tank farm system including the corrective action requirements of RCRA, the State of Washington *Hazardous Waste Management Act of 1976* (HWMA), *Revised Code of Washington* (RCWI 70.105), the *Model Toxics Control Act of 1989* (MTCA), the *Hanford Federal Facility Agreement and Consent Order* (HFFACO) (Ecology et al. 1989), and the Hanford Facility RCRA Permit. It is also intended to achieve equivalency to CERCLA, as required by the HFFACO. As necessary to support closure, the framework also incorporates elements related to the *Atomic Energy Act of 1954* (AEA) as implemented through DOE O 435.1, *Radioactive Waste Management*, and other environmental laws that may affect decisions.

Two major environmental regulatory programs govern cleanup of waste sites at the Hanford Site: RCRA (including the corresponding state law, the HWMA) and CERCLA. RCRA was enacted to manage and prevent releases of hazardous materials at active facilities that generate, store, treat, transport, or dispose of hazardous wastes or hazardous constituents. RCRA was amended to provide for corrective action for past and current releases at RCRA-permitted facilities. CERCLA was enacted to investigate and respond to past releases and potential releases of hazardous substances at inactive sites.

Ecology is the lead regulatory agency for the SST system. The SST system is regulated under RCRA and the HWMA as final status units under interim status standards for treatment, storage, and disposal (TSD) tank systems, and will be closed as RCRA TSD units. Final decision concerning the vadose zone contaminated by releases from the SSTs will be addressed during closure of WMA C.

In addition to these statutes there are requirements under the AEA and DOE O 435.1 that must be addressed as part of the closure process. These multiple requirements create redundant and possibly conflicting administrative requirements. To address this issue, the HFFACO signatories [DOE, Environmental Protection Agency (EPA), and Ecology] established a single, unified closure process that incorporated the administrative and substantive elements of each regulation. The HFFACO was developed to establish how the RCRA and CERCLA programs will be applied at the Hanford Site. The agreement was designed for the following reasons:

- To ensure that environmental impacts associated with activities at the Hanford Site are investigated and that appropriate actions are taken.
- To establish a procedural framework for developing, prioritizing, implementing, and monitoring appropriate actions in accordance with RCRA and CERCLA.
- To ensure compliance with RCRA and the HWMA and provide a procedural framework for permitting RCRA TSD units.

Under Appendix I of HFFACO (Ecology et al. 1989), Ecology is to involve the EPA for the purpose of ensuring work is consistent with future CERCLA remedial decisions, and to provide the EPA and DOE with a basis to evaluate the need for additional work that might be required under CERCLA remedial action authority.

Other key regulatory programs that directly affect corrective actions in a WMA are the AEA, the *National Environmental Policy Act of 1969* (NEPA), and the *Washington State Environmental Policy Act* (SEPA) (RCW 43.21c). The AEA governs management of radioactive wastes. Requirements deriving from the AEA play an important role in the safe management and eventual closure of the WMAs. Where information regarding treatment, management, and disposal of the radioactive source, byproduct material, and/or special nuclear components of mixed waste (as defined by the AEA) is incorporated into this document, it is not incorporated for the purpose of regulating the radiation hazards of such components under the authority of the HWMA; Chapter 70.105, Revised Code of Washington and its implementing regulations; but is provided for information purposes only.

The NEPA requires federal agencies, including DOE, to evaluate any actions they plan to undertake for potential environmental and community impacts and to mitigate impacts as appropriate. Under NEPA, federal agencies must assess the impacts of proposed projects and alternatives prior to making a significant commitment of resources. Thus, any corrective measure activities including selection and implementation of corrective measures must be evaluated to determine what impacts would result from those activities. Similarly, SEPA requires Washington State agencies to evaluate state agency actions for potential environmental and community impacts and to mitigate impacts. DOE is in the process of preparing the Waste Management and Tank Closure Environmental Impact Statement (TC&WM EIS) which is evaluating alternatives for the closure of the Hanford tank farms. The Record of Decision (ROD) for TC&WM EIS is scheduled to be completed in 2009.

4.2.1 HFFACO Milestones

The HFFACO establishes a high-level schedule for overall SST system closure activities. The milestones that have been negotiated in the HFFACO provide a structure for developing detailed plans that specify activities and requirements for SST system closure. A summary of key HFFACO milestones pertinent to characterization of WMA C are presented in Table 4-1.

Table 4-1. Summary of Milestones

Milestone	
M-45-00	Complete closure of all SSTs and requirement that all SST retrieval and closure actions be conducted in compliance with the HFFACO Appendix I process
M-045-00B	Complete retrieval of all WMA C SSTs
M-045-06-T03	Initiate closure actions of one WMA
M-045-06-T04	Complete closure actions of one WMA
M-045-55	Submittal to Ecology of Phase 1 RFI 4 Report for all WMAs
M-045-58	Submittal to Ecology of Phase 2 master work plan for all WMAs
M-045-60	Submittal to Ecology of RFI/CMS work plan and SAP for WMA C
M-45-61	Submittal to Ecology of RFI/CMS for WMA C
M-45-62	Submittal to Ecology of corrective measures implementation work plan for WMA C

The HFFACO milestones are the performance measures of compliance and document that progress is being made toward closure.

4.2.2 RCRA and Hazardous Waste Management Act

Congress passed the RCRA to ensure the proper management of newly generated wastes. Congress then amended RCRA with the *Hazardous and Solid Waste Amendment of 1984* (HSWA) to include requirements for the cleanup of contamination in the environment from improper waste management. The HSWA requires all facilities seeking a permit to treat, store, or dispose of hazardous wastes to clean up environmental contaminants at their site regardless of the time of release. The State of Washington was delegated the authority from EPA to implement RCRA through the State of Washington HWMA.

The RCRA requirements, as implemented through the *Washington Administrative Code* (WAC) 173-303, "Dangerous Waste Regulations," will be specified in the RCRA Site-Wide Permit. As identified in Appendix I of the HFFACO Action Plan, the permit will specify closure actions for tanks and ancillary equipment and corrective actions for soil that must be performed to comply with RCRA requirements, whether the closure action is defined in association with tanks or ancillary equipment under a RCRA closure plan or with contaminated soil under a RCRA RFI/CMS incorporated into the WMA closure action plan.

4.2.3 RCRA TSD Closure Requirements

The RCRA closure requirements call for meeting both the general closure performance standards of WAC 173-303-610, "Closure and post-closure," and the tank closure performance standards specified in WAC 173-303-640(8)(b), "Tank Systems," "Closure and post-closure care." In addition, for evaluation and implementation of landfill closure, the closure performance standards of WAC 173-303-665(6) must be considered. In planning integrated closure actions within the WMA, these standards will determine how closure is achieved under RCRA requirements. The general closure performance standards of WAC 173-303-610(2) require that the facility be closed in a manner that

- Minimizes the need for further maintenance.
- Controls, minimizes, or eliminates to the extent necessary to protect human health and the environment, post-closure escape of dangerous waste, dangerous constituents, leachate, contaminated runoff, or dangerous waste decomposition products to the ground, surface water, groundwater, or the atmosphere.
- 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.

Closure plans will describe how these performance objectives will be met. The closure plan will result in a modification to the Site-Wide Permit authorizing closure actions to proceed. The SST system closure process, pursuant to HFFACO Appendix I, emphasizes closure at the WMA level. Modifications are expected to bring more information into the closure plan and permit actions for groups of components within the WMA by way of common and systematic implementation of retrieval, characterization, and closure.

4.2.4 RCRA Corrective Action Requirements

The RCRA corrective action process requires that contaminated portions of the vadose zone be characterized. Characterization is accomplished through a combination of reviewing existing information on the known process history and conducting field investigations to determine the nature and extent of releases. This information is used to determine the risk associated with confirmed releases to humans and the environment. In the case where a significant risk exists that requires more immediate action, interim measures can be applied until a permanent remedy can be put in place. Otherwise an alternative analysis of corrective measures is conducted to support final closure.

There are four primary steps in the WMA C soil component corrective action process: (1) characterizing and analyzing risk associated with contamination in the soil column, (2) identifying, comparing, and selecting corrective measures to mitigate risk, (3) public review and comments of the selected measures, and (4) performing necessary cleanup as specified in the Site-Wide Permit. The RCRA corrective action process for Hanford's WMAs has the following major steps as defined in HFFACO Appendix I:

- Complete the RFI.
- Conduct a CMS.
- Conduct public participation and receive comments.
- Select cleanup actions in the Site-Wide Permit.
- Corrective Measures Implementation.

An RFI is conducted to verify release(s), and to characterize the nature, extent, and rate of migration for releases of concern. The RFI initially involves verification of suspected releases. DOE/RL-99-36, *Phase 1 RCRA Facility Investigation/Corrective Measures Work Plan for Single-Shell Tank Waste Management Areas*, and its implementation led to the identification and confirmation of major release sites in the WMAs. These findings for WMA C are documented in RPP-35484, *Field Investigation Report for Waste Management Areas C and AX*. The Phase 1 RFI report includes the state of knowledge on characterization, research, and interim measure implementation during the 10 years of the Phase 1 corrective action program. The Phase 1 DOE/ORP-2008-01 includes SST background information, an explanation of field activities performed, and descriptions and findings, including supporting information such as field investigation reports (FIR) and the initial SST system performance assessment.

The WMA C FIR is included in the Phase 1 RFI report. It provides data assessments on the nature and extent of past contaminant releases from tanks. The WMA C FIR also presents computer simulations estimating future groundwater impacts from past releases, as well as a risk assessment.

Efforts will proceed from DOE/ORP-2008-01 (Phase 1 RFI report) into Phase 2 data collection to support risk analyses, including the baseline risk assessment, and the evaluation of alternatives in the CMS to reduce or eliminate risks associated with releases. This DQO defines the data requirements to meet the needs of the Phase 2 RCRA corrective action process. It will be followed by development of a Phase 2 WMA C RFI/CMS work plan and SAP. These plans will be reviewed and approved by Ecology. The WMA C CMS will identify, evaluate, and recommend specific corrective measures to ensure protection of human health and the environment from releases based on the following criteria:

- Overall protection of human health and the environment.
- Compliance with the relevant and appropriate requirements.
- Long-term effectiveness and permanence.
- Reduction of toxicity, mobility, or volume through treatment.

- Short-term effectiveness.
- Implementability.
- Cost.
- State acceptance.
- Community acceptance.

The CMS report becomes the basis for selection of the corrective measure remedy in the RCRA Site-Wide Permit. Following the selection of the remedy, a RCRA Corrective Measures Implementation Plan will be developed for review and approval by Ecology in accordance with the requirements and schedule specified in the permit modification. This plan includes design, construction, operating, maintenance, and monitoring requirements for the corrective measures.

4.2.5 CERCLA Remedial Action Requirements for Groundwater and the 200-IS-1 OU

As indicated in HFFACO Appendix I, groundwater remediation associated with releases from WMA C may be performed pursuant to a CERCLA ROD (interim and final) developed for the associated groundwater OU (200-BP-5). Groundwater monitoring and response actions are integrated within the context of HFFACO Milestones and, as feasible, would be integrated with but separate from the WMA C and Central Plateau source waste site remedial actions. Such remediation is the responsibility of DOE/RL and its contractor.

Releases from ancillary equipment such as pipelines and diversion boxes that are part of the tank farm system but outside of the WMA fenceline are part of 200-IS-1 OU. This OU is addressing the ancillary equipment and contaminated soil in and around the release site. Section 4.2 discusses integration with Central Plateau OUs in more detail.

4.2.6 AEA and DOE O 435.1 Requirements

The closure of the tank farm system must also integrate the applicable requirements of DOE O 435.1. DOE M 435.1-1, *Radioactive Waste Management Manual*, provides direction for waste characterization of radioactive waste and that the characterization is documented to ensure safe management and disposal of radioactive waste. The characterization process is to use a DQO process (or a comparable process) to identify characterization parameters and the acceptable uncertainty in characterization data. Each waste site will be characterized to include information on types and quantities of radioactive and hazardous chemicals from process knowledge. This information is then verified by appropriate sampling/analysis/monitoring techniques. The characterization and verification activities will also include determination of waste migration and potential environmental and health impacts. This information will be used to develop a closure strategy for the waste site(s), utilizing the waste characterization data. The SST performance assessment (PA) and the WMA C PA will assess risk using this characterization data for both radiological and nonradiological contaminants and therefore will serve multiple regulatory functions including those under RCRA, CERCLA, HWMA, *Clean Water Act of 1972*, *Safe Drinking Water Act of 1974*, and the AEA.

4.3 DATA NEEDS

As part of the Phase 1 RFI report, future data needs were summarized and are discussed in greater detail in RPP-33441, *An Evaluation of Hanford Site Tank Subsurface Contamination, FY 2007*. In this document, data gaps are identified in the following general areas: existing subsurface inventory, contaminant release, recharge, and mobile contaminants. In addition, the SST PA identified that further characterization would be required to improve estimates of past release inventories lost to the vadose zone. These documents and their use in defining Phase 2 data needs are discussed in Sections 4.3.1 through 4.3.4.

4.3.1 An Evaluation of Hanford Site Tank Farm Subsurface Contamination, FY 2007 (RPP-33441) (Gaps Report)

RPP-33441 identifies data needs that are important to estimating future risks in performance assessments. These data gaps are also used as inputs to this DQO process.

The Gaps Report is a summary of data needs identified in the Phase 1 RFI report and is an update of RPP-18052 *A Summary and Evaluation of Hanford Site Tank Farm Subsurface Contamination*. The document summarized knowledge of subsurface contamination beneath the tank farms at the time. It included a preliminary conceptual model for migration of tank wastes through the vadose zone and an assessment of data and analysis gaps needed to update the conceptual model. The Gaps Report provides a status of the data, analysis of gaps outlined in RPP-18052, and discussion of the gaps and needs that currently exist to support the mission of the Tank Farm Vadose Zone Project.

The data gaps and needs are arranged in groups that reflect components of the tank farm vadose zone conceptual model:

- Inventory.
- Release.
- Recharge.
- Geohydrology.
- Geochemistry.
- Modeling.

Within each group or component of the conceptual model, the new data gaps and needs are ordered by priority.

For the revised list of data gaps and needs, priorities were assigned based on the impact of the gap/need on groundwater impacts and the associated knowledge level. Impacts are defined as direct, indirect, low, and unclear. An impact is direct if the data or analytical result quantifies a condition or process that strongly influences eventual radionuclide contamination levels in the vadose zone or groundwater. An impact is indirect if it does not quantify a condition or process that influences radionuclide fate and transport in the vadose zone and groundwater. An impact is unclear if the effect of the process, condition, or analytical result on radionuclide migration is not

known but may be significant or provide a means to better understand the current and future distribution of radionuclides.

Knowledge levels are defined as low, medium, and acceptable. A knowledge level is low if no site-specific information is available and no general literature values can be used with confidence to represent the process or parameter in a radionuclide migration model. If the parameter or process is considered vital to the evaluation of radionuclide migration, additional data collection to develop usable values is recommended. Knowledge level is medium if some site-specific quantifiable data or relevant literature values are available. A medium knowledge level is assumed to lead to a database that is sufficient to provide estimated values that can be used in radionuclide migration models to perform a reasonably conservative risk assessment. Use of these medium knowledge level estimates is expected to lead to conservatively high estimates of groundwater contamination. Additional data are expected to clearly improve both quantification of the condition or process and confidence in the values used in a radionuclide migration model. A knowledge level is acceptable if site-specific quantifiable data are available to provide input into a radionuclide migration model, and additional data are expected to only marginally improve understanding. Considering both the determination of impact and knowledge level, the data or analysis needs are ranked for prioritization.

Table 4-2 is a summary of key aspects of the data gaps that were identified. The existing subsurface inventories are relevant data gap needs for this DQO.

Table 4-2. Data Gap Summary.

Area	Description	Driver
Inventory	Retrieval tank leaks and residual waste concentrations will be measured during and after retrieval.	Key driver for intruder impacts; impacts groundwater analyses.
Existing subsurface inventory	Content and extent of contaminants; major leaks have been characterized by borehole and direct push sediment samples as well as field gamma logging and high resistivity measurements.	Key driver for groundwater analyses.
Contaminant release	Release models (including effect of tank fill grout leachate).	Key driver for groundwater analyses for residual wastes in tanks.
Recharge	Gravel surface/surface barriers	Key driver for groundwater analyses
Contaminant mobility	What could cause contaminants not presently mobile to become mobile?	Such contaminants drive the groundwater analyses.

When the Phase 1 program started in the late 1990s, 22 high priority needs were identified. Phase 1 has fully or partially satisfied 14 of them. Based on the experience of Phase 1, additional data needs were identified (RPP-33441) and are shown in Table 4-3.

Table 4-3 includes data needs identified in the Phase 1 DOE/ORP-2008-1 for corrective actions. Other data needs for all decision pathways associated with WMAs were also identified but are not related to the CMS and associated decisions. Other data gaps were identified for RCRA Closure Plan/Permit, CERCLA Source operable unit, CERCLA Groundwater operable unit, Interim Measures, and Operational Support.

Table 4-3. Current Data Needs for Corrective Measures Study (2 sheets)

Data Need	Path Forward	Element of WMA C DQO
Inventory		
Retrieval leak inventories	Potential retrieval leak inventories are calculated using the Hanford Tank Waste System Operations Simulator and the associated leak volume.	No, independent evaluation to support CMS and interim measures, should leak occur
Current distribution of past tank waste discharges[a]	Data from spectral gamma logging and characterization boreholes. Analyses in field investigation reports (RPP-7884, RPP-10098, RPP-23752, RPP-35484, RPP-35485)[b] show less sensitivity to this issue than previously thought. Surface geophysical exploration is being applied to locate contamination and develop three-dimensional plume distributions and guide location of additional boreholes or direct pushes	Yes, supports both CMS and interim measures
Near-surface soil concentrations-inventories	Characterization efforts will be identified through RCRA Corrective Measures Study process. Hydraulic hammer direct-push technology makes characterization more efficient and cost effective. Impacts from direct exposure may need to be considered	Yes, supports both CMS and interim measures
Past leak volumes[a]	Work with Ecology to determine past leak volumes.	No, independent evaluation to support CMS
Recharge		
Recharge through gravel surfaces	Measure recharge under tank farm gravel surfaces (for example, ^{36}Cl and chloride data). Past assumptions have been based on a clean gravel surface; clean surfaces are a rarity. Analysis of the physical properties actual tank farm surfaces can be used to refine recharge estimates.	No, independent evaluation to support CMS
Timing of initial barrier placement	Timing of initial barrier placement is not defined. Path forward is to perform sensitivity studies on the impact of barrier placement timing.	No, independent evaluation to support CMS
Recharge effects from tank farm infrastructure (past events)	Impacts from past operations were evaluated. Corrective interim measures are deployed where appropriate. This need will be revisited as additional information becomes available.	No, independent evaluation to support CMS
Geohydrology		
Vapor flow under low recharge	Review past work at other sites (Beatty, Nevada; Ward Valley, California; Australia) as analogs to evaluate importance of potential vapor flow under low infiltration.	No, independent evaluation to support CMS
Hydraulic properties at low saturation	Review past Hanford work on soil hydraulic properties (e.g., ultracentrifuge measurements) and at other sites to extend existing database on relatively wet and intermediate water contents.	No, independent evaluation to support CMS
Geochemistry		
Waste chemistry effects on uranium(VI) mobility in the vadose zone	Continue leaching studies for sediments at BX-102, TX-104, and other tank farms (e.g., U) to determine the processes controlling uranium geochemistry at each location with the overall goal to determine a “unifying”	No, independent evaluation to support CMS

Table 4-3. Current Data Needs for Corrective Measures Study (2 sheets)

Data Need	Path Forward	Element of WMA C DQO
	conceptual model for uranium(VI). Tank residuals in C Farm are highly enriched in uranium and vadose zone impacts after leaching will need to be addressed.	
Modeling		
Contaminant contribution to vadose zone/ groundwater from nearby non-tank-farms sources	The two DOE Field Offices are having the Hanford Site contractors integrate efforts on source and groundwater contamination. Path forward is to include stable and radioactive isotope signatures.	No, independent evaluation to support CMS
Variation in groundwater contaminant concentrations	Measurements show vertical and short-term temporal changes. Current models do not account for these variations. Determine the importance of variations.	Yes, integration effort between vadose zone conceptual model refinement and groundwater models. Supports conceptual model refinement and CMS

[a] Data need retained from HNF-2603, *A Summary and Evaluation of Hanford Site Tank Farm Subsurface Contamination*, Rev. 0, Lockheed Martin Hanford Company Corporation, Richland, Washington.
[b] RPP-7884, *Field Investigation Report for Waste Management Area S-SX*.
RPP-10098, *Field Investigation Report for Waste Management Area B-BX-BY*.
RPP-23752, *Field Investigation Report for Waste Management Areas T and TX-XY*.
RPP-35484, *Field Investigation Report for Waste Management Areas C and A-AX*.
RPP-35485, *Field Investigation Report for Waste Management Area U*.

This information helped target specific data needs that must be addressed as part of the WMA-specific DQO process and subsequent WMA RFI/CMS work plans and RFI/CMS. WMA-specific data needs were also identified in the following:

- RPP-7884, *Field Investigation Report for Waste Management Area S-SX*.
- RPP-10098, *Field Investigation Report for Waste Management Area B-BX-BY*.
- RPP-23752, *Field Investigation Report for Waste Management Areas T and TX-XY*.
- RPP-35484, *Field Investigation Report for Waste Management Areas C and A-AX*.
- RPP-35485, *Field Investigation Report for Waste Management Area U*.

Specific data needs identified for WMA C include the following:

- Determine bottom of UPR-200E-82 technetium plume.
- Complete near-term Phase 2 characterization activities.
- Conduct SGE with deep electrodes.

4.3.2 Performance Assessment for WMA C

As defined by DOE M 435.1-1, a performance assessment is

> An analysis of a radioactive waste disposal facility conducted to demonstrate there is a reasonable expectation that performance objectives established for the

> long-term protection of the public and the environment will not be exceeded following closure of the facility.

