1223575

OFFICE OF RIVER PROTECTION
P.O. Box 450, MSIN H6-60
Richland, Washington 99352

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Ms. Jane A. Hedges, Program Manager
Nuclear Waste Program
Washington State
Department of Ecology
3100 Port of Benton Boulevard
Richland, Washington 99354

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Ms. Hedges:

THE U.S. DEPARTMENT OF ENERGY, OFFICE OF RIVER PROTECTION SUBMITS THE RETRIEVAL DATA REPORT FOR TANK 241-C-109

Reference: ORP letter from T.W. Fletcher to J.A. Hedges, Ecology, "The U.S. Department of Energy, Office of River Protection Submits the Retrieval Completion Certification and Report for Tank 241-C-109," 13-TF-0037, dated June 4, 2013.

The U.S. Department of Energy, Office of River Protection (ORP) is transmitting RPP-RPT-55284, Rev. 0, *Retrieval Data Report for Single-Shell Tank 241-C-109*, completed in accordance with the requirements of the Hanford Federal Facility Agreement and Consent Order Milestone M-045-86, "Submit a retrieval data report to Ecology for the 19 tanks retrieved under the Consent Decree in *Washington v. DOE*, Case No. 08-5085-FVS…" RPP-RPT-55284, Rev. 0 documents completion of waste retrieval, and post-retrieval sampling at 241-C-109 using modified sluicing as a first retrieval technology and chemical dissolution as a second retrieval technology.

ORP provided a retrieval completion certification on 241-C-109 on June 4, 2013 (Reference).

If you have any questions, please contact Joanne F. Grindstaff, Federal Project Director, Retrieval and Closure, at (509) 376-6202.

Kevin W. Smith
Manager

TF:CJK

Attachment

Distribution see page 2

cc w/attach:
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Environmental Portal, LMSI
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cc w/o attach:
S. Harris, CTUIR
J. Alzheimer, Ecology
J.L. Lyon, Ecology
J.B. Price, Ecology
N.H. Uziemblo, Ecology
C.L. Whalen, Ecology
D.A. Faulk, EPA
S.E. Hudson, HAB
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R.E. Piippo, MSA
G. Bohnee, NPT
K. Niles, ODOE
R. Buck, Wanapum
R.M. Allen, WRPS
S.J. Eberlein, WRPS
L.A. Fort, WRPS
J.A. Joyner, WRPS
J.J. Luke, WRPS
M.G. Peloquin, WRPS
R. Jim, YN
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RETRIEVAL DATA REPORT FOR SINGLE-SHELL TANK 241-C-109

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R. S. Wiegman — Date: 2/24/14 — Date:

Date: — Date:

(c) Responsible Manager – (Print/Sign): S. J. Eberlein — Date: 02/24/14

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T. H. May	H8-04		
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Retrieval Data Report for Single-Shell Tank 241-C-109

Author Name:
L. A. Fort, K. M. Scott – Washington River Protection Solutions, LLC
T. H. May – YAHSGS, LLC
Richland, WA 99352
U.S. Department of Energy Contract DE-AC27-08RV14800

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Abstract: This Retrieval Data Report presents information showing that single-shell tank 241-C-109 has undergone two waste retrieval campaigns, each to its limits of technology. The first waste retrieval technology deployed was modified sluicing with assistance from the FoldTrack® Mobile Retrieval Tool, which left ~7,800 gallons of the initial waste inventory; the second waste retrieval technology was chemical dissolution (caustic cleaning). The residual waste volume contained within tank 241-C-109 following chemical dissolution is estimated to be 1,210 gallons or 230 cubic feet. This Retrieval Data Report also summarizes the potential risk to human health from waste remaining in the tank, provides details on the technologies deployed and their respective performances during the waste removal campaigns, and describes measures taken to prevent and detect leaks during waste retrieval operations.

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L. A. Fort
K. M. Scott
Washington River Protection Solutions, LLC

T. H. May
YAHSGS, LLC

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Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
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washington river protection solutions

P.O. Box 850
Richland, Washington 99352

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EXECUTIVE SUMMARY

This Retrieval Data Report presents information in accordance with the requirements of *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1989) Milestone M-045-86, due 12 months after the U.S. Department of Energy (DOE) certifies to the Washington State Department of Ecology that DOE has completed retrieval of a single-shell tank covered by the Consent Decree in *Washington v. DOE*, Case No. CV-08-5085-FVS. The DOE submitted Revision 1 of its certification of retrieval, RPP-53824, *Retrieval Completion Certification Report for Tank 241-C-109*, on May 9, 2013.