The HFFACO, Appendix I, Section 2.5 (Ecology et al. 1989) states that

> Ecology, is the lead agency for SST System closure, EPA, and DOE have elected to develop and maintain as part of the SST system closure plan one performance assessment for the purposes of evaluating whether SST system closure conditions are protective of human health for all contaminants of concern, both radiological and nonradiological. DOE intends that this performance assessment (PA) will document by reference relevant performance requirements defined by RCRA, HWMA, *Clean Water Act*, *Safe Drinking Water Act*, and the *Atomic Energy Act of 1954* (AEA), and any other performance requirements that might be an applicable or relevant and appropriate requirement under CERCLA. The PA is of larger scope than a risk assessment required solely for nonradiological contaminants. The PA is expected to provide a single source of information that DOE can use to satisfy potentially duplicative functional and/or documentation requirements. A PA will be developed for each WMA and will incorporate the latest information available. These PAs will be approved by Ecology and DOE pursuant to their respective authorities. Ecology approval means incorporation by reference, into the Site-Wide Permit through closure plans.

The data gaps and priorities are described in Section 7.5 of DOE/ORP-2003-11, *Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington*. Data needs associated with WMA C vadose zone characterization include the following:

- **Improved Estimates of Past Release Inventories Lost to the Vadose Zone**

  Estimates of past release inventories that are consequential to the potential compliance status of a WMA will be improved. Large past releases are relatively well characterized; however, in some WMAs, estimates of future environmental impacts exceeded acceptable levels for relatively small release volumes (i.e., less than 6000 gal). These releases have not been investigated in the field under the RCRA corrective action process. Information from soil sampling in the leak area or additional data from geophysical techniques may refine the associated inventory of these leak volumes. Past releases into the vadose zone are clearly indicated as the controlling factor for the estimates of early (i.e., less than 400 years after closure) groundwater impacts. Selected past release estimates will be refined for use in future analyses.

- **Use of Site-Specific Data to Model Each Waste Management Area**

  Site-specific data will be used to evaluate the information used for the WMA C template.

4.3.3 Risk Assessment

Risk in the upper 15 ft of WMA C will be evaluated in the context of direct contact and ecological receptors.

4.3.3.1 Direct Contact Risk Assessment

A direct contact risk assessment will be part of the CMS for WMA C. Information gathered during the Phase 2 WMA C field investigations will support the corrective measures alternative development and analysis, including the no-action alternative.

The approach used to evaluate direct contact for human health protection will be unrestricted land use soil cleanup standards (WAC 173-340-740, "Model Toxics Control Act – Cleanup," "Unrestricted land use soil cleanup standards") based on the closure performance standards in accordance with WAC 173-303-610(2)(b)(i). The standard Method B (i.e., unrestricted land use) cleanup levels for soils shall be at least as stringent as to meet concentrations established under applicable federal and state laws.

For hazardous substances for which sufficiently protective, health-based criteria or standards have not been established under applicable state and federal laws: those concentrations that protect human health as determined by concentrations that due to direct contact with contaminated soil are estimated to result in no acute or chronic noncarcinogenic toxic effects on human health using a hazard quotient of 1 and concentrations for which the upper bound on the estimated excess cancer risk is less than or equal to 1×10^{-6} (WAC 173-340-740(3)(b)(iii)(B). For both noncarcinogens and carcinogens, the exposure pathway is through soil ingestion only. Ecology and DOE have agreed that the preliminary soil cleanup levels will be determined as part of the CMS report due to Ecology in December 2010 (HFFACO Milestone M-45-61) and will be reviewed at the time the CMS is prepared.

Direct contact risk assessment problem formulation entails comparing soil concentrations directly to concentrations protective of soil as established by federal and state laws for both radionuclides and nonradionuclides.

4.3.3.2 Ecological Risk Assessment

An ERA will be part of the Phase 2 RFI/CMS for WMA C. The ERA will integrate with Central Plateau ecological risk assessment (CPERA). Information gathered during the WMA C ERA will support the corrective measures alternative development and analysis, including the no-action alternative.

The approach used to conduct the ERA will be based on applicable portions of WAC 173-340-7490, "Terrestrial Ecological Evaluation Procedures." The WMA C ERA approach is guided by WAC 173-340-7490. Application of the ecological evaluation procedures published in WAC 173-340-7490 is an appropriate approach for evaluating potential threats of hazardous releases to the terrestrial environment and in supporting corrective measures selection for the SST farms.

<u>Summary of Ecological Risk Assessment</u>

The ERA approach to evaluate the SST farms is guided by WAC 173-340-7490. Specifically, WAC 173-340-7493 "Site-Specific Terrestrial Ecological Evaluation," procedure will be used.

- Problem Formulation

  Ecological risk assessment problem formulation entails identifying chemicals of ecological concern, identifying exposure pathways, identifying terrestrial receptors of concern, and performing a toxicological assessment in accordance with WAC 173-340-7493(2)(i) through (iv).

- 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.

  Chemicals of ecological concern for WMA C have been identified taking into account the primary and secondary constituents of tank waste identified in RPP-23403, *Single-Shell Tank Component Closure Data Quality Objectives*, and constituents listed in Table 749-3 (WAC 173-340-900). Analytical methods will be applied for determining the presence of tank waste that may have been released from the tank farm system. In addition to tank system releases, operation and maintenance activities could have potentially resulted in the release of potentially hazardous constituents on the surface, which may not be a component of tank waste. The tank farms are managed and maintained to prevent intrusion by deep-rooting vegetation and burrowing insects inside the tank farm boundary through the licensed application of herbicides and pesticides. By preventing vegetation growth, wildlife habitat is for all practical purposes eliminated thus discouraging use of tank farms by biota.

  Radionuclides, while not identified or regulated as constituents of ecological concern by WAC 173-340-7490, are also known to be present within the SST farms, based on process knowledge and available information. Because the WAC terrestrial ecological evaluation procedures have no mechanism for identifying or addressing radionuclides as contaminants of potential concern, secondary guidance published by the DOE will be consulted. DOE-STD-1153-2002, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*, provides a graded approach (including screening methods, calculation tools, and methods for additional detailed analyses) and related guidance that may be used to evaluate compliance with specified limits on radiation dose to populations of aquatic and terrestrial biota due to anthropogenic sources at DOE sites. Specifically, the technical standard provides dose evaluation methods that can be used to meet the requirements for protection of biota in DOE Order 5400.1, *General Environmental Protection Program*; 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 & Measurements, *Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards* (NCRP 1991), and International Atomic Energy Agency, *Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards* (IEAE 1992).

- Exposure Pathway Identification

  An exposure pathway is the path that a hazardous substance takes or could take from a source to an exposed organism. An exposure pathway describes the mechanism by which an individual or population is exposed or has the potential to be exposed to hazardous substances at or originating from a site. 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.

  Exposure pathways and mechanisms are important considerations in developing corrective measure alternatives. The ERA portion of the CMS report will document potential pathways from contaminant sources to terrestrial biota within the SST farms and adjacent areas where contaminants may have come to be located.

- Terrestrial Receptors of Concern

  Terrestrial receptors of concern to be evaluated in the ERA will be representative of the taxonomic groupings identified in WAC 173-340-9493(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 additional higher trophic predatory species, the badger and the red-tailed hawk, will also be considered.

- Toxicological Assessment

  The purpose of the toxicological assessment is to identify significant adverse effects in the receptors of concern that may result from exposure to the chemicals of concern [WAC 173-340-7493(2)(iv)]. The toxicological assessment will consist of an ecological effects evaluation using nonradionuclide soil indicator concentrations for the protection of plants, soil biota, and wildlife. The ecological effects evaluation for radionuclides in soil will be performed using biota concentration guide (BCG) values for the protection of plants and wildlife in DOE-STD-1153-2002.

4.3.4 Additional Data Needs

Additional data are needed to resolve several questions concerning the volume and nature and extent of contamination in WMA C and to relate this information to closing WMA C. These questions include the following:

- WMA C tanks listed in HNF-EP-0182 as leakers (or suspected leakers) are noted in RPP-23405 as small leakers (~1,000 gal or less). Is the soil contamination surrounding these tanks supportive of the projected tank release quantities cited in one document or the other?
- For WMA C releases previously characterized, what is the extent and how does this relate to SGE results?
- What is nature of ^{60}Co in the region of continuing migration in the vadose zone observed in a few dry wells?

- Are there activities that would aid deep vadose zone sediment characterization of WMA C?
- What are the nature, extent, and concentrations of shallow (less than 15 ft) contamination in WMA C?

DOE/ORP-2005-01, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site*, shows that past unplanned releases from the tank system have the largest estimated impact on groundwater resources relative to waste residuals (assumed to be about 1% by volume in the analysis) that will be left in the tanks and ancillary equipment post-retrieval. The first key question in the characterization of such past releases is to determine which components of the tank system have released waste to the subsurface. Some WMA C tanks (C-101, C-110, C-111, C-201, C-202, C-203, and C-204) are listed as leakers or suspected leakers.

Data are needed on the concentrations of key tank waste constituents (e.g., nitrates, ^{99}Tc, ^{137}Cs) and on vadose zone characteristics showing the effects of tank waste releases (e.g., pH, Na/Ca:Mg exchange). Expected sediment background levels would be similar to those found in samples from borehole 200-E27-22 as reported in PNNL-15617, *Characterization of Vadose Zone Sediments Below the C Tank Farm: Borehole C4297 and RCRA Borehole 299-E27-22*. The concentration of mobile contaminants and the key waste stream indicators (pH, Na/Ca-Mg exchange) in sediment samples obtained in this WMA C campaign would be compared to the uncontaminated background levels to assess whether significant fluid leaks were evident at the sampled locations. Vadose zone sediment samples should be obtained at locations suspected of being near release points or where leak fluids may have cumulated as shown by moisture logs.

4.4 INTEGRATION WITH CENTRAL PLATEAU OPERABLE UNITS

In addition to meeting the data needs of the RCRA corrective action/closure process within WMA C, it is important to understand the combined data needs of WMA C closure with the closure of the Central Plateau. The interfaces between the Central Plateau and WMA C must be clearly accounted for in closure planning. The interactions and interfaces between WMA C closure and other Central Plateau remediation and closure actions include waste sites, infrastructure, and groundwater. Proposed integration strategies for waste site remediation, infrastructure interface definition and remediation, and groundwater decision-making and remediation are presented in the Sections 4.4.1 and 4.4.2. The intent of these strategies is to ensure that the WMA C closure is consistent with the actions taken on the Central Plateau, there is clarity in the responsibilities for these actions, and completeness in the coverage of all actions that must be taken. Fundamental to the integration between WMA C and the Central Plateau is a strategy that allows ORP and RL to understand their respective processes to ensure that decisions and strategies will accommodate structures and facilities at the interface areas and be complementary.

The boundaries for WMAs were defined for purposes of groundwater monitoring. Because there are waste sites and other tank farm system components that exist in both WMA C and the Central Plateau, there is a need to clarify the boundaries in the context of WMA/Central Plateau closure that go beyond the requirements for groundwater monitoring. The interface between

WMA C and the C Farm closure zone of the Central Plateau includes waste sites that require determining which program oversees their closure.

4.4.1 200-BP-5 DQO

Groundwater contamination in the 200-BP-5 OU is primarily related to waste disposal associated with B Plant past operations. A portion of this groundwater OU extends under WMA C. The OU 200-BP-5 DQO summary report identifies and evaluates existing data to better understand data gaps and uncertainties and to define additional data requirements to support the RI/FS process for the 200-BP-5 OU. The OU 200-BP-5 DQO summary report assembles and evaluates existing data to identify COPC and COC, defines the preliminary CSM for both waste site sources and groundwater impact, and identifies data gaps and potentially applicable remedial technologies.

The OU 200-BP-5 DQO summary report identifies the population of interest, the spatial and temporal boundaries, defines the scale of decision-making, and identifies any practical constraints (i.e., hindrances or obstacles) that must be taken into consideration. The OU 200-BP-5 DQO also defines the attributes that define the population of interest which then is used to establish spatial and temporal boundaries of the site under investigation. The vadose zone is considered a population of interest in the OU 200-BP-5 DQO. Vadose zone data are needed to identify COPC and to predict impacts of COPC on groundwater.

WMA C and the Hot Semi Works make up one of nine subgeographic study area boundaries that comprise the 200-BP-5 OU. The area borders the 200-PO-1 groundwater OU to the south and extends to the east 200-BP-5 OU boundary. Iodine-129, ^{99}Tc, and nitrate plumes are known to exist in the groundwater below WMA C. Groundwater monitoring has not identified any contamination that is directly attributable to UPRs or other releases in WMA C. However, groundwater in the vicinity of WMA C has show some contamination which could have originated from one or more releases at WMA C. The presence of contaminants in the vadose zone and groundwater contamination in the vicinity requires characterization and a determination of the potential for resultant environmental impacts, which may provide a basis for remediation or closure.

<u>Comparision of OU 200-BP-5 and WMA C Characterization Schedules</u>

The OU 200-BP-5 DQO summary report defines the major strata that will be the primary focus of the RI efforts. For the 200-BP-5 OU, the major strata are defined based on individual hydrogeologic units overlying and within the OU. These individual strata (vadose zone, unconfined aquifer, basalt aquitard, and confined aquifer units) are used in developing a CSM. For the CSM purposes, these designated strata are useful for evaluating contaminant plumes. For purposes of integration with the WMA C vadose zone characterization efforts, the principal strata of interest is the vadose zone that the OU 200-BP-5 DQO summary report defines as the Hanford formation and overlying eolian deposits.

The OU 200-BP-5 DQO summary report identifies the temporal boundaries that may apply to each of its decision statements. The temporal boundary refers to the time frame over which the data collected will apply to the decision statements and when the optimum time is to collect the

samples. The 200-BP-5 groundwater OU is reviewing new characterization and monitoring data to determine if further characterization is required to complete the baseline risk assessment and determine the appropriate remedial alternatives for groundwater beneath and down gradient of WMA C.

The scale of decision-making is defined by joining the population of interest and the geographic and temporal boundaries of the area under investigation. For the OU 200-BP-5 DQO summary report, the scale of decision-making has been maintained in fairly global terms. The scale of decision-making is a principal integration point between the WMA C vadose zone characterization and the OU 200-BP-5 vadose zone characterization. This integration begins with data collection and characterization phases of the CERCLA remedial RI and RCRA facility investigation process. Table 4-4 presents the basis for establishing the scale of decision-making between the two characterization efforts. Table 4-4 focuses on the RI process of CERCLA because the vadose zone characterization efforts serve as supplemental input to that effort.

Table 4-4. Scale of Decision-making between RCRA Facility Investigation and CERCLA Remedial Investigation

Population of Interest	Geographic Boundaries	Temporal Boundary		Scale of Decision
		Time frame (years)	When to Collect Data	
Vadose zone data needed to identify COPC.	Vadose zone within the 200-BP-5 OU boundary	Oct 2005 to Oct 2006	During DQO process	Within the 200-BP-5 OU vadose zone geographic boundaries from October 2005 to October 2006 (completed)
Vadose zone data needed to predict impact of COPC on groundwater.	Vadose zone within the 200-BP-5 OU boundary	Oct 2005 through Oct 2009	During DQO process and RI	Within the 200-BP-5 OU vadose zone geographic boundaries from October 2005 to October 2009
Concentration of COC in unconfined aquifer or expected to reach the groundwater over the next 1000 years. This data will be used in models to develop risk estimates.	Vadose zone and groundwater within the 200-BP-5 OU boundary	Oct 2005 through Oct 2009	During DQO process and RI	Within the 200-BP-5 OU vadose zone and groundwater geographic boundaries from October 2005 to October 2009
Data required to develop and support a conceptual model for migration of uranium and technetium to groundwater.	Vadose zone within the 200-BP-5 OU boundary	Oct 2005 through Oct 2009	During DQO process and RI	Within the 200-BP-5 OU vadose zone and groundwater geographic boundaries from October 2005 to October 2009

4.4.2 200-IS-1 DQO

D&D-30262, *Data Quality Objectives Summary Report for the 200-IS-1 Operable Unit Pipelines and Appurtenances*, supports site characterization decisions for RI of the 200-IS-1 tanks/lines/pits/waste group OU process waste pipelines. The 200-IS-1 OU consists of RCRA

past-practice waste sites and TSD units that exist outside of the WMAs and includes an extensive network of pipelines, diversion boxes, catch tanks, valve pits, related infrastructure, and associated unplanned releases. The process waste pipeline systems were used to transport process waste from the separations facilities to the SST and double-shell tanks and to control or divert flow to disposal waste sites that received liquid waste streams. The process-waste pipeline systems primarily are located within the industrial 200 Areas of the Central Plateau.

The primary objectives of the DQO process for the process-waste pipeline systems include the following.

- Determine the environmental measurements necessary to support the RI/FS process and remedial decision-making.
- Identify data needed for development of the RI/FS work plan and SAP.
- Identify evaluation strategies that are inclusive of both RCRA and CERCLA requirements for the 200-IS-1 OU pipelines.
- Develop preliminary conceptual contaminant distribution model(s) that reflect the physical characteristics of the process-waste pipeline systems and surrounding soil and the anticipated distribution of contaminants. Data collection will support refinement of the model(s).

Data collected during the RI will be used to determine if the process-waste pipeline systems are contaminated above levels that will require remedial action, to support evaluation of remedial alternatives and/or closure strategies, and to verify or refine the preliminary conceptual contaminant distribution models.

During the DQO process, a binning strategy was developed that groups process-waste pipelines with similar process histories and contaminants for field investigations and sampling during RI activities. A two-phase sampling approach, with different data collection objectives and requirements for each phase, was identified for the process waste pipeline systems. Phase 1 will consist of acquisition of a data set that is smaller than that required for Phase 2. The purpose of the Phase 1 investigation will be to gather limited data in support of existing information that indicates the presence of contaminant concentrations above preliminary cleanup levels. The data collected will be used to determine whether contaminant levels are consistently above action levels and to support remedial decision-making (other than the no-action alternative).

IS-1 Phase 2 sampling will be used for evaluation of those pipelines and associated structures where there is considerable uncertainty concerning whether contamination exceeding action levels is present. Proceeding directly to Phase 2 sampling would be appropriate for those pipelines where existing information indicates that contamination will not be present and/or where considerable variability is expected in potential results. Phase 2 sampling will be required if all remedial alternatives need to be assessed, including the no-action alternative. Phase 2 sampling requires a larger data set for decision-making.

The interiors of pipelines, associated appurtenances, and surrounding soils were identified as requiring data collection for remedial decision-making. Measured concentrations will be

compared with the preliminary cleanup levels. The nature (e.g., contaminant type and concentration) and extent of the contamination are the major RI data needs.

Targeted characterization sites include low points in the system, bends in the pipelines, and known or suspected release sites. The tank farm pipeline characterization locations will be associated with transfer lines that conveyed waste into WMA C. Three candidate sampling locations have been identified on the cross-site transfer pipeline going into WMA C and two candidate sites are on the transfer pipelines between WMA C and WMA A-AX. One candidate site is at the location of UPR-E-86, which is located outside of the WMA C fenceline. This UPR is also associated with WMA C and the vadose zone at this site will be characterized as part of this DQO effort. Pipeline characterization will be accomplished as part of the 200-IS-1 efforts.

4.5 ANALYTICAL PARAMETERS

This DQO uses the same approach as and includes at least all of the contaminants in RPP-23403, *Single-Shell Tank Component Closure Data Quality Objectives*, 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 Single-Shell Tank System (CH2M HILL 2003) (Part A), underlying hazardous constituents, Title 10, *Code of Federal Regulations*, 61.55, "Licensing Requirements for Land Disposal of Radioactive Waste," "Waste Classification," (10 CFR 61.55), 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 has been adopted in D&D-30262 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 this DQO.

Chemicals of ecological concern for WMA C have been identified taking into account the primary and secondary constituents of tank waste identified in RPP-23403 and constituents listed in Table 749-3 (WAC 173-340-900).

Extensive lists of sample analysis methods and analytes (chemicals and radionuclides) have been identified for this DQO. However, not all methods will be performed on every sample. Analysis methods that will be performed or analytes that will be available on specific samples are identified in Chapter 8.

Note that in this report, the specified EPA SW-846, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, are shown without suffixes indicating method revisions. For these methods, the most recent revisions are preferred. Some substitutions, deviations, or modifications to SW-846 methods may be necessary to address radiological concerns and some matrix conditions found in soils contaminated with tank waste.

Analytical parameters for major constituent categories (inorganic chemicals, organic chemicals, and radionuclides) are discussed in Sections 4.6 through 4.8.

4.6 INORGANIC CHEMICALS

Inorganic chemicals will be analyzed using the following methods: inductively coupled plasma/atomic emissions spectroscopy (ICP/AES) for cations, ion chromatography (IC) for anions and ammonia, cold vapor atomic absorption (CVAA) for mercury, spectrophotometric analysis for cyanide, ion selective electrode for sulfide, and pH. The ICP/AES and IC methods are capable of analyzing multiple constituents. Primary and secondary constituents for these methods, as identified in RPP-23403, are shown in Tables 4-5 and 4-6.

Note that chromium and cyanide data will be used as conservative estimates of hexavalent chromium and ferrocyanide, respectively. If the estimates are overly conservative and calculations using the estimates result in unacceptably high risk, analysis for hexavalent chromium and ferrocyanide may be performed.

4.7 ORGANIC CHEMICALS

Organic chemicals will be analyzed by the following methods: gas chromatography/mass spectrometry (GC/MS) 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 polychlorinated biphenyls (PCB). In addition, a number of samples will be analyzed by high resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS) for PCB congeners. Samples to be analyzed for organics are identified in Section 8.

For VOCs and SVOCs, primary and secondary constituents as identified by RPP-24303 are shown in Tables 4-7, 4-8, and 4-9. The lists of primary constituents include a number of chemicals identified in WMP-28945 or D&D-30262. Analytical strategy for VOCs and SVOCs was developed in RPP-24303 and is summarized in the following.

Table 4-10 presents the pesticide and petroleum hydrocarbon constituents that will be evaluated relative to ecological risk but will not be evaluated in the human health assessment. Ecological risk assessment for petroleum hydrocarbons will include gasoline- and diesel-range organics. Table 4-10 identifies the pesticides and lists the relevant ecological soil indicator concentrations for representative terrestrial biota receptor groups. Table 4-10 presents the ecological soil indicator concentration for the pesticides and the gasoline and diesel range organics and lists the relevant ecological soil indicator concentrations for representative terrestrial biota receptor groups.