This Retrieval Data Report presents information showing that single-shell tank 241-C-109 (C-109) has undergone two waste retrieval campaigns, each to its limits of technology. The Best-Basis Inventory estimated that tank C-109 initially contained ~ 63,400 gal (~8,480 ft^3) of waste at the start of retrieval operations. The first waste retrieval technology deployed, approved by the Washington State Department of Ecology on June 15, 2005, was modified sluicing with assistance from the FoldTrack®[1] Mobile Retrieval Tool. This technology removed all but ~7,800 gal (1,043 ft^3) of the initial waste inventory. The second waste removal technology, approved by the Washington State Department of Ecology on February 16, 2012, was chemical dissolution (caustic cleaning). A final estimate of residual waste volume indicates that tank C-109 contains 230 ft^3 with an upper confidence level of 270 ft^3 (RPP-CALC-54759, *Post-Hard Heel Retrieval Camera/CAD Modeling System Waste Volume Estimate for Tank 241-C-109*). The DOE has determined the Consent Decree waste residue goal has been met and that deployment of a third waste retrieval technology is not necessary. This Retrieval Data Report also summarizes the potential risk to human health from waste remaining in the tank, provides details on the technologies deployed and their respective performance during the waste removal campaigns, and describes measures taken to prevent and detect leaks during waste retrieval operations.

The tank C-109 modified sluicing waste retrieval campaign began June 19, 2007 and reached the limits of technology on August 23, 2007. The FoldTrack® Mobile Retrieval Tool began sluicing operations on June 2, 2008. At the end of bulk retrieval using modified sluicing and the FoldTrack® Mobile Retrieval Tool, the remaining waste was comprised mostly of solids (hard heel) that were not mobilized by sluicing and were insoluble in the double-shell tank 241-AN-106 supernate. The caustic cleaning retrieval operations began on March 8, 2012 and reached the limits of technology on September 12, 2012. The tank C-109 waste which was removed was transferred to double-shell tank 241-AN-106.

The tank C-109 leak detection, monitoring, and mitigation program deployed during retrieval operations consisted of high-resolution resistivity techniques along with readings from a combination of drywell moisture measurements, waste volume assessments (mass balances), and visual inspection to detect and control potential leaks. No leaks were detected during tank C-109 retrieval operations.

[1] The FoldTrack® Mobile Retrieval Tool is manufactured by Non Entry Systems Ltd., UK Patent Application No: 0718573.9.

The inventory of constituents in the residual waste remaining in tank C-109 was determined by laboratory analysis of waste samples taken. Composition of the residual waste in tank C-109 is documented in RPP-RPT-55803, *Tank 241-C-109 Residual Waste Inventory Estimates for Component Closure Risk Assessment*. The risk assessment for the residual waste in tank C-109, based on sampling analysis, shows that for the groundwater pathway, the estimated risk impacts for tank C-109 were well below performance objectives. For all inadvertent intruder scenarios other than the suburban garden scenario (a sensitivity case) at 100 years after closure, the estimated risk impacts for tank C-109 were well below performance objectives. For the suburban garden scenario at 500 years after closure, the effects are below performance objectives.

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LIST OF TERMS

Abbreviations and Acronyms

3D	three-dimensional
BBI	Best-Basis Inventory
BBIM	Best-Basis Inventory Maintenance
CAD	computer-aided design
CAS	Chemical Abstract Services
CCMS	Camera/CAD Modeling System
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
DQO	Data Quality Objective
DST	double-shell tank
Ecology	State of Washington Department of Ecology
EPA	U.S. Environmental Protection Agency
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
HRR	high-resolution resistivity
HTWOS	Hanford Tank Waste Operations Simulator
ICP	inductively coupled plasma
ILCR	incremental lifetime cancer risk
LDM	leak detection and monitoring
LDMM	leak detection, monitoring, and mitigation
MS	mass spectrometry
MTCA	*Model Toxics Control Act*
ORP	U.S. Department of Energy Office of River Protection
ORSS	Off-Riser Sampling System