Table 4-5. Primary Inorganic Constituents and Analytical Methods.

Constituent	Reason for Inclusion	Analytical Method	Alternate Method
Aluminum – Al	E, R, W	6010C (ICP/AES)	6020A (ICP/MS)
Antimony – Sb	E, R, W	6010C (ICP/AES)	6020A (ICP/MS)
Arsenic – As	A, E, U, W	6010C (ICP/AES)	6020A (ICP/MS)
Barium – Ba	A, E, U, W	6010C (ICP/AES)	6020A (ICP/MS)
Beryllium – Be	E, U, W	6010C (ICP/AES)	6020A (ICP/MS)
Cadmium – Cd	A, E, U, W	6010C (ICP/AES)	6020A (ICP/MS)
Chromium – Cr	A, E, U, W	6010C (ICP/AES)	6020A (ICP/MS)
Cobalt – Co	E, R, W	6010C (ICP/AES)	6020A (ICP/MS)
Copper – Cu	E, R, W	6010C (ICP/AES)	6020A (ICP/MS)
Iron – Fe	R, W	6010C (ICP/AES)	6020A (ICP/MS)
Lead – Pb	A, E, U, W	6010C (ICP/AES)	6020A (ICP/MS)
Manganese – Mn	E, R, W	6010C (ICP/AES)	6020A (ICP/MS)
Nickel – Ni	E, U, W	6010C (ICP/AES)	6020A (ICP/MS)
Selenium – Se	A, E, U, W	6010C (ICP/AES)	6020A (ICP/MS)
Silver – Ag	A, E, U, W	6010C (ICP/AES)	6020A (ICP/MS)
Strontium – Sr	R	6010C (ICP/AES)	6020A (ICP/MS)
Thallium – Tl	E, U, W	6010C (ICP/AES)	6020A (ICP/MS)
Uranium – U	E, R, W	6010C (ICP/AES)	6020A (ICP/MS)
Vanadium – V	E, U, W	6010C (ICP/AES)	
Zinc – Zn	E, U, W	6010C (ICP/AES)	6020A (ICP/MS)
Mercury – Hg	A, E, U, W	7470A, 7471B (CVAA)	
Fluoride – F^-	U, W	9056A (IC)	
Nitrite – NO_2^-	R, W	9056A (IC)	
Nitrate – NO_3^-	R, W	9056A (IC)	
Acetate – $C_2H_3O_2^-$	R	9056A (IC)	
Formate – CHO_2^-	R	9056A (IC)	
Glycolate – $C_2H_3O_3^-$	R	9056A (IC)	
Oxalate – $C_2O_4^{2-}$	R	9056A (IC)	
Cyanide – CN^-	A, U, W	9014 (spectrophotometric)	
Ferrocyanide – $Fe(CN)_6^{4-}$	A, U, W	Estimated from total cyanide.	
Sulfide – S^{2-}	U, W	9215 (ion selective electrode)	9034 (titration)
Ammonium – NH_4^+ *	W	EPA 300.7 (IC)	
pH [(a)]	W	9045D	
Chloride – Cl^-		9056A (IC)	
Sulfate – SO_4^{2-}		9056A (IC)	

* Constituents added during DQO process meetings.

A = Part A constituent.
E = ecological risk assessment
R = risk assessment constituent.
U = UHC constituent.
W = constituent in PNNL-12040.
CVAA = cold vapor atomic absorption
IC = ion chromatography.
ICP/AES = inductively coupled plasma/atomic emissions spectroscopy.
ICP/MS = inductively coupled plasma/mass spectrometry

Table 4-6. Secondary Inorganic Constituents.

Constituent	Constituent
Method 6010C (ICP/AES)	**Method 9056A (IC)**
Boron – B	Bromide – Br^-
Bismuth – Bi	Phosphate – PO_4^{3-}
Calcium – Ca	
Lithium – Li	
Molybdenum – Mo	
Magnesium – Mg	
Sodium – Na	
Phosphorus – P	
Potassium – K	
Rhodium – Rh	
Sulfur – S	
Silicon – Si	
Tin – Sn	
Tantalum – Ta	
Tungsten – W	
Yttrium – Y	
Zirconium – Zr	
Cerium – Ce	
Europium – Eu	
Lanthanum – La	
Niobium – Nb	
Neodymium – Nd	
Palladium – Pd	
Praseodymium – Pr	
Rubidium – Rb	
Ruthenium – Ru	
Samarium – Sm	
Tellurium – Te	
Thorium – Th	
Titanium – Ti	

IC = ion chromatography
ICP/AES = inductively coupled plasma/atomic emission spectroscopy

Table 4-7. Primary Volatile Organic Compound Parameters

Constituent	CAS	Reason for Inclusion	Comments
1,1,1-Trichloroethane	71-55-6	A, U, W	
1,1,2,2-Tetrachloroethene	127-18-4	A, W	
1,1,2,2-Tetrachloroethane	79-34-5	A, U, W	
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	A, W	
1,1,2-Trichloroethane	79-00-5	A, W	
1,1,2-Trichloroethylene	79-01-6	A, U, W	
1,1-Dichloroethene	75-35-4	A, U, W	
1,2-Dichloroethane	107-06-2	A, W	
Chloroethene (vinyl chloride)	75-01-4	A, W	
2-Butanone (MEK)	78-93-3	A, U, W	
2-Nitropropane	79-46-9	A	
2-Propanone (Acetone)	67-64-1	A, U, W	
4-Methyl-2-pentanone (MIBK)	108-10-1	A, U, W	
Benzene	71-43-2	U, W	
Carbon disulfide	75-15-0	A, W	
Carbon tetrachloride	56-23-5	A, U, W	
Chlorobenzene	108-90-7	A, U, W	
Chloroform	67-66-3	A, W	
Dichloromethane (methylene chloride)	75-09-2	A, U W	
Ethyl Acetate	141-78-6	A, W	
Ethylbenzene	100-41-4	A, W	
Diethyl ether	60-29-7	A	
Isobutanol*	78-83-1	A	
Methanol	67-56-1	A, W	
n-Butyl alcohol (1-butanol)*	71-36-3	A, U, W	
Toluene	108-88-3	A, E, U, W	
trans-1,3-dichloropropene	10061-02-6	U, W	
Trichlorofluoromethane	75-69-4	A, W	
Xylenes	1330-20-7	A, W	
o-Xylene	95-47-6	A, W	
m-Xylene	108-38-3	A, W	May be analyzed as m- and p-xylene
p-Xylene	106-42-3	A, W	May be analyzed as m- and p-xylene
Cis-1,2-dichlorobenzene	156-59-2	In WMP-28945	
Trans-1,2-dichlorobenzene	159-60-5	In WMP-28945	

* Constituent may be analyzed by the VOC (8260B) method or the SVOC (8270D) method.

A = Part A constituent.
CAS = Chemical Abstracts Service
E = ecological risk assessment
U = UHC constituent.
W = constituent in PNNL-12040.

Table 4-8. Primary Semivolatile Organic Parameters (2 sheets)

Constituent	CAS	Reason for Inclusion	Comments
1,2,4-Trichlorobenzene*	120-82-1	E, U, W	
2,4-Dinitrotoluene	121-14-2	A	
2,4,5-Trichlorophenol	95-95-4	A, E, U	
2,4,6-Trichlorophenol	88-06-2	E, U	
2,6-Bis (tert-butyl)-4-methylphenol	128-37-0	A, W	
2-Chlorophenol	95-57-8	U	
2-Ethoxyethanol	110-80-5	A	
2-Methylphenol (o-cresol)	95-48-7	A	
4-Methylphenol (p-cresol)	106-44-5	A	
Acenaphthene	83-32-9	E, U	
Butylbenzylphthalate	85-68-7	U	
Cresylic acid (cresol, mixed isomers)	1319-77-3	A	
Cyclohexanone	108-94-1	A, W	
Di-n-butylphthalate	84-74-2	E, U	
Di-n-octylphthalate	117-84-0	U	
N-nitroso-di-n-propylamine	621-64-7	U	
Ethylene glycol	107-21-1	In WMP-28945	Analyzed separately by GC/FID
Fluoranthene	206-44-0	U	
Hexachlorobutadiene*	87-68-3	A, W	
Hexachloroethane*	67-72-1	A	
m-Cresol (3-Methylphenol)	108-39-4	A	
Naphthalene	91-20-3	U	
Nitrobenzene*	98-95-3	A, E, W	
n-Nitrosomorpholine	59-89-2	U	
o-Dichlorobenzene*	95-50-1	A, W	
o-Nitrophenol	88-75-5	U	
p-Chloro-m-cresol (4-Chloro-3-methylphenol)	59-50-7	U	
Pyrene	129-00-0	U	
Pyridine*	110-86-1	A, W	
Tributyl phosphate	126-73-8	R, W	
Benzo(a) anthracene	56-55-3	In D&D-30262	
Benzo(b)fluoranthene	205-99-2	In D&D-30262	
Benzo(k)fluoranthene	207-08-9	In D&D-30262	
Benzo(a)pyrene	50-32-8	E, In D&D-30262	
Chrysene	218-01-9	In D&D-30262	
Indeno (1,2,3-cd) pyrene	193-39-5	In D&D-30262	

Table 4-8. Primary Semivolatile Organic Parameters (2 sheets)

Constituent	CAS	Reason for Inclusion	Comments
Dibenz(a,h)anthracene	53-70-3	In D&D-30262	
Dibutyl phosphate	107-66-4	In D&D-30262	May be analyzed by high-performance liquid chromatography
Monobutyl phosphate	NA	In D&D-30262	May be analyzed by high-performance liquid chromatography
Bis(2-ethylhexyl)phthalate	117-81-7	In WMP-28945	

A = Part A constituent.
CAS = Chemical Abstracts Service. Constituent may be analyzed by the SVOC (8270D) method or the VOC (8260B) method.
E = ecological risk assessment
GC/FID = gas chromatography/flame ionization detection
R = risk assessment constituent.
U = UHC constituent.
W = constituent in PNNL-12040.

Table 4-9. Secondary Organic Constituents - "Hanford Library" (2 sheets)

Method 8260B VOC	CAS	Method 8270D SVOC	CAS
cis-1,3-Dichloropropene	10061-01-5	p-Nitrochlorobenzene	100-00-5
Ethylene dibromide (1,2, Dibromoethane)	106-93-4	1,4-Dinitrobenzene	100-25-4
Butane	106-97-8	1,4-Dichlorobenzene	106-46-7
1,3-Butadiene	106-99-0	Phenol	108-95-2
Acrolein (propenal)	107-02-8	Hexachlorobenzene	118-74-1
3-Chloropropene (Allyl chloride)	107-05-1	N,N-Diphenylamine	122-39-4
Propionitrile (Ethyl cyanide)	107-12-0	Pentachloronaphthalene	1321-64-8
Acrylonitrile	107-13-1	Hexachloronaphtahlene*	1335-87-1
2-Pentanone	107-87-9	Tetrachloronaphthalene	1335-88-2
Methylcyclohexane	108-87-2	Octachloronaphthalene	2234-13-1
n-Pentane	109-66-0	Isodrin*	465-73-6
5-Methyl-2-hexanone	110-12-3	Benzo[a]pyrene*	50-32-8
2-Heptanone	110-43-0	Dibenz[a,h]anthracene*	53-70-3
n-Hexane	110-54-3	1,3-Dichlorobenzene	541-73-1
Cyclohexane	110-82-7	3-Methyl-2-butanone	563-80-4
n-Octane	111-65-9	N-Nitroso-N,N-dimethylamine	62-75-9
4-Heptanone	123-19-3	Hexafluoroacetone	684-16-2
Acetic acid, n-butylester	123-86-4	Pentachloronitrobenzene (PCNB)	82-68-8
1,4-Dioxane	123-91-1	Pentachlorophenol	87-86-5
n-Heptane	142-82-5	2-sec-Butyl-4,6-dinitrophenol (Dinoseb)	88-85-7

Table 4-9. Secondary Organic Constituents - "Hanford Library" (2 sheets)

Method 8260B VOC	CAS	Method 8270D SVOC	CAS
Cyclopentane	287-92-3	1,1'-Biphenyl	92-52-4
Ethyl alcohol	64-17-5	Acetophenone	98-86-2
2-Propyl alcohol	67-63-0	Toxaphene*	8001-35-2
n-propyl alcohol (1-propanol)	71-23-8	Nitric acid, propyl ester	627-13-4
Bromomethane	74-83-9	Aldrin*	309-00-2
Chloroethane	75-00-3	alpha-BHC*	319-84-6
Acetonitrile	75-05-8	beta-BHC*	319-85-7
1,1 Dichloroethane	75-34-3	gamma-BHC (Lindane)*	58-89-9
Dichlorofluromethane	75-43-4	Dieldrin*	60-57-1
Chlorodifluoromethane	75-45-6	Endrin*	72-20-8
3-Methy-2-butanone*	563-80-4	1,1-Dimethylhydrazine	57-14-7
Hexafluoroacetone*	684-16-2	Methylhydrazine	60-34-4
2-Butenaldehyde (2-Butenal)	4170-30-3	n-Nitrosomethylethylamine	10595-95-6
Methyl isocyanate	624-83-9	n-Nitrosodi-n-butylamine	924-16-3
n-Propionaldehyde	123-38-6		
3-Heptanone	106-35-4		
Chloromethane	74-87-3		
n-Nonane	111-84-2		
Styrene	100-42-5		
Tetrahydrofuran	109-99-9		
Cyclohexene	110-83-8		
2-Methyl-2-propenenitrile	126-98-7		
2-Hexanone	591-78-6		
Triethylamine	121-44-8		
Oxirane	75-21-8		
2-Methyl-2-propanol	75-65-0		
Dichlorodifluoromethane	75-71-8		
1,2-Dichloro-1,1,2,2-tetrafluoroethane	76-14-2		
Heptachlor	76-44-8		
1,2-Dichloropropane	78-87-5		
1-Methylpropyl alcohol	78-92-2		
3-Pentanone	96-22-0		

* Constituent may be analyzed by an alternate method.
CAS = Chemical Abstracts Service

Table 4-10. Ecological Indicator Soil Concentrations (mg/kg) for Protection of Terrestrial Biota (Adapted from WAC 173-340-900 Table 749-3)

	Plants	Soil Biota	Wildlife
Pesticides			
Aldrin			0.1
Benzene hexachloride (including lindane)			6
Chlordane		1	2.7
DDT/DDD/DDE (total)			0.75
Dieldrin			0.07
Endrin			0.2
Hexachlorobenzene			17
Heptachlor/heptachlor epoxide (total)			0.4
Pentachlorophenol	3	6	4.5
Petroleum			
Gasoline		100	5000 except that the concentration shall not exceed residual saturation at the soil surface
Diesel		200	5000 except that the concentration shall not exceed residual saturation at the soil surface

The primary constituents would be analyzed with the specified level of quality control (QC). This means they would be included in the calibration of the gas chromatographs and method detection limits (MDL) would be determined for each constituent.

Detected organic constituents that are not part of the calibration mix (primary constituents) are tentatively identified compounds (TIC). If a TIC is determined to be real (i.e., not an artifact of analytical methods), it will be evaluated against a gas chromatographic library containing the secondary compounds of interest. This library of compounds (called the "Hanford library") is composed of constituents that have been identified as possibly being present in Hanford Site waste in the Regulatory DQO (PNNL-12040, *Regulatory Data Quality Objectives Supporting Tank Waste Remediation System Privatization Project*) but not identified as primary constituents.

The "Hanford library" was developed by running single standards of the constituents on the laboratory's GC/MS systems. The results of these analyses provide accurate retention time information and mass response factors for these compounds and permit a better evaluation of the TIC. If a TIC is identified in the "Hanford library" of compounds, a semiquantitative estimate (estimated off of an archived one-point calibration) of its concentration is made.

If the TIC is not found in the "Hanford library" of compounds, then the TIC will be evaluated against the standard National Institute of Standards and Technology (NIST) library of compounds. This library has over 100,000 compounds. However, because they are collected on different instruments from those used for the actual analysis, the retention times and response factors will be different. Before the analyst can name or identify the TIC, the analyst must be confident that the chromatogram and mass spectra match well enough to name the compound. If the analyst cannot confidently name the compound, it is identified as an unknown and no further action is required. When a TIC is identified in the NIST library, then the TIC will be evaluated in a similar manner as a "Hanford library" TIC.

The TICs are identified using the reconstructed ion chromatogram. The reconstructed ion chromatogram is evaluated for TICs by identifying peaks that have not already been identified as target compounds according to the criteria discussed in the following, which are from Volume 4 of DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Documents* (HASQARD).

The library match for a TIC should be higher than 75% before this detailed evaluation is initiated. The method-specified tune criteria should be met. Special attention to the tune at low masses should be taken when evaluating volatile compounds. The concentration of a TIC should be greater than 10% of the nearest internal standard or estimated 5 ng on column injection, whichever is smaller. Early (injection peak) and late eluting peaks (column bleed and coeluting compounds) should have adequate background subtraction to permit use of these TIC criteria. If isotopic patterns are present, the mass ratios should agree with the reference spectrum within 10%. The base mass peak for the sample should be the same as the reference spectrum. If a molecular ion is present in the reference spectrum, the sample should also have a molecular ion mass. Reference spectrum ions greater than 20% should be in the sample spectrum. Sample ions greater than 20% that are not in the reference spectrum need to be evaluated. Major sample ions (greater than 20%) should match relative intensities to the base peak to those same ratios for the reference spectrum within 10-30%.

The TIC evaluation is limited to the 30 largest TICs for the volatile organic analysis (VOA) and the 30 largest for the semivolatile analysis meeting the criteria discussed here.

A TIC compound may be upgraded to a positively identified compound. This is achieved by obtaining the compound, analyzing it under the same conditions as the initial identification, and matching retention time and mass spectrum. This may be done at the customer's request if they deem it necessary for the program.

Polychlorinated biphenyls will be analyzed by GC/ECD and HRGC/HRMS. In addition, percent water is required for solids so the PCB concentration can be reported on a dry weight basis.

Polychlorinated biphenyls Aroclors will be measured by GC/ECD. If necessary, total PCB concentrations would be calculated by summing the concentrations of seven Aroclors (1016, 1221, 1232, 1242, 1248, 1254, and 1260) found in a sample. The total PCBs in a sample are calculated by summing only detected Aroclors. If no Aroclors are detected, the total PCB concentration is considered the detection limit for the single most common Aroclor expected in the sample. Tank results indicate Aroclor 1254 is by far the most common Aroclor in Hanford Site tank waste. The policy of determining total PCB concentrations is the policy of the EPA Manchester Laboratory for determining total PCB concentrations in a sample. In addition, this method was specified by agreement in a meeting with representatives from EPA Region 10, EPA Manchester Laboratory, Ecology, DOE, Pacific Northwest National Laboratory, and CH2M HILL Hanford Group, Inc. In addition, PCB congeners will be analyzed by HRGC/HRMS. The HRGC/RHMS results will be used to evaluate congener estimates based on GC/ECD analyses.

Kerosene and diesel are included as COPCs in WMP-28945. Many of the organics in these mixtures can be analyzed by GC/MS. Therefore, separate analyses for kerosene and diesel will not be required.

Monobutyl phosphate and dibutyl phosphate degrade when injected into a GC. Special preparations will be required to allow these chemicals to be analyzed by GC/MS. Alternatively, these chemicals may be analyzed by high-performance liquid chromatography.

4.8 RADIOLOGICAL PARAMETERS

Radionuclides will be analyzed by the following methods: gamma energy analysis (GEA) for gamma emitters, ICP/MS for uranium and neptunium isotopes, separation and ICP/MS for ^{99}Tc, alpha energy analysis for plutonium, americium, and curium isotopes, liquid scintillation for ^{14}C, tritium, and ^{79}Se, separation and GEA for ^{129}I, and beta counting for ^{90}Sr. Primary constituents for these methods, as identified in RPP-23403, are shown in Table 4-11. Thorium-234 is identified as a COPC in WMP-28945 and is included in Table 4-11 as a primary constituent.

Radionuclides analyzed and evaluated for the ERA are limited to those identified during the CMS DQO process (Table 4-12).

The only truly multiple constituent analytical method for radiochemistry is GEA. Therefore, the secondary constituents are those found in the GEA library. If a constituent in the GEA library is detected, the concentration will be reported.

Thorium-230 and ^{232}Th can be determined by alpha analysis but are normally measured by ICP/MS because of their long half-life. Thorium 228 concentration is generally determined by alpha counting or by calculation based on ^{232}Th and ^{232}U concentrations.

4.9 QUALITY CONTROL FOR FIELD SAMPLING

Field QC samples shall be collected to evaluate the potential for cross-contamination and laboratory performance. Soil sampling will require the collection of field duplicates, equipment rinsate blank, and trip blank samples, where appropriate. Field QC sample types and frequency for collection are described in the Sections 4.9.1 through 4.9.4.

4.9.1 Field Duplicates

Field duplicates are not appropriate when using small diameter sampling equipment. The soil sample contains three 6-in. stainless-steel liners with a diameter of ~1.0-in. The 1-in. soil liner may not contain sufficient soil mass to perform duplicate samples since soil sampling intervals are biased toward soils with higher moisture content. Soil zones with higher moisture content are typically thinned beds of fine-grained soils. The field personnel will selected the interval for collecting the duplicate sample by visually inspecting the soils at the end of the soil liner. Then the soil liner is extruded in the field and split into two samples in containers where the soil moisture will equilibrate with the volume of air in the sample container instead of being

Table 4-11. Primary Radiological Parameters

Constituent	Reason for Inclusion	Analytical Method	Alternate Method
^{137}Cs	10 CFR 61.55	GEA	
^{60}Co	10 CFR 61.55	GEA	
^{152}Eu	Potential major activity contributor	GEA	
^{154}Eu	Potential major activity contributor	GEA	
^{155}Eu	Potential major activity contributor	GEA	
^{14}C	10 CFR 61.55	Liquid scintillation counting	
^{3}H	10 CFR 61.55	Liquid scintillation counting	
^{129}I	10 CFR 61.55	Low energy gamma counting	
^{63}Ni	10 CFR 61.55	Liquid scintillation counting	
^{90}Sr	10 CFR 61.55	Beta proportional counting	
^{99}Tc	10 CFR 61.55	ICP/MS	Liquid scintillation counting
^{125}Sb	Risk assessment	GEA	
^{79}Se	Risk assessment	Liquid scintillation counting	
^{126}Sn	Risk assessment	ICP/MS	
^{233}U	Potential major activity contributor	ICP/MS	
^{234}U	Potential major activity contributor	ICP/MS	
^{235}U	Potential major activity contributor	ICP/MS	
^{236}U	Potential major activity contributor	ICP/MS	
^{238}U	Potential major activity contributor	ICP/MS	
^{237}Np	10 CFR 61.55	ICP/MS	Alpha counting
^{238}Pu	10 CFR 61.55	Alpha counting	ICP/MS
$^{239/240}Pu$	10 CFR 61.55	Alpha counting	ICP/MS as ^{239}Pu and ^{240}Pu
^{241}Pu	10 CFR 61.55	Calculate from ^{238}Pu and $^{239/240}Pu$	Liquid scintillation counting
^{241}Am	10 CFR 61.55	Alpha counting	ICP/MS
^{242}Cm	10 CFR 61.55	Alpha counting	
^{243}Cm	10 CFR 61.55	Alpha counting	
^{244}Cm	10 CFR 61.55	Alpha counting	
^{228}Th	Possibly significant in some tanks.	Calculation	GEA
^{230}Th	Possibly significant in some tanks.	ICP/MS	
^{232}Th	Possibly significant in some tanks.	ICP/MS	
^{234}Th	In WMP-28945	ICP/MS	

GEA = Gamma energy analysis
ICP/MS = Inductively coupled plasma/mass spectrometry

Table 4-12. Soil Biota Concentration Guides (BCGs) 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)
^{241}Am	3.9E+03	2.2E+04
^{14}C	4.8E+03	6.1E+04
^{141}Ce	7.9E+03	7.6E+04
^{242}Cm	2.1E+03	7.9E+04
^{244}Cm	4.1E+03	1.5E+05
^{60}Co	6.9E+02	6.1E+03
^{137}Cs	2.1E+01	2.2E+03
^{152}Eu	1.5E+03	1.5E+04
^{154}Eu	1.3E+03	1.3E+04
^{155}Eu	1.6E+04	1.5E+05
Tritium (H-3)	1.7E+05	1.7E+06
^{129}I-	5.7E+03	1.7E+05
^{237}Np	3.9E+03	8.2E+03
^{238}Pu	5.3E+03	1.8E+04
^{239}Pu	6.1E+03	1.3E+04
^{125}Sb	3.5E+03	3.5E+04
^{75}Se	4.8E+03	4.4E+04
^{90}Sr	2.3E+01	3.6E+03
^{99}Tc	4.5E+03	2.2E+04
^{228}Th	5.3E+02	6.4E+03
^{230}Th	1.0E+04	1.8E+05
^{232}Th	1.5E+03	2.4E+04
^{234}Th	2.2E+03	2.2E+04
^{233}U	4.8E+03	5.2E+04
^{234}U	5.1E+03	5.2E+04
^{235}U	2.8E+03	2.7E+04
^{238}U	1.6E+03	1.6E+04

delivered to the laboratory in the original liner with capped and sealed end minimizing the moisture loss. The laboratory duplicate analyses will provide better data quality information. The soil sample liners will be opened in the laboratory with less moisture loss. A zone of sufficient soil mass can be selected to perform all duplicate analyses.

Duplicate samples will be taken when boreholes are drilled using a cable tool drill or methods that bring soil cutting to the surface during borehole advancement.

Field duplicates are used to evaluate precision of the sampling process. For direct-push samples that can be homogenized in the field, at least 5% (i.e., one duplicate will be collected for every 20 samples) of the total collected soil samples will be duplicated by splitting the homogenized sample into two. The duplicate samples shall be shipped to the laboratory in the same manner as the primary samples. They will be analyzed using the stepped approach described in Chapter 8. If VOA samples are required, they will be collected before homogenization.

For surface soil samples, collocated samples will be taken. These duplicate samples shall be shipped and analyzed as the primary samples.

4.9.2 Equipment Rinsate Blanks

Equipment rinsate blanks are used to verify the adequacy of sampling equipment decontamination procedures and shall be collected for each sampling method or type of equipment used. Equipment blanks shall consist of deionized water washed through decontaminated sampling equipment. Equipment rinsate blanks shall be analyzed for the following.

- GEA.
- AEA.
- Metals (excluding hexavalent chromium and mercury).
- Anions (except cyanide).
- VOCs.
- SVOCs.

These analytes are considered the best indicators of decontamination effectiveness.

4.9.3 Trip Blanks

The volatile organic trip blanks will constitute at least 5% of all VOC samples. Trip blanks shall consist of laboratory-grade deionized water added to a clean sample container. The trip blanks shall travel to the field with the associated bottle sets and will be returned to the laboratory with the samples. They will remain unopened during their transport and handling. Trip blanks are prepared as a check for possible contamination originating from container preparation methods, shipment, handling, storage, or site conditions. Trip blanks are needed for each sample delivery group that contains samples containing VOCs. The trip blank shall be analyzed for VOCs only.

4.9.4 Prevention of Cross-Contamination

Special care should be taken to prevent cross-contamination of soil samples. Particular care will be exercised to avoid the following common ways in which cross-contamination or background contamination may compromise the samples:

- Improperly storing or transporting sampling equipment and sample containers.
- Contaminating the equipment or sample bottles by setting them on or near potential contamination sources, such as uncovered ground.
- Handling bottles or equipment with dirty hands.
- Improperly decontaminating equipment before sampling or between sampling events.

4.10 REQUIRED QUALITY CONTROL FOR ANALYSIS

Hanford onsite laboratories and/or subcontracting laboratories performing analyses in support of this DQO shall have approved and implemented quality assurance (QA) plans. Hanford onsite laboratory QA plans shall meet the DOE/RL-96-68 minimum requirements as the baseline for laboratory quality systems. If subcontracting any portion of the analytical requirements to a commercial laboratory off the Hanford site, the subcontractor's implementing QA program shall comply with U.S. Department of Energy Consolidated Audit Program (DOECAP) Quality Systems for Analytical Services.

At a minimum, a duplicate analysis, a matrix spike, a laboratory blank, and a laboratory control sample (LCS) are required for each batch of samples. In addition, a matrix spike duplicate is required for VOA, semivolatile organic analysis, PCB, and Hg analyses. The matrix spike duplicate is needed due to the high number of "less than" for these analyses. Instances where these requirements are not applicable are shown in Table 4-13. Evaluation criteria for these QC analyses are shown in Table 4-13.

Table 4-13. Quality Control Parameters for Constituents (2 sheets)

Constituents	Method	QC Acceptance Criteria		
		LCS % Recovery[a]	Spike % Recovery[b]	Solid % RPD[c]
Al, Ag, As, Ba, Be, Cd, Co, Cr, Cu, Fe, Pb, Mn, Ni, Sb, Se, Sr, Tl, U, V, Zn	ICP/AES	80–120%	75–125%	≤30%
Hg	ICP-MS	80–120%	75–125%	≤30%
F^-, NH_4^+, NO_2^-, NO_3^-, $C_2H_3O_2^-$, CHO_2^-, $C_2H_3O_3^-$, $C_2O_4^{2-}$	IC	80–120%	75–125%	≤30%
CN^-	9014 (spectrophotometric)	80–120%	75–125%	≤30%
S^{2-}	9215	80–120%	75–125%	≤30%
OH^-	Titration[d]	80–120%	N/A	≤30%
	pH	± 0.1 pH Units	N/A	N/A
PCB by Aroclors	GC/ECD	70–130%	70–130%	≤30%
PCB by congengers	HRGC/HRMS	TBD	TBD	TBD
VOC	GC/MS	70–130%	70–130%	≤30%
SVOC	GC/MS (or GC/FID for ethylene glycol)	70–130%	70–130%	≤30%
% H_2O	Gravimetric	80–120%	N/A	≤30%
Bulk Density	Gravimetric	N/A	N/A	≤30%
^{235}U, ^{238}U, ^{237}Np, ^{232}Th, ^{126}Sn	ICP/MS	80–120%	75–125%	≤30%
^{233}U, ^{234}U, ^{236}U, ^{230}Th, ^{234}Th	ICP/MS	N/A[e]	N/A[e]	≤30%
^{228}Th	Calculation	N/A	N/A	N/A
^{60}Co, ^{137}Cs, ^{125}Sb	GEA	80–120%	N/A[f]	≤30%
^{152}Eu, ^{154}Eu, ^{155}Eu	GEA	N/A	N/A[f]	≤30%

Table 4-13. Quality Control Parameters for Constituents (2 sheets)

Constituents	Method	QC Acceptance Criteria		
		LCS % Recovery[a]	Spike % Recovery[b]	Solid % RPD[c]
^{129}I	GEA	80–120%	N/A[g]	≤30%
^{14}C, ^{3}H	Liquid scintillation counting	80–120%	75–125%	≤30%
^{63}Ni	Liquid scintillation counting	80–120%	N/A[g]	≤30%
^{90}Sr	Beta counting	80–120%	N/Ag[g]	≤30%
^{99}Tc	ICP/MS	80–120%	75–125%	≤30%
^{79}Se	Liquid scintillation counting	NP	N/A[g]	≤30%
^{238}Pu	Alpha counting	N/A[(f)]	N/A[g]	≤30%
$^{239/240}Pu$	Alpha counting	80–120%	N/A[g]	≤30%
^{241}Pu	Calculation from ^{238}Pu and $^{239/240}Pu$	N/A	N/A	N/A
^{241}Am	Alpha counting	80–120%	N/A[g]	≤30%
^{242}Cm, $^{243/244}Cm$	Calculation from ^{241}Am	N/A	N/A	N/A

CVAA = cold vapor atomic absorption
GEA = gamma energy analysis
GC/ECD = gas chromatography/electron capture detection
GC/FID = gas chromatography/flame ionization detection
GC/MS = gas chromatography/mass spectrometry
HRGC/HRMS = high-resolution gas chromatography/high-resolution mass spectroscopy
IC = ion chromatography
ICP/AES = inductively coupled plasma/atomic emission spectroscopy
ICP/MS = inductively coupled plasma/mass spectroscopy
QC = quality control
TGA = thermogravimetric analysis
N/A = not applicable
NP = not performed

[a] LCS = Laboratory control sample. This sample is carried through the entire analytical method. The accuracy of a method is usually expressed as the percent recovery of the LCS. The LCS is a matrix with known concentration of constituents processed with each preparation and analyses batch. It is expressed as percent recovery; i.e., the amount measured, divided by the known concentration, times 100.

[b] For some methods, the sample accuracy is expressed as the percent recovery of a matrix spike sample. It is expressed as percent recovery; i.e., the amount measured, less the amount in the sample, divided by the spike added, times 100. One matrix spike is performed per analytical batch. Samples are batched with similar matrices. For other constituents, the accuracy is determined based on use of serial dilutions.

[c] RPD = Relative percent difference between the samples. Sample precision is estimated by analyzing duplicates taken separately through preparation and analysis. Acceptable sample precision is usually ≤20% RPD for liquids or ≤ 30% for solids if the sample result is at least 10 times the instrument detection limit.
RPD = [(absolute difference between primary and duplicate)/mean] x 100.

[d] OH^- titration not conducted for solids. pH is determined for solids as described in the text.

[e] No standards are run for these constituents.

[f] The measurement is a direct reading of the energy and the analysis is not affected by the sample matrix; therefore, a matrix spike is not required.

[g] Matrix spike analyses are not required for this method because a carrier or tracer is used to correct for constituent loss during sample preparation and analysis. The result generated using the carrier or tracer accounts for any inaccuracy of the method on the matrix. The reported results reflect this correction.

The QC criteria in Table 4-13 are goals for demonstrating reliable method performance. The laboratory's internal QA system will be used to evaluate the analytical data and processes whenever a criterion is exceeded. The laboratory may reanalyze based on the internal evaluation. Otherwise, the data will be further evaluated in accordance with the strategies described in RPP-24303. Primary constituent data not meeting the QC requirements will be noted accordingly and discussed in the narrative of the laboratory data report.

4.11 REQUIRED METHOD DETECTION LIMITS

RPP-24303 specifies action levels for a number of radionuclides. It also states that required detection limits are set an order of magnitude below the action limits. The resulting required detection limits are shown in Table 4-14. The DQO does not provide detection guidance for the remaining parameters. However, D&D-30262 provides cleanup levels and corresponding target detection limits for tank farm pipelines and associated soil. These target detection limits are adopted for use in analysis of WMA C vadose zone soil samples (Tables 4-15 and 4-16). The laboratories are required to meet the required detection limits and shall strive to meet the target detection limits.

Table 4-14. Required Detection Limits (2 sheets)

Analyte	Analytical Method	Alternate Analytical Method	Source 10 CFR 61.55 Class C Waste pCi/g	Required Detection Limits pCi/g
^{241}Am	Alpha counting	Not available	9.00E+03	9.00E+02
^{14}C	Liquid scintillation counting	Not available	5.33E+06	5.33E+05
^{242}Cm	Alpha counting	Not available	9.00E+03	9.00E+02
^{243}Cm	Alpha counting	Not available	9.00E+03	9.00E+02
^{244}Cm	Alpha counting	Not available	9.00E+03	9.00E+02
^{60}Co	GEA	Not available		
^{137}Cs	GEA	Not available	3.07E+09	3.07E+08
^{152}Eu	GEA	Not available	Not available	Not available
^{154}Eu	GEA	Not available	Not available	Not available
^{155}Eu	GEA	Not available	Not available	Not available
^{3}H	Liquid scintillation counting	Not available	Not available	Not available
^{129}I	Low energy gamma counting	Not available	5.33E+04	5.33E+03
^{63}Ni	Liquid scintillation counting	Not available	4.67E+08	4.67E+07
^{237}Np	ICP/MS	Alpha counting	9.00E+03	9.00E+02
^{238}Pu	Alpha counting	ICP/MS	9.00E+03	9.00E+02
^{239}Pu	Alpha counting	ICP/MS	9.00E+03 (as $^{239/240}$Pu)	9.00E+02 (as $^{239/240}$Pu)
^{240}Pu	Alpha counting	ICP/MS	9.00E+03 (as $^{239/240}$Pu)	9.00E+02 (as $^{239/240}$Pu)
^{241}Pu	Calculate from ^{238}Pu and $^{239/240}$Pu	ICP/MS	3.50E+09	3.50E+08
^{125}Sb	GEA	Not available	Not available	Not available
^{79}Se	Liquid scintillation counting	Not available	Not available	Not available
^{90}Sr	Beta proportional counting	Not available	4.67E+09	4.67E+08
^{99}Tc	Liquid scintillation counting	ICP/MS	2.00E+06	2.00E+05

Table 4-14. Required Detection Limits (2 sheets)

Analyte	Analytical Method	Alternate Analytical Method	Source 10 CFR 61.55 Class C Waste pCi/g	Required Detection Limits pCi/g
^{126}Sn	ICP/MS	Not available	Not available	Not available
^{228}Th	Calculation	GEA	Not available	Not available
^{230}Th	ICP/MS	Not available	Not available	Not available
^{232}Th	ICP/MS	Not available	Not available	Not available
^{233}U	ICP/MS	Not available	9.00E+03	9.00E+02
^{234}U	ICP/MS	Not available	9.00E+03	9.00E+02
^{235}U	ICP/MS	Not available	9.00E+03	9.00E+02
^{236}U	ICP/MS	Not available		
^{238}U	ICP/MS	Not available	9.00E+03	9.00E+02

Table 4-15. Target Detection Limits for Primary Radionuclides (2 sheets)

CAS or Constituent Identifier	Analyte	Survey or Analytical Method	Lowest Overall CUL (pCi/g)	Target Detection Limits (pCi/g)
14234-35-6	Antimony-125	Gamma GS	--	0.3
14596-10-2	Americium-241	^{241}Am alpha energy analysis	31.1	1
14762-75-5	Carbon-14	C-14 LSC (low level)	4.65	1
10045-97-3	Cesium-137	Gamma GS	6.2	0.1
10198-40-0	Cobalt-60	Gamma GS	1.4	0.05
15510-73-3	Curium-242	^{241}Am/^{244}Cu alpha energy analysis	--	1.0
15757-87-6	Curium-243	^{241}Am/^{244}Cu alpha energy analysis	110	1.0
13981-15-2	Curium-244	^{241}Am/^{244}Cu alpha energy analysis	744	1.0
14683-23-9	Europium-152	Gamma GS	3.3	0.1
15585-10-1	Europium-154	Gamma GS	3.0	0.1
14391-16-3	Europium-155	Gamma GS	125	0.1
15046-84-1	Iodine 129	^{129}I LSC	0.12	2
13994-20-2	Neptunium-237	ICP/MS	2.5	1
13981-37-8	Nickel-63	^{63}Ni LSC	4,026	30
13981-16-3	Plutonium-238	Alpha energy analysis	37.4	1
Pu-239/240	Plutonium-239/240	Alpha energy analysis	33.9	1
13982-63-3	Radium-226	Gamma GS	7.03	0.2
15758-85-9	Selenium-79	^{79}Se LSC	197,000	10
Rad-Sr	Strontium-90	^{89,90} Sr total Sr - gas proportional counting	4.5	1
14133-76-7	Technetium-99	ICP/MS	1.93	1
14274-82-9	Thorium-228	TBD	7.73	1
14269-63-7	Thorium-230	ICP/MS	20.1	1
TH-232	Thorium-232		4.8	1

Table 4-15. Target Detection Limits for Primary Radionuclides (2 sheets)

CAS or Constituent Identifier	Analyte	Survey or Analytical Method	Lowest Overall CUL (pCi/g)	Target Detection Limits (pCi/g)
10028-17-8	Tritium	Tritium – H-3 LSC(mid level)	48.2	30
13966-29-5	Uranium-233/234	ICP/MS	1.1	1
15117-96-1	Uranium-235		101	1
U-238	Uranium-238		1.06	1

CAS = Chemical Abstracts Service
CUL = cleanup level
GS = gamma spectroscopy.
LSC = liquid scintillation counter.
ICP/MS = inductively coupled plasma/mass spectrometry
TBD = to be determined

Table 4-16. Target Detection Limits for Primary Chemicals (5 sheets)

CAS or Constituent Identifier.	Analyte	Survey or Analytical Method	Lowest Overall CUL (mg/kg)	Target Detection Limits (mg/kg)
7429-90-5	Aluminum	EPA Method 6010B	45.2	5
7440-36-0	Antimony	EPA Methods 6010B, 6020, or 200.8 (trace)	5	0.6
7440-38-2	Arsenic	EPA Methods 6010B, 6020, or 200.8	6.5	1
7440-39-3	Barium	EPA Methods 6010B, 6020, or 200.8	132	20
7440-41-7	Beryllium	EPA Methods 6010B, 6020, or 200.8	10	0.5
7440-43-9	Cadmium	EPA Methods 6010B, 6020, or 200.8	0.81	0.5
7440-47-3	Chromium (III)/chromium (total)	EPA Methods 6010B, 6020, or 200.8	42	1
7440-48-4	Cobalt	EPA Methods 6010B, 6020, or 200.8	20	2
7440-50-8	Copper	EPA Methods 6010B, 6020, or 200.8	50	1
7439-89-6	Iron	EPA Methods 6010B, 6020, or 200.8	152	5
7439-92-1	Lead	EPA Methods 6010B, 6020, or 200.8	50	5
7439-96-5	Manganese	EPA Methods 6010B, 6020, or 200.8	512	1.9*
7439-97-6	Mercury	EPA Methods 7470A, 7471A, 6020, or 200.8	0.33	0.2
7439-98-7	Molybdenum	EPA Methods 7470A, 7471A, 6020, or 200.8	2	19*
7440-02-0	Nickel	EPA Methods 6010B, 6020, or 200.8	30	4

Table 4-16. Target Detection Limits for Primary Chemicals (5 sheets)

CAS or Constituent Identifier.	Analyte	Survey or Analytical Method	Lowest Overall CUL (mg/kg)	Target Detection Limits (mg/kg)
7782-49-2	Selenium	EPA Methods 6010B, 6020, or 200.8	0.3	1
7440-22-4	Silver	EPA Methods 6010B, 6020, or 200.8	2	2
7440-24-6	Strontium	EPA Methods 6010B, 6020, or 200.8	2,920	1
7440-28-0	Thallium	EPA Methods 6010B, 6020, or 200.8	1	0.5
7440-61-1	Uranium	EPA Methods 200.8, 6020, or kinetic phosphorescence absorption	3.21	1
7440-62-2	Vanadium	EPA Methods 6010B, 6020, or 200.8	560	2.5
7440-66-6	Zinc	EPA Methods 6010B, 6020, or 200.8	86	1
57-12-5	Cyanide (includes ferrocyanide)	EPA Methods 9010C total cyanide or 335	0.8	0.5
16984-48-8	Fluoride	IC, EPA Method 9056 or 300.0	5.78	5
14797-55-8	Nitrate	IC, EPA Method 9056 or 300.0	40	2.5
14797-65-0	Nitrite	IC, EPA Method 9056 or 300.0	4	2.5
16887-00-6	Chloride	IC, EPA Method 9056 or 300.0	1000	0.3*
14808-79-8	Sulfate	IC, EPA Method 9056 or 300.0	1000	2.7*
71-50-1	Acetate	IC, EPA Method 9056 or 300.0	--	4.5*
64-18-6	Formate	IC, EPA Method 9056 or 300.0	--	10.0
79-14-1	Glycolate	IC, EPA Method 9056 or 300.0	---	3.8*
144-62-7	Oxalate	IC, EPA Method 9056 or 300.0	--	2*
18496-25-8	Sulfide	EPA Method 9030	--	5
NA	Ammonium (NH_4)	EPA Method 300.7	9.23	0.5
67-64-1	Acetone	EPA Method 8260	28.9	0.02
71-43-2	Benzene	EPA Method 8260	0.00448	0.0015
75-15-0	Carbon disulfide	EPA Method 8260	5.65	0.005
56-23-5	Carbon tetrachloride	EPA Method 8260	0.00310	0.0015
108-90-7	Chlorobenzene	EPA Method 8260	0.874	0.005
67-66-3	Chloroform (trichloromethane)	EPA Method 8260	0.0381	0.005
108-94-1	Cyclohexanone	EPA Method 8270C	344	0.5
107-06-2	1,2-Dichloroethane	EPA Method 8260	0.00232	0.0015
75-35-4	1,1-Dichloroethylene	EPA Method 8260	0.000522	0.01
75-09-2	Dichloromethane (methylene chloride)	EPA Method 8260	0.0218	0.002
10061-02-6	Dichloropropene; 1,3,- (trans-)	EPA Method 8260	0.00141	0.005
141-78-6	Ethyl acetate	EPA Method 8015	59.5	5