PA	performance assessment
RCW	*Revised Code of Washington*
RDR	Retrieval Data Report
RSD	relative standard deviation
SST	single-shell tank
SVOA	semivolatile organics analysis
TIC	tentatively identified compound
TSAP	tank sampling and analysis plan
TSR	Technical Safety Requirement
TWINS	Tank Waste Information Network System
UCL	upper confidence level
VOA	volatile organic analysis
WAC	*Washington Administrative Code*
WMA	waste management area
WRPS	Washington River Protection Solutions, LLC
WRS	waste retrieval system
WTT	drywell-to-tank
WTW	drywell-to-drywell

Units

ft^3	cubic feet
gal	gallon
in.	inch
kgal	thousand gallons

1.0 INTRODUCTION AND BACKGROUND

Retrieval of single-shell tank (SST) 241-C-109 (C-109) waste was completed in two campaigns, modified sluicing and caustic cleaning. The first campaign, approved by the Washington State Department of Ecology (Ecology) on June 15, 2005, consisted of modified sluicing technology as described in Revision 3C of RPP-21895, *241-C-103 and 241-C-109 Tanks Waste Retrieval Work Plan*. The campaign began on June 19, 2007 and reached its limit of technology on August 23, 2007. Volume displacement calculations and video evaluation performed during the July 26, 2007 supernatant soak of solids estimated that ~ 9,400 gal (~1,260 ft^3) of waste remained in tank C-109 (RPP-CALC-34573, *Estimate of Waste Volume and Percent Retrieved for Single-Shell Tank 241-C-109*). The supernatant soak process had no measurable effect on retrieval efficiency.

On June 2, 2008 the FoldTrack®[2] Mobile Retrieval Tool began operations to assist in the sluicing operations, leaving a volume of ~7,800 gal (~1,040 ft^3) of sludge remaining (RPP-RPT-51343, *Derivation of Best-Basis Inventory for Tank 241-C-109 as of October 1, 2012*). The FoldTrack® Mobile Retrieval Tool was deployed as a demonstration prior to the execution and implementation of the retrieval requirement in the Consent Decree (hereinafter) in *Washington v. DOE*, Case No. CV-08-5085-FVS (October 25, 2010). No credit was taken for the FoldTrack® Mobile Retrieval Tool as a separate technology in removing waste from tank C-109 under the Consent Decree requirements.

The second campaign, approved by Ecology on February 16, 2012, used a caustic cleaning retrieval operation. The campaign began on March 8, 2012 and reached its limit of technology on September 12, 2012. After concluding the second waste retrieval campaign, the quantity of waste remaining in tank C-109 was estimated to be ~1,720 gal or ~230 ft^3 (RPP-CALC-54759, *Post-Hard Heel Retrieval Camera/CAD Modeling System Waste Volume Estimate for Tank 241-C-109*). The chemical retrieval process (caustic cleaning) was identified as the second technology as described (and approved by Ecology on February 16, 2012) in Revision 5 of RPP-21895.

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 *Atomic Energy Act of 1954*, as amended) has been incorporated into this document, it is not incorporated for the purpose of regulating the radiation hazards of such components under the authority of Chapter 70.105, "Hazardous Waste Management," *Revised Code of Washington* (RCW) (known as the *Hazardous Waste Management Act*) and its implementing regulations, but is provided for information purposes only.

[2] The FoldTrack® Mobile Retrieval Tool is manufactured by Non Entry Systems Ltd., UK Patent Application No: 0718573.9.

1.1 PURPOSE

This Retrieval Data Report (RDR) provides information required by *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1989) (HFFACO) Milestone M-045-86. The report documents the following aspects of tank C-109 retrieval:

- Residual tank waste volume measurement, including associated calculations
- The results of residual tank waste characterization
- Retrieval technology performance documentation
- The U.S. Department of Energy (DOE)'s updated post-retrieval risk assessment
- Opportunities and actions being taken to refine or develop tank waste retrieval technologies based on lessons learned
- Leak detection monitoring and performance results.