Table 4-16. Target Detection Limits for Primary Chemicals (5 sheets)

CAS or Constituent Identifier.	Analyte	Survey or Analytical Method	Lowest Overall CUL (mg/kg)	Target Detection Limits (mg/kg)
60-29-7	Diethyl ether	EPA Method 8015, 8260	6.68	5
100-41-4	Ethyl benzene	EPA Method 8260	6.05	0.005
67-72-1	Hexachloroethane	EPA Method 8270C	0.125	0.33
108-10-1	Methyl isobutyl ketone (MIBK hexone)	EPA Method 8260	2.71	0.01
78-93-3	Methyl ethyl ketone (MEK)	EPA Method 8260	19.6	0.01
79-46-9	Nitropropane; 2-	EPA Method 8260	0.0000208	0.002*
79-34-5	Tetrachloroethane; 1,1,2,2-	EPA Method 8260	0.00123	0.005
127-18-4	Tetrachloroethene (PCE)	EPA Method 8260	0.000859	0.005
108-88-3	Toluene	EPA Method 8260	4.65	0.005
76-13-1	trichloro-1,2,2-trifluoroethane; 1,1,2-	EPA Method 8260	22,000	0.010
71-55-6	1,1,1-Trichloroethane (TCA)	EPA Method 8260	1.58	0.005
79-00-5	1,1,2-Trichloroethane	EPA Method 8260	0.00427	0.002
107-21-1	Ethylene glycol	EPA Method 8015	---	5
156-59-2	Cis-1,2,-dichlorobenzene	EPA Method 8260	--	0.0003*
156-60-5	Trans-1,2-dichlorobenzene	EPA Method 8260	---	0.0004*
83-32-9	Acenaphthene	EPA Method 8270C	20	0.33
117-81-7	Bis(2-ethylhexyl)phthalate	EPA Method 8270C	--	2.95*
71-36-3	Butanol; n- (n-butyl alcohol)	EPA Method 8260, 8015	6.62	5
85-68-7	Butylbenzylphthalate	EPA Method 8270C	893	0.33
95-57-8	Chlorophenol; 2-	EPA Method 8270C	0.943	0.33
M + P CRESOL	Cresol; m + p (3/4-Methylphenol)	EPA Method 8270C	10.1	0.33
95-48-7	Cresol; o- (2-Methylphenol)	EPA Method 8270C	10.3	0.33
1319-77-3	Cresylic acid (cresol, mixed isomers)	EPA Method 8270C	--	0.5*
84-74-2	Dibutylphthalate (Di-n-butylphthalate)	EPA Method 8270C	2.2	0.33
117-84-0	Di-n-octylphthalate	EPA Method 8270C	0.524	0.33
95-50-1	Dichlorobenzene; 1,2- (ortho-)	EPA Method 8270C	7.03	0.33
121-14-2	Dinitrotoluene; 2,4-	EPA Method 8270C	0.189	0.33
110-80-5	Ethoxyethanol; 2-	TBD	25.7	TBD
206-44-0	Fluoranthene	EPA Method 8270C	631	0.33
87-68-3	Hexachlorobutadiene	EPA Method 8270C	0.605	0.33

Table 4-16. Target Detection Limits for Primary Chemicals (5 sheets)

CAS or Constituent Identifier.	Analyte	Survey or Analytical Method	Lowest Overall CUL (mg/kg)	Target Detection Limits (mg/kg)
78-83-1	Isobutyl alcohol (Isobutanol)	EPA Methods 8260 or 8015	19.4	5
128-37-0	methylphenol; 2,6-Bis(tert-butyl)-4-	EPA Method 8270C	--	1.2*
59-50-7	methylphenol; 4-Chloro-3- (p-Chloro-m-cresol)	EPA Method 8270C	4,000	0.33
91-20-3	Naphthalene	EPA Method 8270C	4.46	0.33
98-95-3	Nitrobenzene	EPA Method 8270C	0.026	0.33
88-75-5	Nitrophenol; o-	EPA Method 8270C	---	0.66
621-64-7	Nitroso-di-n-propylamine	EPA Method 8270C	0.000056	0.33
79-01-6	Trichloroethylene (TCE)	EPA Method 8260	7.21E-4	3.7E-4*
75-69-4	Trichlorofluoromethane	EPA Method 8260	28.4	0.01
75-04-1	Vinyl chloride	EPA Method 8260	0.000184	0.01
1330-20-7	Xylenes	EPA Method 8260	14.6	0.01
108-38-3	Xylene; m-	EPA Method 8260	84.4	5.1E-4*
95-47-6	Xylene; o-	EPA Method 8260	91.9	2.4E-4*
106-42-3	Xylene; p-	EPA Method 8260	172	5.1E-4*
120-82-1	1,2,4 - Trichlorobenzene	EPA Method 8270C	2.98	0.33
59-89-2	Nitrosomorpholine; N-	EPA Method 8270C	--	0.33
129-00-0	Pyrene	EPA Method 8270C	655	0.33
110-86-1	Pyridine	EPA Method 8270C	0.0746	0.66
95-95-4	Trichlorophenol; 2,4,5-	EPA Method 8270C	4	0.33
88-06-2	Trichlorophenol; 2,4,6-	EPA Method 8270C	0.0924	0.33
		EPA Method 8041		0.165
126-73-8	Tributyl phosphate	EPA Method 8270C	6.18	3.3
107-66-4	Dibutyl phosphate*	EPA Method 8270C	--	TBD
--	Monobutyl phosphate*	EPA Method 8270C	--	TBD
56-55-3	Benzo (a) anthracene*	EPA Method 8270C	0.856	0.33
205-99-2	Benzo (b) fluorathene*	EPA Method 8270C	1.37	0.33
207-08-9	Benzo (k) fluorathene*	EPA Method 8270C	13.7	0.33
50-32-8	Benzo (a) pyrene*	EPA Method 8270C	0.137	0.33
218-01-9	Chrysene*	EPA Method 8270C	95.6	0.33
53-70-3	Dibenzo (ab) anthracene*	EPA Method 8270C	0.137	0.33
193-39-5	Indeno (123-cd) pyrene*	EPA Method 8270C	1.37	0.33
2674-11-2	Aroclor 1016	PCBs, EPA Method 8082	0.092	0.02
11104-26-2	Aroclor 1221	PCBs, EPA Method 8082	0.092	0.02

Table 4-16. Target Detection Limits for Primary Chemicals (5 sheets)

CAS or Constituent Identifier.	Analyte	Survey or Analytical Method	Lowest Overall CUL (mg/kg)	Target Detection Limits (mg/kg)
11141-16-5	Aroclor 1232	PCBs, EPA Method 8082	0.092	0.02
53969-21-9	Aroclor 1242	PCBs, EPA Method 8082	0.0394	0.02
126572-29-6	Aroclor 1248	PCBs, EPA Method 8082	0.0386	0.02
11097-6999-1	Aroclor 1254	PCBs, EPA Method 8082	0.066	0.02
11096-82-5	Aroclor 1260	PCBs, EPA Method 8082	0.072	0.02
Not available	PCB congeners	PCBs, EPA Method 1668	TBD	TBD

* Target detection limit for this analyte is not specified in D&D-30262. It is based on detection limits achieved in the recent analyses of soil samples taken near tank 241-S-102 (RPP-RPT-36439, *Final Report for the Contaminated Soil Samples at Tank 241-S-102 in Support of the Type A Investigation of the Tank Waste Spill*).

CAS = Chemical Abstracts Service
CUL = cleanup level.
EPA = U.S. Environmental Protection Agency.
IC = ion chromatography.
N/A = not applicable.
PCB = polychlorinated biphenyl.
TBD = to be determined

5. STEP 4 – STUDY BOUNDARIES

This step in the DQO process defines the spatial and temporal boundaries for the required sampling and analyses needed to support the decisions. The spatial boundaries define the physical area to which the decisions will apply and where the samples should be taken. The temporal boundaries describe the time frame that the data will represent and when the samples should be taken. In addition, this portion of the DQO addresses any sampling constraints.

5.1 SPATIAL AND TEMPORAL BOUNDARIES

The spatial boundary for the sampling and analyses covered by this DQO is the vadose zone in and around WMA C, including all areas where there have been releases known or suspected of emanating from WMA C. The horizontal spatial boundary for this DQO is illustrated in Figure 5-1, and the vertical boundary is from the ground surface to the capillary fringe immediately above groundwater.

The temporal boundary for the data collected as specified in this DQO will be the final CMS for WMA C. Because the data will represent the condition of the contamination in the vadose zone between now and when the final CMS is completed, the timing of the sample collection must reflect these conditions. This DQO will be in effect until the sampling and analysis for the soil remedy selection for WMA C is complete.

5.2 POTENTIAL SAMPLE DESIGN LIMITATIONS

Impediments may be encountered during the data collection process. The practical constraints developed in Step 4 are shown in Table 5-1.

Figure 5-1. Aerial Boundary of WMA C

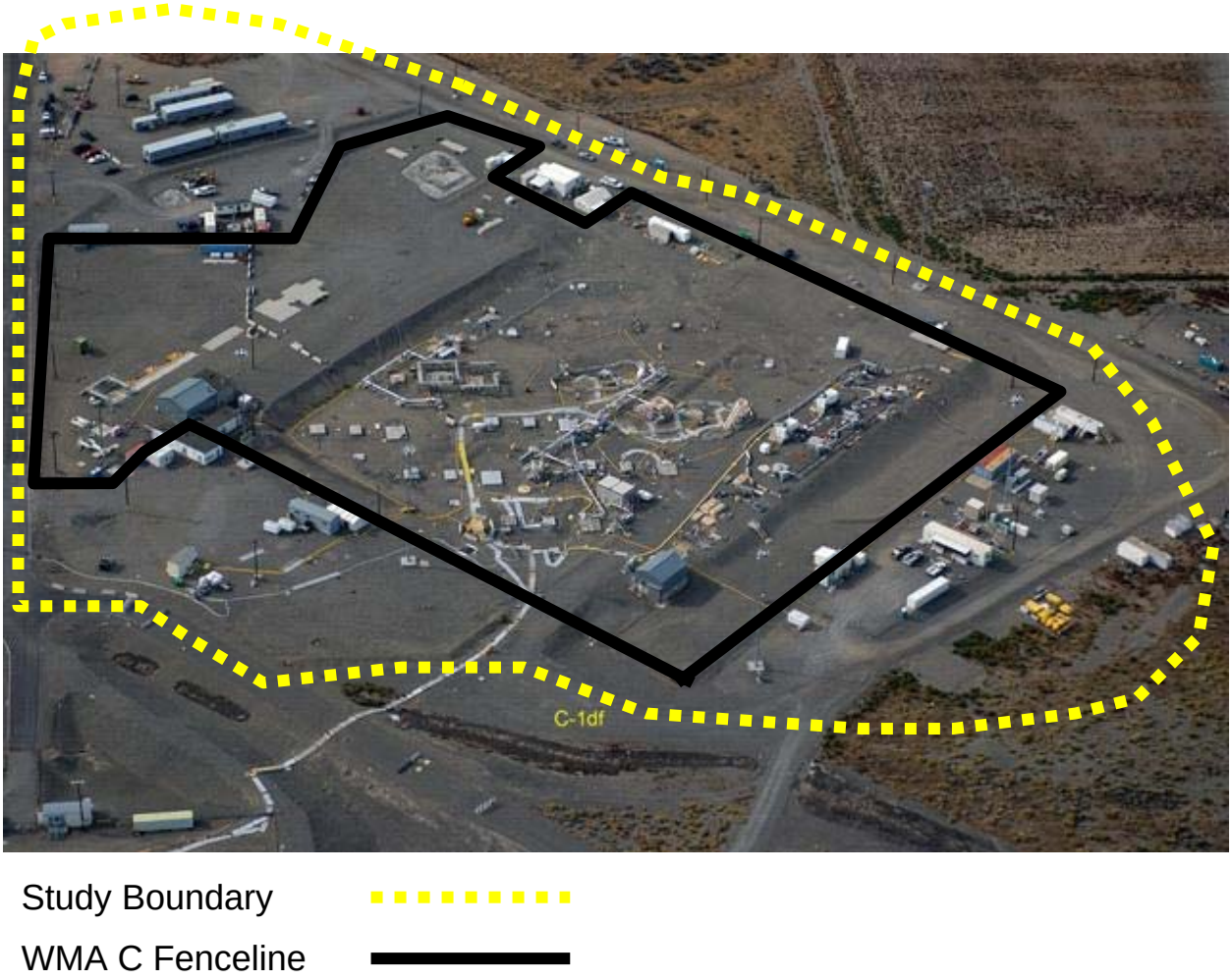


Table 5-1. Practical Constraints on Data Collection.

Constraint	Details
Physical access	Placing driven soil probes, borings, or excavations near tank farm system structures (i.e., SSTs, lines, diversion boxes, catch tanks) will pose additional access challenges because of the following: • Limited access to some locations because of topography. • Surface and subsurface obstructions.
Methods	The methods selected for investigations, such as excavations (e.g., trenching, test pits), driven soil probes, or borings, will influence the following: • An investigative method is selected depending on data needs (sample volume, number of samples, depth, potential radiological content, instrumentation installed, geophysical logging needs, location, groundwater well installed, etc.) not vice versa.
Radiological controls	Radiological issues that could influence the ability to perform the work involve the following: • Handling contaminated samples (high or very high radiation).
Field screening techniques	The ability of field screening to meet quality assurance/QC or detection requirements may be limited as follows: • Gross gamma logging in soils may be limited by background radiation levels from adjacent structures (e.g., pipelines or diversion boxes). Small diameter gross gamma tool has a higher quantification level than the large diameter spectral stoller tools. Therefore, very low levels of cobalt will not be detected by a small diameter logging tool. • Passive neutron logging may be limited because of lower than expected quantities of neutron-emitting isotopes.
Analytical laboratory capabilities	Radiological controls and constraints at the sampling location (primarily high contamination levels) that delay delivery of the samples to the laboratory, causing exceedance of hold time limits. • Radiological controls and constraints at the laboratory (primarily high contamination levels) that delay analysis, causing exceedance of hold time limits. • Highly contaminated samples may require substantial dilution causing inability to analyze other contaminants effectively (e.g., reduced contaminant concentrations below detection limits).

6. STEP 5 – DECISION RULES

The DQO process includes development of decision rules, which define the actions to be taken as a result of exceeding an action level. Decision rules require action levels and alternative actions that will be taken if the action levels are exceeded and are expressed as "if …then" statements that incorporate the parameter of interest, the scale of decision-making, the action level, and the actions that would result from resolution of the decision rule. For this DQO, four decision rules were developed to address the decision statement in Chapter 3. The four decision rules are not sequential but are applied in parallel. All of the decision rules must be met before corrective actions can proceed.

The first decision statement in Chapter 3 addresses the human health risks through direct contact with nonradioactive contaminants.

Decision Rule 1

If the risk to human health through direct contact in the top 15 ft of soil from nonradioactive COPCs under an unrestricted land use scenario based on the maximum concentration or 95% upper confidence limit (UCL) (as appropriate) is >10E-5 cumulative and >10E-6 individually for COPCs for lifetime cancer risk and the Hazard Index is >1, then corrective measures will be required; otherwise corrective measures for the vadose zone to protect human health through direct contact will not be evaluated.

The second decision statement addresses the human health risks through direct contact with radioactive contaminants.

Decision Rule 2

If the risk to human health through direct contact in the top 15 ft of soil from radioactive COPCs based on the maximum concentration or 95% UCL (as appropriate) is >10E-4 lifetime cancer risk, then corrective measures will be required; otherwise corrective measures for the vadose zone to protect human health through direct contact will not be evaluated.

The third decision statement addresses the lifetime cancer risk through groundwater contamination with nonradioactive contaminants.

Decision Rule 3

If the risk to groundwater protection throughout the vadose zone from nonradioactive COPCs based on the maximum concentration or 95% UCL (as appropriate) in the vadose zone is >10E-5 cumulative and >10E-6 individually for COPCs for lifetime cancer risk and the Hazard Index is >1, then corrective measures will be required; otherwise corrective measures for the vadose zone to protect groundwater will not be evaluated.

The fourth decision statement addresses the lifetime cancer risk through groundwater contamination with radioactive contaminants.

Decision Rule 4

If the risk to groundwater protection throughout the vadose zone from radioactive COPCs based on the maximum concentration or 95% UCL (as appropriate) in the vadose zone is >10E-4 lifetime cancer risk, then corrective measures will be required; otherwise corrective measures for the vadose zone to protect groundwater will not be evaluated.

7. STEP 6 – SPECIFY TOLERABLE LIMITS ON DECISION ERRORS

The purpose of Step 6 is to specify the decision makers' tolerable limits on decision errors, which are used for limiting uncertainty in the data. Since analytical data can only provide an estimate of the true condition of a site, decisions that are based on these data could potentially be in error. Step 6 provides a mechanism for allowing the decision maker to define tolerable limits on the probability of making a decision error.

Decision errors are due to errors in sampling and measurements. These errors occur because sampling designs generally do not capture completely the heterogeneity that exists in the true state of the environment. Also, sampling and analysis methods and instruments are not perfect.

Table 7-1. Tolerable Limits on Decision Errors

Action	Possible Decision Error	Severity of Consequences of Decision Error				Decision Error that has More Severe Consequences Near the Action Level
		Far Below the Action Level	Below but Near the Action Level	Above but Near the Action Level	Far Above the Action Level	
Conduct corrective action	Remediate an uncontaminated site	Severe	Moderate	None	None	Not remediating a contaminated site
Take no further action	Failing to remediate a contaminated site	None	None	Moderate	Severe	

Notes:

Justification for rating severity of consequences as "severe."

The decision error for remediating an uncontaminated site where the concentration is far below the action limit is rated as severe. The greater the cost incurred if an incorrect decision is made, the greater the severity.

The decision error for not remediating shallow and deep soils when the concentrations are far above the action level is also rated as severe. In this case, soil with concentrations that may pose serious health risks would remain at the site.

7.1 INVENTORY LEAK ESTIMATE UNCERTAINTIES

Inventory leak estimates are a simple calculation of the liquid waste composition at the time of a leak multiplied by waste volume. Inventory uncertainties are a combination of composition and leak volume uncertainties. Uncertainties deriving from limitation on the data sources could include, but are not limited to the following:

1. Tank process reports and assessment.
    a. Incomplete records.
    b. Partial description of the problem.
    c. Incorrect interpretation of data.
    d. Historical analysis was sometimes performed with incomplete data sets.

2. In-tank liquid level measurements.
   a. Precision, accuracy, and frequency varies with instrumentation and waste surface.
   b. Evaporation and barometric pressure effects may not have been considered.
   c. Records are sometimes incomplete and often were not available for early tank leaks.
   d. Liquid level decreases difficult to identify for tanks with frequent transfers.
   e. Not usable for self-boiling tanks and waste operated for evaporation.

3. Waste transfer records.
   a. Gaps in transfer records generally rolled up to monthly or quarterly summaries.
   b. Uncertainty in transfer volumes were not well defined, particularly during times of high volume throughput, which could mask relatively small volume leak events.

4. Gross gamma logging data.
   a. Restricted time period (1974–1994).
   b. Uncalibrated data does not provide radionuclide specific identification.
   c. Multiple probe types with different results were used to obtain data.
   d. Restricted to available boreholes (i.e., existing drywells).
   e. Gamma logging generally identifies activity only within 12 to 18 in. from well.
   f. Data often post dates leak events, sometimes by years.

5. Spectral gamma logging data.
   a. Restricted time period (1995–2001) with limited logging from 2002 to present.
   b. Restricted to available boreholes (i.e., existing drywells).
   c. Gamma logging generally identifies activity only within 12 to 18 in. from well.
   d. Data often post dates leak events, sometimes by years.
   e. Detection of gamma-emitting radionuclides only; unable to detect beta emitters such as ^{90}Sr, ^{99}Tc, or tritium.
   f. Detected radionuclides include ^{137}Cs, ^{60}Co, ^{154}Eu, ^{152}Eu, ^{126}Sn, ^{125}Sb, ^{238}U, and ^{235}U.
   g. High rate detector capable of quantifying ^{137}Cs up to about 1E9 pCi/g.
   h. High levels of ^{137}Cs may mask other radionuclides.

6. Moisture monitoring data.
   a. Limited data available.
   b. No moisture baseline for tank farms.

7. Vadose Zone Program reports.
   a. Field investigation reports are limited.
   b. Analysis generally focused more on tank integrity.

   c. Accuracy limited by data availability/reviewed.
   d. Some reports do not include supporting data or are unclear.

8. Tank line data.
   a. Limited data available.
   b. Data post-date leak events, sometime by years.
   c. Most data limited to ^{137}Cs.
   d. Total gamma only (generally interpreted as ^{137}Cs).

9. Vadose zone sample and analysis.
   a. Limited data available.
   b. Sampling and analytical precision and accuracy.
   c. Depth and special variability of contaminants in vadose zone.

10. Earth resistivity.
   a. Measures resistivity anomalies in the soil, which may correlate to areas of contamination.
   b. Generally does not provide depth information (currently only two-dimensional).
   c. Tank farm infrastructure interferences causing ambiguous data interpretation.
   d. Indirect measurement not correlated to chemistry or radioactivity.

Considering the sources of uncertainty listed in items 1 through 10, it can be expected that assessments of the inventory that leaked will be based on a wide range of data with various levels of pedigree. Some of the data may be inconsistent or ambiguous.

Based on process knowledge and the results of the Phase 1 RFI, it is known that the WMA C vadose zone is contaminated. An action level is a concentration at which point a predetermined action is taken depending on whether the results of the analyses are above or below the specified action level. To account for uncertainty in the data in the vadose zone 0 to 15 ft bgs, analytical results are compared to the action level at an UCL of 95%. Because of the uncertainty in whether sufficient data will be collected to calculate a meaningful 95% UCL, the option is to use the maximum concentration. DOE, Ecology, and the Tank Farm Contractor reached agreement on a process to address inventory uncertainty that includes an assessment of the quality of the available data and to achieve a consensus on the source, volume, and composition of the material that has leaked, which includes a justifiable uncertainty range for the values determined (RPP-32681).

7.2 REDUCING UNCERTAINTY IN CHARACTERIZATION THROUGH TECHNOLOGY DEVELOPMENT

The U.S. Department of Energy's Office of Environmental Management (EM) Engineering and Technology Program was established with the overall objective to reduce the technical risk and uncertainty in the DOE's cleanup programs and projects. Risks are known technical issues that

could prevent project success. Uncertainties are indefinite or unpredictable technical aspects of a project. To reduce those risks and uncertainties, the Applied Research and Technology Development and Deployment component of this program will provide technical solutions where none exist, improved solutions that enhance safety and operating efficiency, or technical alternatives that reduce programmatic risks (cost, schedule, or effectiveness). The *Engineering and Technical Roadmap Reducing Technical Risk and Uncertainty in the EM Program* (DOE 2008) for this work identifies the following:

- The engineering and technical risks the DOE-EM program faces over the next 10 years.
- The strategies EM will use to minimize these risks.
- The planned outcomes of implementing those strategies.

The technical risks are identified as follows:

- The roadmap identified a set of technical risks which are divided into six program areas: Waste Processing; Groundwater and Soil Remediation; Deactivation and Decommissioning, and Facility Engineering; DOE Spent Nuclear Fuel; Challenging Materials; and Integration. Strategic initiatives that address each technical risk and uncertainty in the EM program are expected to produce solutions for application at each of the DOE sites facing the same risk.
- The technical risks in the groundwater and soil remediation included sampling and characterization. The technical risk and uncertainty in this area included:
    - Current sampling techniques and characterization technologies result in costly, time-consuming characterization programs may leave large gaps in plume delineation, and may lead to uncertainty in the selection of cleanup strategies.
    - Incomplete understanding of contaminant subsurface behavior results in long-term uncertainty regarding risks to human health and the environment.

The strategic initiatives to improved sampling and characterization include the following:

- Develop advanced sampling and characterization technologies and strategies for multiple contaminants (organics, metals, and radionuclides) in challenging environments (e.g., around subsurface interferences, at intermediate and great depths, and in low and high permeability zones).
- Use basic and applied research to gain a better understanding of contaminant behavior in the subsurface and to provide defensible prediction of risk.

Field Measurement of Technetium-99

At the present time, levels of ^{99}Tc contamination in soil are determined by laboratory analysis of soil samples. This methodology is labor intensive and provides samples only at selected intervals in the vadose zone. In keeping with DOE's roadmap strategy to develop advanced sampling and characterization technologies is the development of a ^{99}Tc sensor. A ^{99}Tc sensor can be deployed during the placement of direct-push probeholes, which could quickly indicate

where sampling intervals should be located. The advantage such a probe would provide in soil characterization efforts is to avoid costs associated with null sample results that result from sampling an uncontaminated zone in the soil column. The ^{99}Tc sensor would be based on the 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 ^{99}Tc sensor would first be built and tested in the laboratory which, assuming funding is available, is currently anticipated in FY 2009. 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 in FY 2010.

8. STEP 7 – OPTIMIZE THE SAMPLING DESIGN

8.1 PURPOSE

The purpose of DQO Step 7 is to optimize data collection to meet the data quality requirements specified in DQO Steps 1 through 6. Elements of Step 7 include the following:

- Conceptual models.
- Sample design.

This section presents the approaches for conducting the characterization of the vadose zone in and around WMA C for the CMS and associated decision-making. Investigative and sampling techniques are identified that are aligned with the key elements of WMA C conceptual site models. The details of conducting the field characterization effort will be presented in a WMA C specific work plan and SAP, which will be released in FY 2009.

"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 specified field site in the context of recognized problem." Furthermore, as the 2006 Darcy Lecture for the National Groundwater Association, Dr. Eileen Poeter (Colorado School of Mines) recommended using "multiple working hypotheses" (alternative conceptual models) when studying complex geohydrologic systems. This section provides an overview discussion 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 waste management areas 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).

8.1.1 Alternative 1: Phase 1 Conceptual Model

This model is documented in Chapter 16 of DOE/ORP-2008-01 and was derived from process records, gross gamma logging information collected from 1960s through the 1990s,[4] spectral gamma data collected in the late 1990s to early 2000s,[5] and the data collected during the Phase 1 characterization efforts conducted from 2000 to 2007.[6] 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 (i.e. ^{99}Tc, nitrate, etc.) 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).

The complete Phase 1 conceptual model is described in DOE/ORP-2008-01 (Appendix A). Rather than evaluating individual leaks sequentially, this summary discussion 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 a summary level, the following key characteristics and processes are concluded to be the primary components of the conceptual model and common to all major leak events.

8.1.1.1 Initial Leak Period

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

- 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.

- 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.

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[4] 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).

[5] 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.

[6] See field investigation reports (RPP-7884, RPP-10098, RPP-23748, DOE/ORP-2008-01 Appendixes L and M.

Consequently, waste contacted an expanded vadose zone volume compared to the initial volume of the released waste.

- 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 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 (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, nitrate).

8.1.1.2 Current Conditions

- 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 fill that covers the SST system in the tank farm. Chemical reactions continued that were primarily controlled by the ambient environment.

- 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 SX-108 where enhanced ^{137}Cs mobility occurred due to the presence of high sodium concentrations in the tank waste (RPP-7884).

- Under natural recharge conditions through a gravel cover, vertical migration rates of 1 to 3 ft/yr in the vadose zone for ^{60}Co have been observed at a few dry wells in WMAs C and B-BX-BY, most notably at dry wells 22-03-09, 22-06-05 (HNF-3532, *Analysis of Historical Gross Gamma Logging Data from BY Tank Farm*) and 30-08-02 (RPP-8820, *Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-C Tank Farm - 200 East Area*).

- A number of characterization boreholes were installed during the Phase 1 characterization activities. Technetium-99 was found between about 85 and 150 ft bgs for the 200 West WMAs and 130 to 170 ft bgs for the 200 East WMAs (DOE/ORP-2008-01). Drilling depths 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 less than 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, approximately 70 to 150 ft above the unconfined aquifer.

- The lower Cold Creek unit is present in the 200 West Area but not in the 200 East Area. Due to the cementing within this layer, this may form a hydraulic break to the vertical flow causing contaminants to move laterally across the top of this unit.

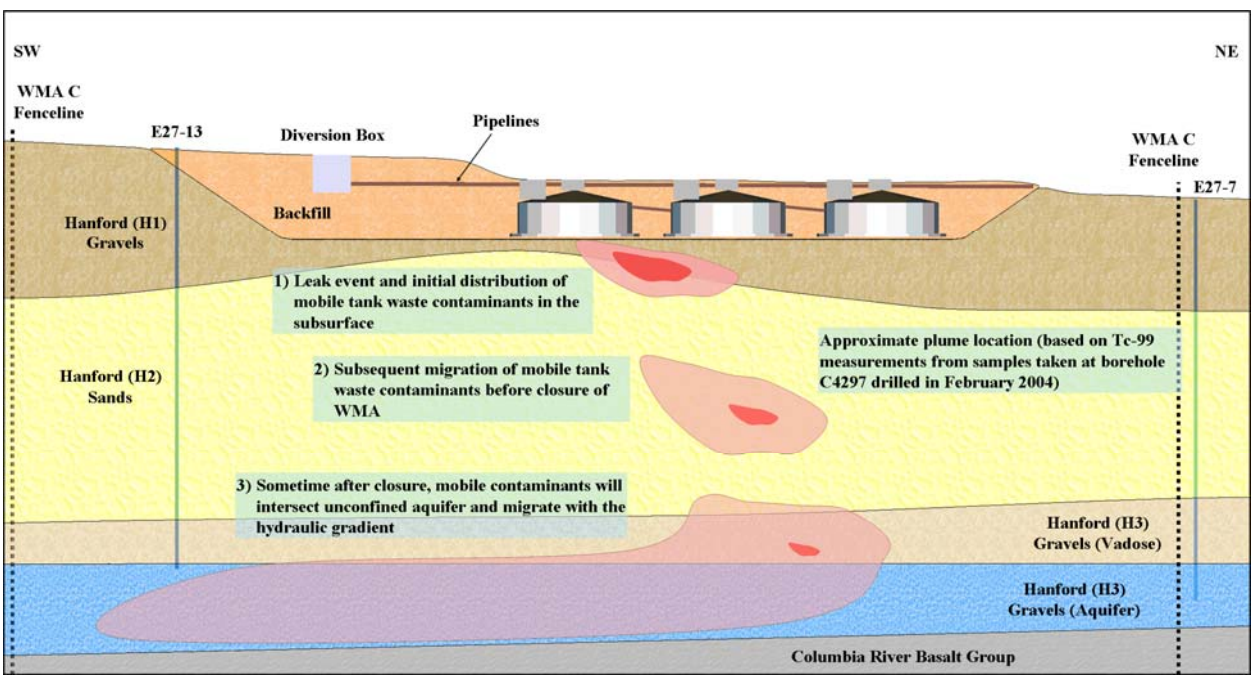
8.1.1.3 Future Conditions

- Future migration rates could be diminished if engineered barriers are installed that reduce recharge rates from as much as 100 mm/yr to much less than 1.0 mm/yr for some time (Connelly 2006). This rate is expected to 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.

- 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 MCL sometime in the future (RPP-7884, RPP-10098, RPP-23752, and DOE/ORP-2005-01).

These general periods are shown as different plume locations in Figure 8-1. 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 8-1. Alternative 1: Phase 1 Conceptual Model



8.1.1.4 Importance of Water as a Driving Force

Despite the measurement of the highest levels of nonreactive to slightly-reactive contaminants (^{99}Tc, chromium, nitrate) in the vadose zone, approximately 70 to 120 ft above the water table,

groundwater monitoring data from wells near waste management area fencelines indicate that some tank waste has reached the aquifer in discrete locations, notably on the southern side of the SX 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 maximum contaminant level (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 must be expanded to include these observations.

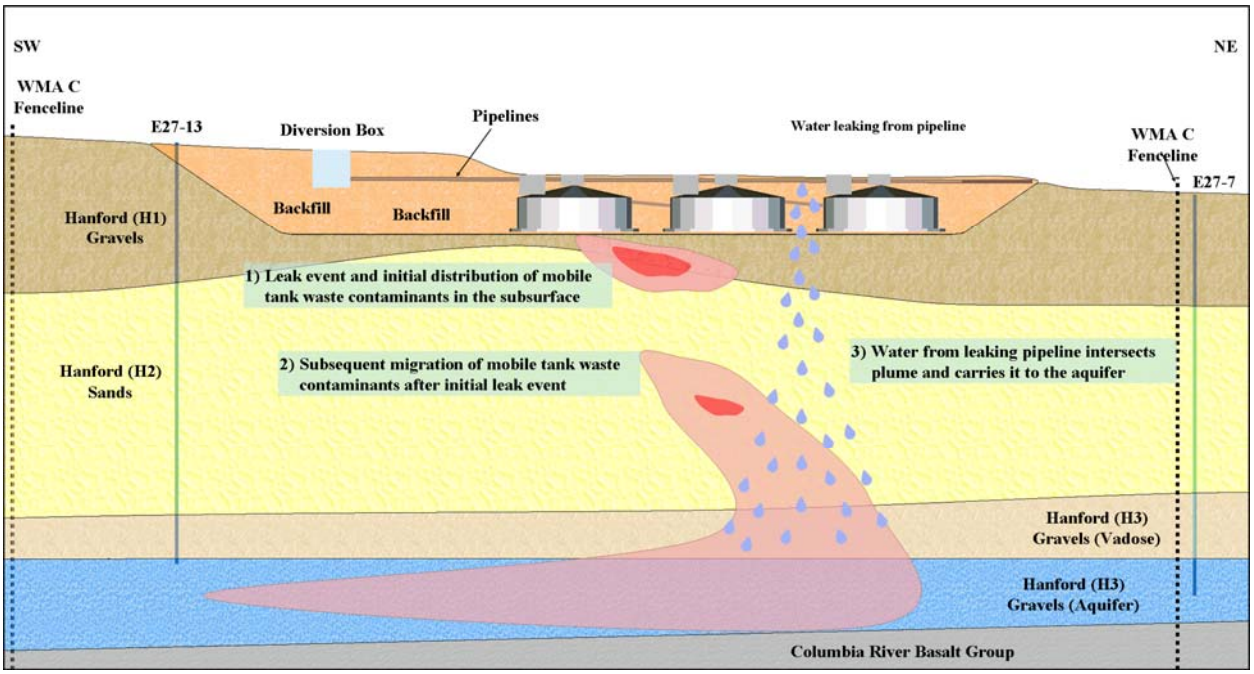
Examination of site-specific conditions at the WMAs suggests a mechanism that explains these observations. This mechanism is enhanced recharge of raw water or waste water by one or more of the following: (1) localized unintentional from leaking pipelines, (2) flooding of the tank farm due to rapid snow melting, and/or (3) intentional releases from nearby cribs, trenches, and ditches. The following are specific examples of known enhanced recharge within the WMAs:

- 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 8-2).

- 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 2642 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.

- 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).

Figure 8-2. Expanded Phase 1 Conceptual Model (Accounting for Artificial Recharge due to Pipeline Leak)



- Large intentional discharges of raw water or waste water occurred in cribs, trenches, and ditches close to WMAs B-BX-BY and U. WMA B-BX-BY is bounded on the west and north by cribs that have received approximately 30,000,000 gal of liquid effluent. At this location, a perched water table is observed approximately 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 west to the West. Large volumes of water (~346,000,000 gal) were discharge to these trenches of water during their operational lifetime. Perching occurred on top of the Cold Creek unit and elevated moisture content was observed in the vadose at WMA U (DOE/ORP-2008-01 Appendix M). Intentional discharges to cribs, ditches and trenches ceased in the mid-1990s.

It is inferred from these observations that when enhanced recharge encounters tank waste in the vadose, tank waste is transported to the unconfined aquifer. Because of the detrimental impact of enhanced recharge in the tank farms, a series of interim measures (Section 2.2) has been implemented to prevent enhanced recharge.

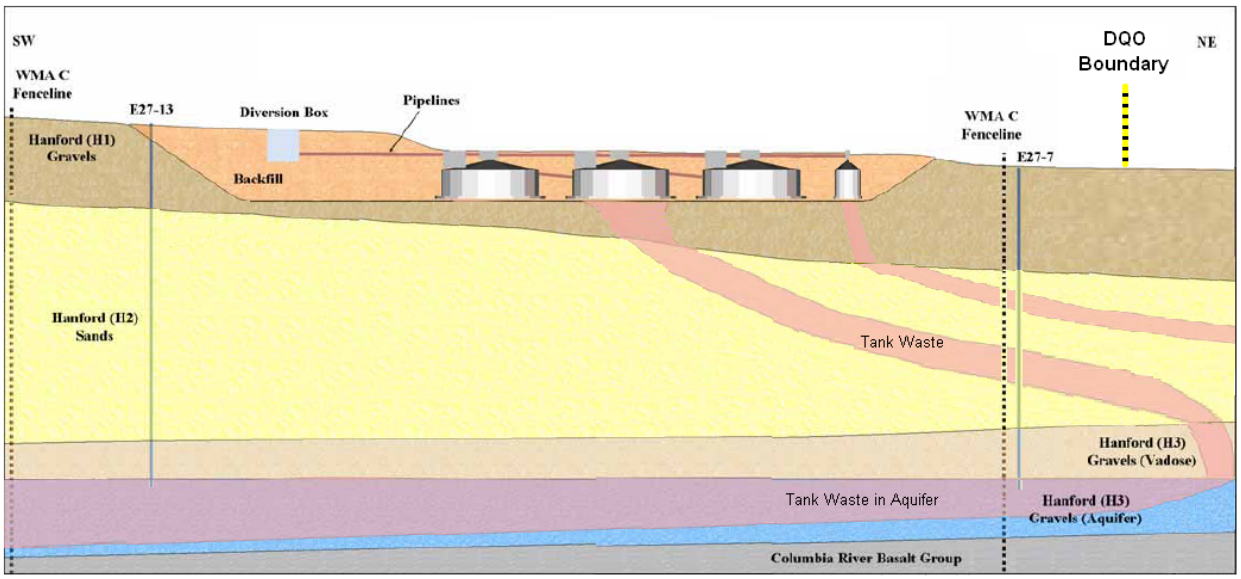
8.1.2 Alternative 2: Movement of Contaminants down Stratigraphic Dip Conceptual Model

This conceptual model correlates transport of ^{60}Co from spectral gamma measurements at WMA C with the stratigraphic dip to the northeast. Dr. Stan Sobczyk has provided an updated

depiction of the 2007 conceptual model (Figure 8-3). Dr. Sobczyk bases this conceptual model on the following:

- Tank and/or pipelines leak.
- Tank waste migrates primarily vertically through backfill and H1 gravels.
- Tank waste and moisture migrates primarily laterally through the H2 sands following stratigraphic dip.
- Tank waste migrates primarily vertically through the coarser material in the lower H2 and H3 gravels until it reaches groundwater.
- Tank waste is denser than groundwater and sinks in the aquifer as it is transported to the southwest under the tank farm.

Figure 8-3. Alternative 2: Movement of Contaminants down Stratigraphic Dip Conceptual Model



Dr. Sobczyk has suggested a similar conceptual model for the release from tank BX-102 for the movement of uranium from the 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.

8.1.3 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.

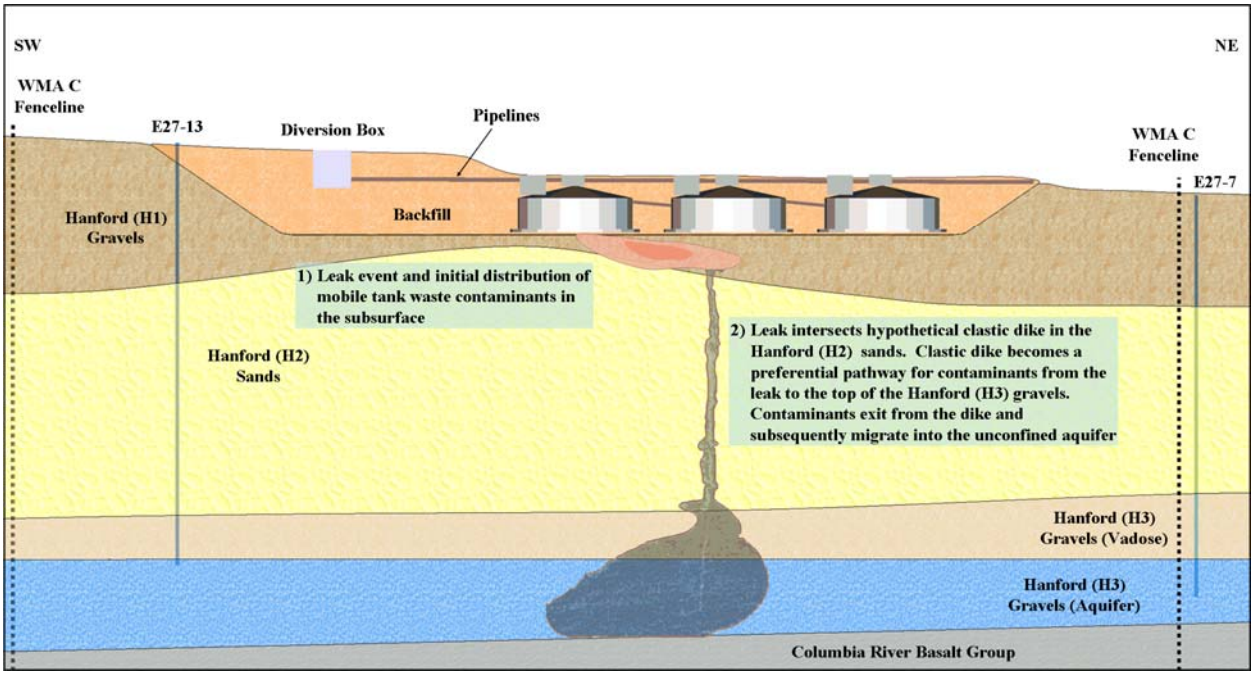
Poorly constructed wells might allow the contaminant to move vertically downward between the casing and the surrounding media. However, at tank farms, the depth of almost all drywells within the tank farms is 100 ft bgs, while groundwater is 230 to 300 ft bgs. Therefore, it is unlikely that a poorly 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 tubular and tapered intrusive bodies that are composed of continental clastic sediments. BHI-01103 published a photograph (Figure 9-44 on p 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, p 9-55 of BHI-01103 was used to develop a conceptualization of contaminant movement down a clastic dike (Figure 8-4).

Figure 8-4. Alternative 3: Preferential Pathways (Clastic Dikes) Conceptual Model



8.1.4 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 8-5 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, -82, and -86.