1.2 REGULATORY REQUIREMENTS

Retrieval of waste from tank C-109 and submittal of this RDR (in accordance with conditions stated in the HFFACO) are necessary requirements for closing the Hanford SST system. The HFFACO Milestone M-045-86 provides in pertinent part:

> "Submit a retrieval data report to Ecology for the 19 tanks retrieved under the Consent Decree in *Washington v. DOE*, Case No. 08-5085-FVS, which report shall include the following elements only of Section 2.1.7 of Appendix I to the HFFACO:
>
> 1) Residual tank waste volume measurement, including associated calculations;
> 2) The results of residual tank waste characterization;
> 3) Retrieval technology performance documentation;
> 4) DOE's updated post-retrieval risk assessment;
> 5) Opportunities and actions being taken to refine or develop tank waste retrieval technologies, based on lessons learned and,
> 6) LDMM monitoring and performance results."

The TWRWP establishes the two retrieval technologies that are to be deployed to their respective "limits of technology" in an effort to obtain the Consent Decree waste residue goal of 360 ft^3 or less. The two technologies established by the TWRWP for tank C-109 were deployed to their limits of technology, resulting in a waste residual volume of ~230 ft^3, less than the Consent Decree goal of 360 ft^3; as a result, DOE is not required to deploy a third retrieval technology in tank C-109.

1.3 DOCUMENT STRUCTURE

This tank C-109 RDR is organized to present information required by Milestone M-045-86 of the HFFACO Action Plan.

- **Section 1**, *Introduction and Background* discusses the purpose and scope of tank C-109 waste retrieval, presents requirements applicable to this report, and outlines the report structure.

- **Section 2**, *Single-Shell Tank 241-C-109 Residual Waste Volume Measurement* describes the method for determining the volume of residual waste in tank C-109 and presents results of the volume measurement process.

- **Section 3**, *Residual Tank Waste Characterization* lists requirements for characterization of tank waste, describes methods and procedures used to sample and analyze the waste, and describes the results of laboratory analysis.

- **Section 4**, *Retrieval System Performance* provides an evaluation of how well the waste retrieval system (WRS) performed and provides a comparison of actual performance against predicted performance.

- **Section 5**, *Post-Retrieval Single-Shell Tank 241-C-109 Risk Assessment* describes the potential risk to human health from tank C-109 residual waste. This section identifies and discusses contaminants of potential concern in the waste, describes the effects of waste retrieval and closure on long-term human health risk, presents expected cumulative health effects of source terms, relates calculated risk to residual waste volume, and summarizes overall conclusions of the risk assessment. To satisfy recent requests by Ecology, this section also provides additional risk management information related to how concentrations of constituents remaining in waste residuals within tank C-109 compare against the *Washington Administrative Code* (WAC) 173-340, "Model Toxics Control Act – Cleanup" cleanup standards. These soil cleanup standards are developed to be protective of direct contact exposures and groundwater use.

- **Section 6**, *Opportunities* discusses recommendations for future actions associated with tank C-109 and opportunities to refine future waste retrieval operations at other tanks based on lessons learned.

- **Section 7**, *Leak Detection, Monitoring, and Mitigation* describes leak detection, monitoring, and mitigation (LDMM) methods and procedures, presents an LDMM chronology for tank C-109 waste retrieval, and summarizes LDMM results.

- **Section 8**, *References* contains references for material cited in the report.

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2.0 SINGLE-SHELL TANK 241-C-109 RESIDUAL WASTE VOLUME MEASUREMENT

The waste in tank C-109 was retrieved using modified sluicing and chemical cleaning, as described by RPP-21895. A description of the retrieval systems and chronology of the retrieval processes may be found in RPP-53824, *Retrieval Completion Certification Report for Tank 241-C-109*. Following retrieval, the residual waste volume was determined. This section presents the residual waste volume measurement process and the results for tank C-109. The total measured volume of residual waste in tank C-109 was the sum of volumes remaining in the tank dish, on the tank walls, on the stiffener rings, and in the void spaces in equipment left in the tank.