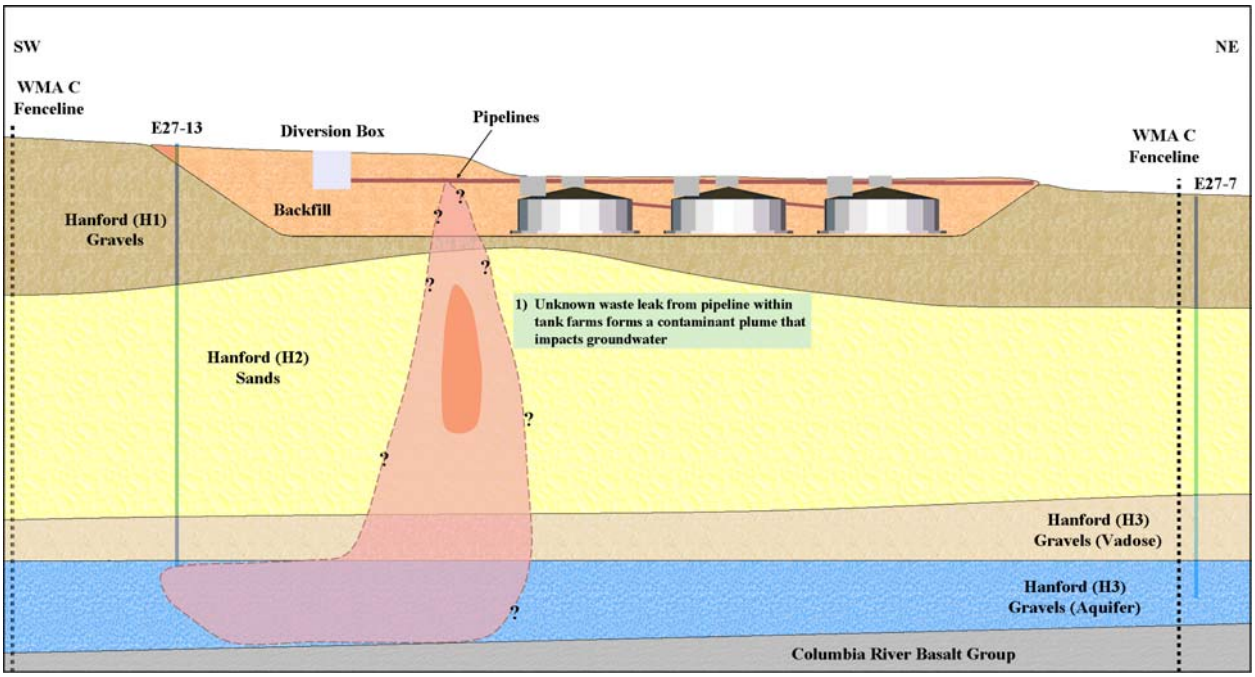
8.1.5 Conceptual Models of WMA C

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 configurations:

- Interior portions of the tank farm including the C-100-series tanks and associated infrastructure.
- C-200-series tanks and associated infrastructure.

- Pipelines, and diversion boxes in the western portion of the tank farm.
- Pipelines, and drains located outside of the tank farm.
- Airborne contaminated surface sites outside of the tank farm.

Figure 8-5. Alternative 4: Unknown Leak Conceptual Model



8.1.5.1 Conceptual Model for Interior Portions of the C Farm

The conceptual model for unplanned releases within the interior portions of C Farm includes consideration of the generalized conceptualization for model 1 conceptual model and alternative models 1 and 3. It 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. However, since ^{99}Tc is present in the aquifer at levels above the MCL and there are no other nearby sources (i.e., cribs, ditches, and trenches) to WMA C, the source of groundwater contamination must be WMA C, and further characterization of WMA C is necessary. Other events at WMA C are most likely the cause for contamination to the groundwater. These events (tank leaks, overfilling tanks, and pipeline leaks) can be either known (C-101 release) 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 3) that have occurred and migrated to at least 175 ft and possibly to groundwater.

8.1.5.2 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 is estimated at 400 gal (HNF-EP-0182, Rev. 240) containing PUREX waste minus the uranium separations (7G400-03-SMM-003 – interoffice memo). 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, such that dissolved contaminants can be detected near the tank bottoms and that the waste has not migrated to groundwater.

8.1.5.3 Conceptual Model for 244-CR Vault, Pipelines and Diversion Boxes in the Western Portions of the C Farm

This conceptual model for releases at these locations includes consideration of alternative models 1, 2, and 4. This model is also based on information associated with UPR-82, -86, -81 and documented flooding of the 244-CR vault. This 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 UPRs-82 and -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 advanced at UPR-82. The vertical probeholes were drilled to depth of 30 to 60 ft bgs around the outer edges of the gunite pile over this pipeline leak, while the deepest slant probehole was driven to depth of 80 ft bgs directly under this location. Technetium-99 was found at this depth. Because, 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.

8.1.5.4 Conceptual Model for Near Surface, Shallow, Small Releases outside of the Tank Farm

The conceptual model for these includes consideration of 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 Tank Farm Process Condensate was discharged to the 216-C-8 French drain from January 1960 through March 1965. At the cesium loadout facility (241-C-801), located in the northeastern corner of the WMA C, cesium and technetium were loaded onto casks containing ion exchange resin. The origin of the waste was from 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 potentially discharged to the drain from the valve pit, the potential exists for discharges to have occurred. 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 none 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.

8.1.5.5 Conceptual Model of Contaminated Surface Sites outside the C Farm

The conceptual model for these sites describes surface contamination. This model is based on information associated with UPR-91, -107, -115, and -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).

- UPR-91: the contaminated area was scraped and contaminated material removed [RL-TPA-90-0001, *Tri-Party Agreement Handbook Management Procedures*, TPA-MP-14, "Maintenance of the Waste Information Data System (WIDS)"].
- 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.
- 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 radiological 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.
- UPR-200-E-118 is located in the northeast portion of the tank farm and extends north up to about 300 m (1000 ft) beyond the fenceline. It was the result of an airborne release from C-107 that occurred in April 1957.

These releases and the conceptual model are not believed to represent a risk to groundwater but potentially are a risk through direct contact and to ecological receptors.

8.1.6 Conceptual Site Models and Contaminant Distribution

The contaminant distribution identifies where within the vadose zone waste is known or suspected to be located. This is used in defining sampling techniques as well as in the CMS alternatives evaluation and associated decision-making process. Contaminant distributions potentially requiring a decision include the following:

- Surface (airborne and surface waste—to resolve direct contact and ecological risks.
- Near surface (0-15 ft)—to resolve direct contact, ecological risks, and possibly groundwater risks depending on contaminant mobility.

- To excavatable depth—to resolve direct contact, ecological risks, and possible groundwater risks depending on contaminant mobility.
- Deep vadose to resolve possible groundwater risks.

Chapter 2 of this report provides a discussion concerning the current knowledge of known and suspected potential distribution of contaminants in and around WMA C. More detail on applying conceptual models to the site selection process is presented in RPP-PLAN-39114, *RCRA Facility Investigation/Corrrective Measures Study Work Plan for Waste Management Area C*.

8.2 GENERAL SAMPLE DESIGN PROCESS

Sections 8.2.1 through 8.2.4 describe the candidate sample locations and the strategy for sample analysis. Also described is how the testing and deployment of SGE at WMA C will be accomplished.

8.2.1 Candidate Sample Site Locations

A random sampling strategy cannot be applied in WMA C because of the extensive amount of interferences caused by buried infrastructure and topographic constraints. Therefore, a nonprobabilistic (or judgmental) sampling strategy that targets locations based on existing knowledge will be used. This approach provides the highest potential for confirming and characterizing known and suspected releases in and around WMA C and will help refine the WMA C conceptual site models. However, this approach is less likely to provide information on the influence preferential pathways may have on the migration of waste through the vadose zone (alternative conceptual model 2). An attempt will be made to identify any unknown releases (conceptual model 3) by using SGE (or other technology) across the entire tank farm after the initial testing has refined the ability to identify known release plumes.

Candidate sample locations were identified using an iterative approach that considered the following:

- Known and suspected releases were identified that would support characterization of WMA C for the CMS and help further refine one or more of the conceptual models.
- Interferences and constraints to accessing and sampling candidate locations were defined.
- Alternative sampling methods were considered to mitigate constraints (i.e., slant pushes instead of vertical).

Figure 8-6 shows the location of known and suspected releases in and around WMA C and the location of the candidate sample sites. Figure 8-7 shows the candidate sample locations in relationship to existing surface features and Figure 8-8 shows the candidate sample locations relative to subsurface interferences. The final sample locations will be established based on geophysical data collected, and facility walkdowns conducted prior to deployment of the sampling equipment to the sample site. Table 8-1 presents a general description of the candidate location where sampling would occur.

Figure 8-6. Candidate Sample Locations and Surface Geophysical Exploration Interrogation Areas

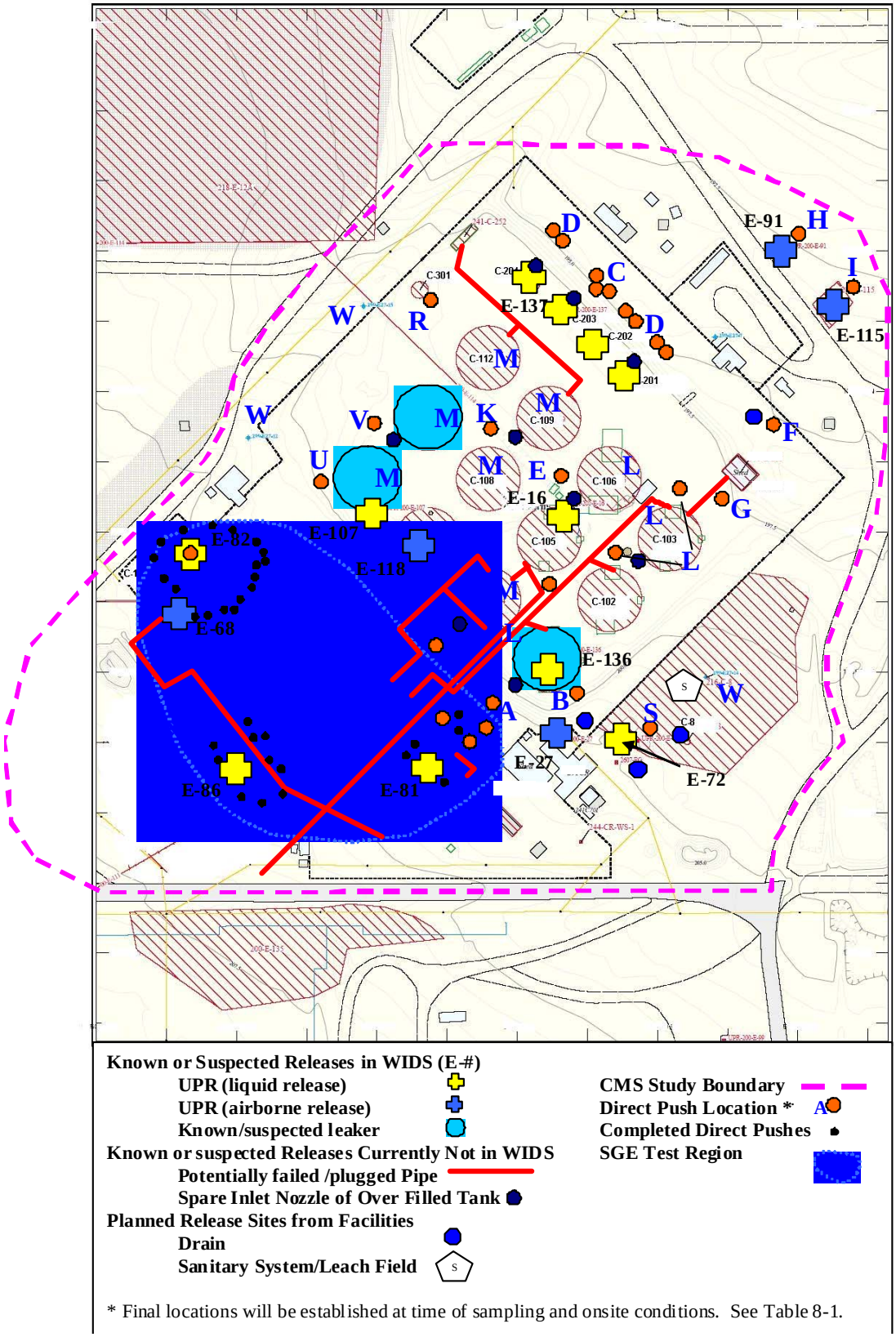


Figure 8-7. Surface Facilities as of October 2007, Candidate Sample Locations and Surface Geophysical Exploration Interrogation Areas

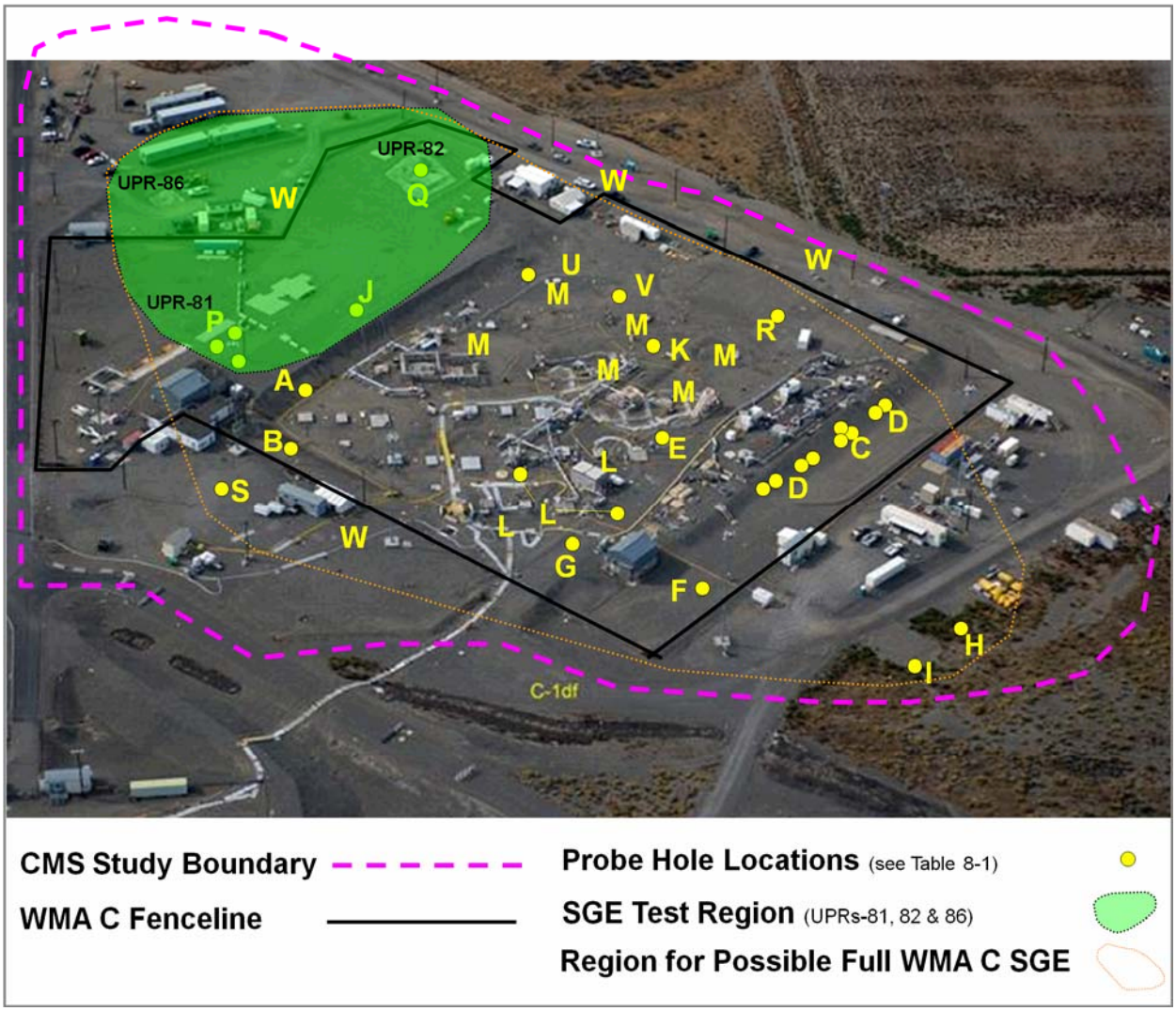


Figure 8-8. Candidate Sample Locations and Infrastructure Constraints

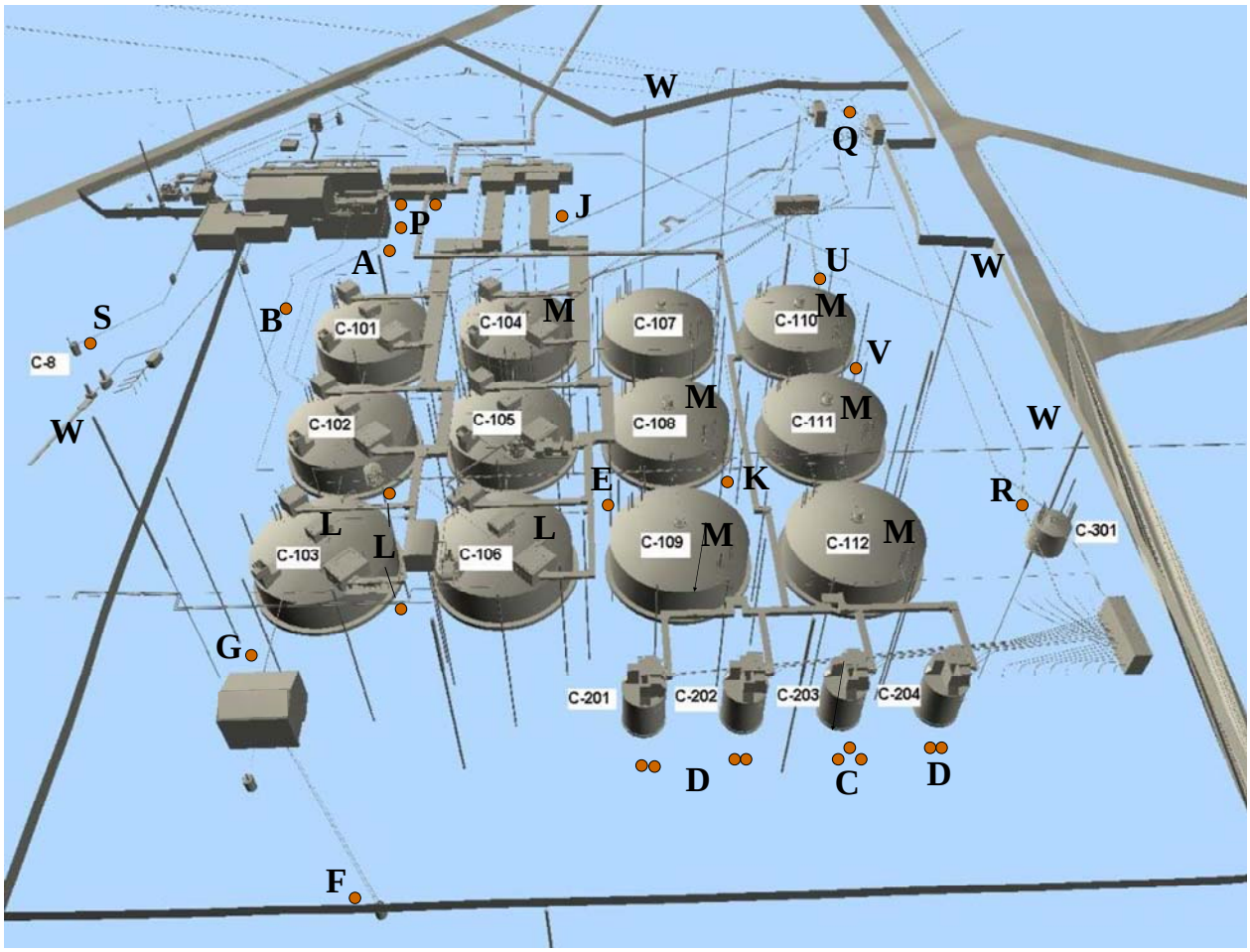


Table 8-1. Sample Plan WMA C Phase 2 Characterization for CMS (3 sheets)

Site Designation	Location	Deployment	Number of Sampling Probe Holes	Average Number of Samples	Known or Suspected Event	Objective	Access Availability	Ecology/ Stakeholder Interest
A	Spare inlet 241-C-101	Direct push, slant	1-2	8	Tank overfill. Loss through spare inlet	Characterize C-101 release and conceptual models 1, 2, and 4	Fair	High
B	241-C-101, south side	Direct push, vertical or slant	1	8	Tank release	Characterize C-101 release and conceptual models 1, 2, and 4	Poor for vertical push	High
C	241-C-203	Direct push, slant	3	4: 0-14 ft 15: >15 ft	Tank leak and/or tank overfill. Loss through spare inlet	Determine if C-200 actually leaked and conceptual models 1, 2, and 4	Fair	Moderate to high
D	241-C-201* 241-C-202 241-C-204	Direct push, slant	1-2/tank	8	200 series tank leaks	Determine if C-200 actually leaked and conceptual models 1, 2, and 4	Fair	Moderate, depending on C-203 results
E	Between 241-C-106 and 200-C-109	Direct push, vertical	1	8	Suspected release	Assess ^{60}Co and conceptual models 1, 2, and 4	Fair	High
F	Building C-801 chemical drain	Direct push, vertical	1	8	Suspected release site	Assess release of PUREX waste, Cs and Tc, and ^{60}Co and conceptual models 1, 2, and 4	Good	Moderate to high
G	Between Building C-801 and 241-C-103	Direct push, vertical	1	8	Suspected transfer line release site	Assess release and ^{60}Co and conceptual models 1, 2, and 4	Good	High
H	Northeast side of E-91	Direct push, vertical	1	8	Surface release	Surface exposures assess ^{60}Co and surface release conceptual model	Good	High
I	Northeast side of E-115	Direct push, vertical or slant	1	8	Surface release	Surface exposures assess ^{60}Co and surface release conceptual models 1, 2, and 4	Good	High
J	241-C-104	Direct push, slant	1	8	Tank release	Assess suspected release and conceptual models 1,	Fair	High

Table 8-1. Sample Plan WMA C Phase 2 Characterization for CMS (3 sheets)

Site Designation	Location	Deployment	Number of Sampling Probe Holes	Average Number of Samples	Known or Suspected Event	Objective	Access Availability	Ecology/ Stakeholder Interest
						2, and 4		
K	241-C-108	Direct push, vertical or slant	1	8	Transfer line leak, hot dry well (09-02)	Assess suspected release and conceptual models 1, 2, and 4	Poor	High
L	241-C-103 and 241-C-106	Drywell logging and direct push, vertical	2/all drywells	8	Potential transfer line leak and tank overfill	Update logging data for U, ^{60}Co, ^{137} Cs, and moisture and assess potential release and conceptual models 1, 2, and 4	Fair	Moderate
M	241-C-104, 108, 109, 110, 111, and 112	Drywell logging	All drywells			Update logging data for U, ^{60}Co, ^{137} Cs, and moisture	Fair to good	Moderate
N	UPR-86, UPR-82 and UPR 81	SGE	Use existing network			Test SGE, define plume at UPR-82 and -86 and conceptual models 1, 2, and 4	Good	High
O	WMA C	SGE	TBD supplement existing network			3-D vision of suspected releases – may lead to supplemental sample locations	Good	High
P	UPR-81	Evaluate existing data and complete entire work scope of eight investigative site or collected soil sample at the five investigative site with geophysical logging results	3	8	Known release site	Characterize release and conceptual models 1, 2, and 4	Good	High
Q	UPR-82	Direct push through center of UPR-82 for determining the depth of ^{99}Tc	1	8	Known release site	Penetrate center of mass to assess ^{137}Cs activity at a depth ~14 ft bgs, and conceptual models 1, 2, and 4	Good, needs preparatory work for a level work surface.	High

Table 8-1. Sample Plan WMA C Phase 2 Characterization for CMS (3 sheets)

Site Designation	Location	Deployment	Number of Sampling Probe Holes	Average Number of Samples	Known or Suspected Event	Objective	Access Availability	Ecology/ Stakeholder Interest
R	241-C-301 catch tank	Direct push vertical	1	8	Unlined concrete catch tank	Assess potential catch tank release and conceptual models 1, 2, and 4	Good	Moderate to high
S	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 conceptual models 1, 2, and 4 and near surface	Good	Moderate to high
T	TBD, based on SGE data for entire WMA	TBD, direct push vertical and/or slant	TBD	TBD	Previously unknown release sites	Assess suspected release and conceptual models 1, 2, and 4	TBD	Moderate to high
U	C-110	Direct push, slant	1	8	Tank leak and/or tank overfill. Loss through spare inlet	Characterize C-110 release and conceptual models 1, 2, and 4	Fair	High
V	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
W	299-E27-12, 299-E27-13, 299-E27-14, 299-E27-15	Log groundwater monitoring wells outside of WMA C				Log wells to collect data on U, ^{60}Co, ^{137}Cs, and moisture	Good	High

* Sampling the vadose zone around these three tanks will be dependent on the result of C-203. If there is no indication of a release from C-203, there would be no samples collected at these three tanks.

TBD = to be determined

8.2.1.1 Areas not Characterized

Three areas of known or suspected releases in and around WMA C currently are not planned to be characterized to support the CMS. These areas include UPR-107, -118, and -135.

Unplanned release UPR-107 is a surface spill. The exact location of this release is unclear. The WIDS general summary report for UPR-200-E-107 states the release was reported at the 241-CR-100 tank. The original incident report states it occurred at the 241-CR-110 tank in the 241-CR tank farm. WIDS states that the location should be the 241-C-110 tank in the 241-C tank farm. 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. "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). The size of the release and the uncertainty as to where the release actually occurred and where the contaminated soil was actually placed does not support an attempt to locate and characterize this release.

UPR-200-E-118 is located in the northeast portion of the tank farm and extends north up to about 300 m (1000 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). Radiological surveys of the tank farm have not demonstrated surface contamination over this broad area, which supports a determination to not attempt to characterize this release.

UPR-135 is located south and west of WMA C. This site was identified as contaminated vegetation, which has subsequently been removed. The source of contamination is suspected to be an underground leaking pipe in the area. This site will be investigated as part of the 200-IS-1 OU remedial investigation.

8.2.1.2 Integration with OU 200-BP-5

It is anticipated that all data will be provided to support further evaluations associated with the 200-BP-5 OU groundwater studies around WMA C. In addition, the 200-BP-5 team is in the planning process to possible construction of additional boreholes into the groundwater northeast of WMA C. Depending on the timing in which the characterization data are available for the vadose zone from this borehole, it may be used to supplement the data used in the WMA C CMS.

8.2.2 Characterization Field Activities

The methods identified to achieve the characterization objectives are presented in Table 8-2.

Table 8-2. Sampling Design Elements.

Surface geophysical survey	Perform ground-penetrating radar and/or electromagnetic imaging over the general area and conduct facility walk down.	• Surface geophysical surveys and walkdowns are used to verify the presence and location of subsurface and surface feature that would interfere with sampling activities. • Results are used to determine if any other undocumented buried structures occur in the area of interest.
Direct-push geophysical survey	Install direct-push rods to depth for gross gamma and active neutron logging (for moisture). Pushes will be installed around the location under investigation.	• Vertical geophysical survey data will be used in the assessment of releases by evaluating the presence of gamma-emitting radionuclides in areas where a release might have occurred. • ^{137}Cs is considered a good gamma radiation indicator of contamination because of its prevalence in the waste stream and ease of identification. • Results mainly will be used to evaluate the extent of gross gamma contaminant and moisture profile in the vadose zone.
Direct-push samples	Collect soil sample from the depth interval of highest contamination detected at each geophysical survey location.	• Discrete soil samples will be collected to confirm levels of contamination or absence of contamination as indicated by vertical geophysical logging. • Analytical results provide concentration data for radionuclides and nonradionuclides. • Analytical results will be used for evaluating direct contact risk, risk to groundwater and refining conceptual models
Surface samples	Collect soil samples in the top 12 in. using spatula, scoop, miniature core sampler, etc.	• Analytical results will be used for evaluating ecological and direct contact risk
SGE	Map zones of contamination beneath the infrastructure of WMA C if it can be successfully deployed.	• A means to extrapolate environmental information between sampling locations.

Characterization data will be used to determine if constituent concentrations exceed preliminary action levels in the vadose zone. Sampling will occur at locations where known or suspected releases have occurred and in areas that are assumed to have the greatest potential to encounter contamination. The sampling plan for WMA C has been optimized by utilizing a set of strategies that complement one another in conducting the characterization effort in such a way that they address the data needs of this DQO to support the alternative evaluations in the CMS and associated decision-making. The strategies include the following:

- Collect surface samples for screening and sampling for ecological and direct contact risk analysis.

- Deployment of direct-push technologies for screening and sampling throughout the vadose zone coupled with placement of SGE electrodes at each of the 27 sample locations.
- Conduct re-logging of drywells located around 200-C-103 and 200-C-106 tanks.
- Test the capability of SGE to discriminate below ground anomalies in an infrastructure rich environment between UPR-81, -82, and -86.
- Based on the SGE test results being successful, conduct SGE interrogation across WMA C to identify additional subsurface anomalies that may be characterized by additional direct push sampling and analysis.

This plan currently has 27 sample locations and it is anticipated that the number of vadose zone samples to be collected will be approximately 208. An average of eight samples is assumed. This includes four samples at approximately 0, 5, 10, and 14 ft bgs and an average of four samples below 15 ft at each sample hole. Including the completed work at UPR -82, -86, and -81 and the C-105 borehole, the total number of samples from WMA C for characterization will be approximately 392.

The general sampling approach for vertical direct pushes will include an initial push at each sample location to a depth of no greater than 200 ft bgs or refusal. Testing for gross gamma activity and neutron moisture logging will be done to identify candidate sample zone(s). A second direct push will be made to collect sample(s) material in the zone(s) of interest. Three samples will be collected at 5 ft, 10 ft, and 14 ft bgs. Additional samples will be collected at depths >15 ft based on gross gamma and neutron moisture logging data. Sufficient sample material is expected to be obtained to conduct a screening evaluation and if necessary, the full list of analytes.

Three locations are expected to require a slant direct push. These locations are associated with the C-101 (location A), C-104 (location J), and the C-200 tanks (locations C and D). Target areas of the vadose zone are beneath the spare inlet nozzles on these tanks, which are suspected to be a release site from tank overfilling. In addition, pipelines and cascade lines are targeted that could have produced releases adjacent to these tanks. Target areas and associated depth of samples are further defined in the WMA C work plan. Three samples will be collected at 5 ft, 10 ft, and 14 ft bgs at each location, and additional samples will be collected at depths >15 ft.

At C-203 three slant direct pushes will be made and 15 samples (five per each direct push) will be collected at depths >15 ft. Based on the data produced from the 15 samples collected at C-203, a determination will be made as to whether the balance of the C-200 tanks (C-201, -202, and -204) will require further characterization. If the data indicate that there has been no release from C-203, then no further vadose zone sampling at the C-200 tanks will be conducted. If data indicate a release occurred, then two slant direct pushes at each of the remaining C-200 tanks will be made to collect vadose zone samples.

At each of the direct push locations an array of SGE electrodes will be placed in anticipation of conducting an SGE evaluation of the entire tank farm.

8.2.3 Optimizing Characterization of WMA C

This section describes how the analytical evaluations of the vadose zone samples will be analyzed in a cost-effective manner without compromising the characterization effort to meet the requirements of this DQO.

8.2.3.1 Step Approach in Optimization of Characterization

To optimize the cost effectiveness of this characterization effort, the analysis of vadose zone samples will use a two-step approach. There are two key variables in this approach: (1) the concentration of any hazardous substance or radionuclide and (2) the risk created by these constituents. Step 1 is to assess if there are chemicals present that are of concern in the context of human health and biotic risk. If the answer is yes, proceed to step 2 which will provide the data to determine the extent of the risk created by the presences 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. Step 1 will employ a method-based screening process to determine if the soil has been contaminated with tank waste or pesticides and herbicides applied during tank farm operations. A select set of threshold indicator constituents will be used to indicate the presence of tank waste. If any one of the tank waste indicator analytes threshold is met or exceeded, then the full suite of step 2 analytes will be analyzed for (see Chapter 5). The step 1 analytes and their threshold values[7] 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	Detected at or above 232 µg/g
Cr (for Cr-6):	Detected at or above 26.8 µg/g
^{99}Tc	Detected
^{129}I	Detected
CN	Detected
TBP	Detected

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.

The following methods will be performed on samples to get the above analytes: inductively coupled plasma/mass spectrometry for ^{238}U, ^{239}Pu, and ^{99}Tc; ICP/AES for chromium; IC for NO_3; GEA for ^{137}Cs; separation/beta counting for ^{90}Sr; separation/GEA for ^{129}I; spectrophotometric for cyanide (CN), and semivolatile organic analysis by GC/MS for TBP.

[7] 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.*

Alpha energy analysis may be used as an alternative method for ^{239}Pu. While not an indicator analyte, ^{60}Co mobility will be evaluated. 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.

8.2.3.2 Optimizing for Organics, PCBs, Pesticides, and Gasoline and Diesel Range Organics

Optimizing the characterization of the vadose zone in and around WMA C involves several steps. Twenty-seven locations are identified for characterization of which five direct-push locations have been identified as candidate sites that have the highest potential for proving data on organic waste releases associated with tank wastes. A flow diagram for the overall optimization of sample analyses is provided in Figure 8-9. The five candidate direct-push sites are associated with URP-81(three locations) (location P) and on the northwest and northeast side of C-103 (two locations) (location L). At these five locations, following the spectral gamma and neutron logging, the entire suite of analytes will be analyzed in the sample zones (see Chapter 5). Tributyl phosphate will be used as the indicator organic for the occurrence of any organic contamination associated with tank waste. If TBP is not detected in any of the samples, then organics will be eliminated from the list of COPCs 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. Tributyl phosphate is selected as a specific tank waste contaminant. Other volatile and semivolatile compounds are 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.

Figure 8-9. Optimization of Sample Analysis (2 sheets)

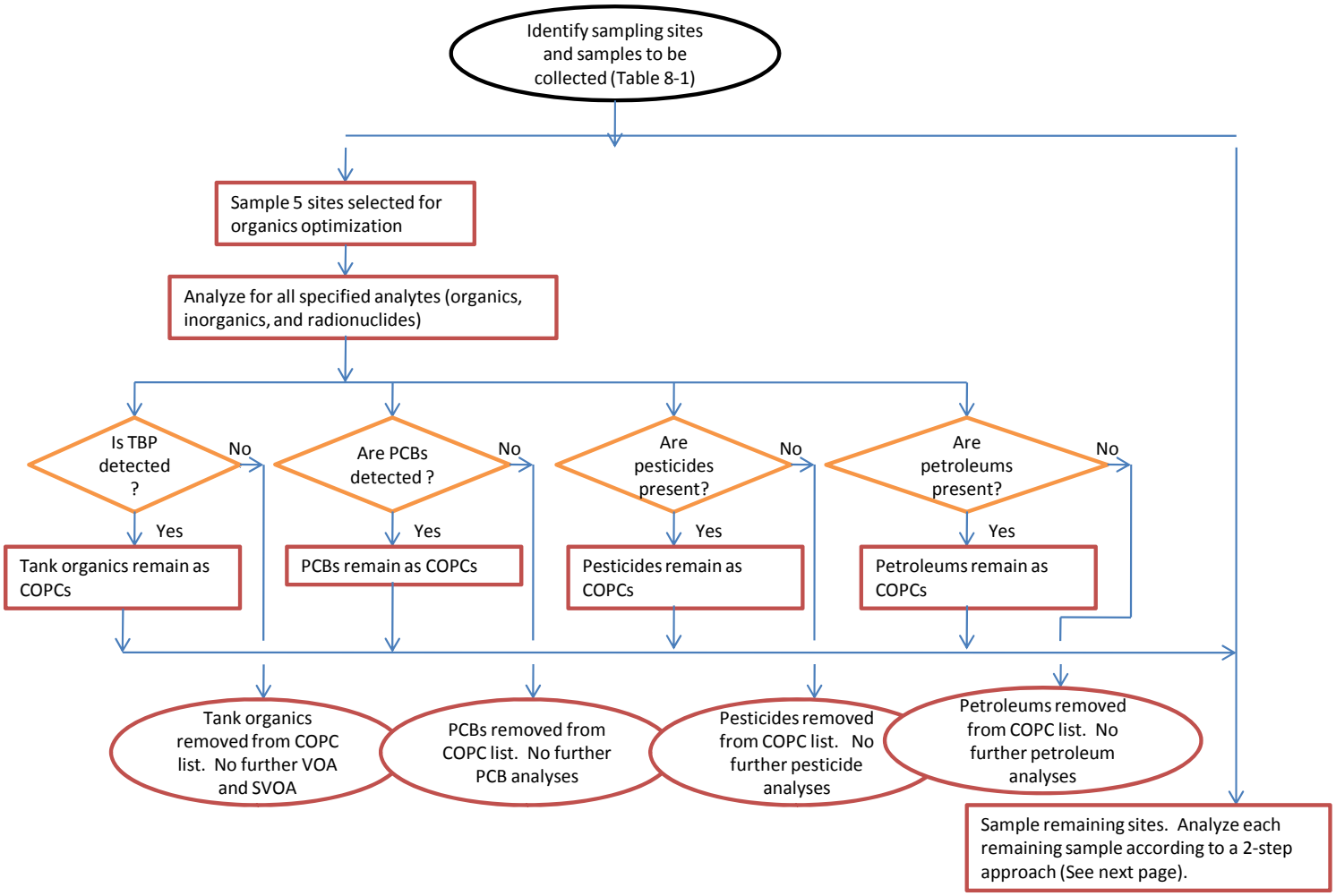
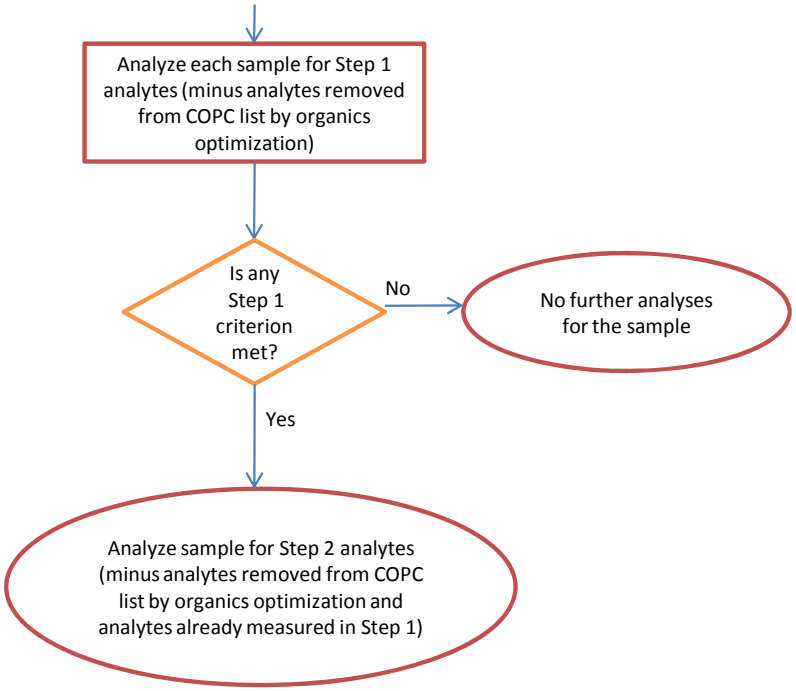


Figure 8-9. Optimization of Sample Analysis (2 sheets)



This list is not all inclusive but 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. The decision error for remediating an uncontaminated site where the reported contaminate does not exist can have severe consequences. The greater the cost incurred if an incorrect decision is made, the greater the severity (see Chapter 7).

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 discussed above (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 samples 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 farm as part of the operation and maintenance activities to prevent vegetation from establishing itself. Petroleum produces were also used, principally as fuels. At these five sites the collected samples from 0 to 14 ft will be evaluated for pesticides and petroleum. If a pesticide or petroleum product is detected at or above their 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 for and their threshold levels 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
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 would be conducted.

Similarly, if gasoline-range organics and diesel-range organics are not present in any of the samples from the five sites, these petroleum organics will be eliminated from the list of COPCs. If they are present in any of the samples, gasoline-range organics will remain on the list of COPCs for step 1 analyses of near-surface samples; diesel-range organics will be analyzed by gas chromatography/flame ionization detection only if GC/MS indicates that they are present in a sample.

Note: Sites P and L are identified as candidate sites where samples will be collected for organic optimization. Before sampling soils at other candidate sites, organic analyses on samples taken from sites P and L should be completed to evaluate if further organic analyses at the other sites are warranted. However, while preparing this DQO, the tank farm schedule was modified to include retrieval of waste in the 244-CR vault. The waste retrieval activity is expected to restrict access to site P. Furthermore, aboveground infrastructure near tank 241-C-103 may prevent early sampling at site L. Therefore, discussions with DOE and Ecology will be initiated during the Ecology review of the WMA C work plan and SAP to identify different sampling sites within the WMA C boundary for organic optimization.

8.2.4 Surface Geophysical Exploration

Confirming SGE findings is a significant and important aspect of the Phase 2 characterization effort at WMA C. Surface geophysical exploration has the potential to provide a means to extrapolate environmental information between sampling locations. The process of determining the limits of SGE requires deployment of SGE in an area where releases to the vadose zone are known to have occurred. The objective of confirming the application of SGE in WMA C will be to design and implement supplemental sampling efforts that target specific locations and to improve how to deploy SGE for use across the entire WMA. Selection of supplemental sampling locations will be based on the ability to successfully depict the three-dimensional (3-D) distribution of a soil resistivity anomaly from the SGE data.

Testing of this approach is a high priority in testing the overall application of SGE as a means of mapping existing zones (known and unknown) of contamination beneath the infrastructure of WMAs. Further development of both the data collection and the data analysis portions of SGE are also part of the confirmation process.

8.2.4.1 Process of Using SGE to Interrogate UPRs -81, -82 and -86 in WMA C

The subsurface in the vicinity of UPRs -81, -82, and -86 contains extensive buried infrastructure that supported waste transfers in and out of the C Farm. Buried infrastructure has regularly had a negative impact on the analysis and interpretation of SGE data. Electrodes have been placed at depth in WMA C in the vicinity of UPRs -81, -82, and -86. These electrodes have been emplaced to provide a means of interrogating the vadose zone from beneath the tank farm

infrastructure (e.g., pipelines, vaults, and diversion boxes) with the intent that these electrodes be used to enable resistivity measurements, representative of the sub-infrastructure vadose zone, to be taken.

A fully 3-D interrogation of the subsurface will be conducted. This 3-D view is produced from data provided by an array of electrodes consisting of surface electrodes and buried electrodes. The surface electrodes would be laid out in a closely spaced grid (approximating 3 m x 3 m spacing). All surface electrodes would be connected simultaneously to the data acquisition system along with the buried electrodes in the pattern. Collection of resistivity measurements across all pairs of electrodes provides the best opportunity to produce a 3-D visualization of the presence of any anomaly that resulted from releases associated with these UPRs or other unknown releases in the area of the test.

8.2.4.2 Evaluation of SGE analysis

The full 3-D interrogation of the subsurface in the test area provides the optimum opportunity to assess the capability of SGE in the infrastructure-rich environment of a tank farm. Samples from direct-push investigation around the three UPRs has indicated that the environmental spread of contaminants at these release sites is potentially far less than anticipated. Two hypotheses exist to explain this lack of spreading:

- The movement of contaminants was primarily vertical, and/or
- The releases were much less than originally estimated.

The 3-D application of SGE is expected to provide data to assess these hypotheses. Vertical resolution of the data is essential. If the SGE analysis indicates the presence of an anomaly, then supplemental direct-push sampling of that anomaly will help determine the applicability of SGE to guide the selection of sampling locations in subsequent characterization efforts including the potential refinement of information on unknown releases.

8.2.4.3 Decision Process to Deploy SGE Across WMA C

Following the confirmation testing of SGE between UPRs -81, -82, and -86, the decision will be made as to how SGE should be applied across the entirety of WMA C. This decision will be based on an analysis of the field test data, which must provide a sufficient degree of assurance that the data and analysis are able to discriminate, with a high degree of confidence, subsurface anomalies. As noted, the subsurface infrastructure (including over 10 miles of pipeline in WMA C) creates a difficult environment for SGE. Prior to applying SGE across WMA C, there are several issues that must be address based on the initial test data analysis:

- Should SGE be applied in the surface-to-surface, well-to-well, and well-to-surface configurations within the C Farm?
- Do buried electrodes provide sufficient value that they should be incorporated into the high resolution resistivity-leak detection monitoring system in addition to the drywells?

- Do buried electrodes provide information not attainable through the sole use of surface electrodes?
- Should consideration be given to shifting from SGE to an electrical resistance tomography approach for characterization?

Based on the answers to these questions and a thorough evaluation of the SGE test data, the decision will be made on how the full deployment of SGE across the entire C Farm will be made.

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