2.1 RESIDUAL WASTE VOLUME MEASUREMENT PROCESS

The waste volume measurement approach is summarized in Sections 2.1.1 through 2.1.3 and is described in RPP-CALC-53490, *Estimated Waste Volume Remaining in Single-Shell Tank 241-C-109 after Hard Heel Retrieval* and RPP-CALC-54759. All solids were covered for Honeywell Enraf[3] (hereafter referred to as Enraf) volume displacement estimates.

Video assessments provided the primary basis for preliminary waste volume estimates in RPP-RPT-53486, *Single-Shell Tank 241-C-109 Hard Heel Retrieval Completion Report*.

The Camera/computer-aided design (CAD) Modeling System (CCMS) volume estimate is the official estimate included in the tank C-109 RDR and is used for tank inventory estimates and risk calculations in accordance with Appendix I of the HFFACO (Ecology et al. 1989). The post-retrieval CCMS volume estimates were completed in accordance with RPP-23403, *Single-Shell Tank Component Closure Data Quality Objectives*.

The residual tank waste volume estimates include waste in the following four locations:

- Tank bottom (section 2.1.1)
- Stiffener rings (section 2.1.2)
- Tank wall (section 2.1.2)
- Void spaces of equipment in the tank (Section 2.1.3).

2.1.1 Video Camera/Computer-aided Design Modeling System

The post-hard heel retrieval waste volume in the bottom of tank C-109 was estimated using the CCMS method per TFC-ENG-FACSUP-CD-22, "Post-Retrieval Tank Waste Volume Determination." The CCMS videos of tank C-109 were taken on February 6, 2013 from cameras located in riser 3 and riser 5 and videos were recorded at heights of ~13 ft and 18 ft above the bottom of the tank (Figures 2-1, 2-2, and 2-3). Instructions for obtaining the CCMS videos can be found in Appendix A of RPP-CALC-54759. Video at 8 ft above the bottom of the tank could

[3] Honeywell Enraf is a product of Honeywell Process Solutions, Strahlenbergerstr. 110-112, 63067 Offenbach, Germany.

not be obtained because both camera cables "bird-nested" (bunched up) at the top of the riser and could not be lowered further.

After the CCMS video was completed, the video was reviewed to develop an AutoCAD Civil 3D[4] drawing of tank C-109 and the tank waste residuals and to complete tank bottom volume estimates per TFC-ENG-FACSUP-CD-22. The AutoCAD Civil 3D software was tested and verified per RPP-52784, *Video Camera/CAD Modeling System for Retrieval: HISI #3254 Software Management Plan.*

A template of the 100-series 241-C Farm tanks was developed from tank construction drawings (BPF-73550, *Specifications For Construction of Composite Storage Tanks Bldg. No. 241 Hanford Engineer Works Project 9536*, Drawing D-3). The area and depth of waste and equipment in the tank bottom was estimated based on tank features and the dimensions of equipment and debris observed in the CCMS video. The waste contour information was then added to the template drawing to show waste remaining in the tank bottom. After completing the drawings, the AutoCAD Civil 3D software calculated a waste volume by integrating between the waste contour lines and the tank bottom profile.

The estimated volume of waste on the tank bottom, calculated using Auto CAD Civil 3D, was 191.8 ft^3. The waste volume consists of an estimated 92.6 ft^3 (2.622 $m^3 \times 35.31\ ft^3/m^3$) of solids piles and a 99.2 ft^3 (2.809 $m^3 \times 35.31\ ft^3/m^3$) pool of liquids and submerged solids near the center of the tank (Figure 2-3). The shape of the pool, not round and off-centered, indicates that the shape of the tank dish is not the same as in the tank template drawing. This was considered in estimating the depth of waste at different locations in the tank. It is conservatively assumed that the waste in the pool and on the tank bottom remains saturated, and the tank bottom waste volume is not adjusted for porosity.

2.1.2 Estimation of Waste Remaining on Tank Surfaces

The estimated volume of waste on the stiffener rings and tank walls after hard heel retrieval was 35.7 ft^3 (267 gal). This was estimated based on the surface area of four sets of stiffener rings located at 4.5-ft intervals from the top of the tank dish and the average depth of waste on the rings at each level. RPP-CALC-53490 provides a detailed analysis of the estimated waste thickness on the tank walls and each of the stiffener rings.

The volume of waste on the stiffener rings was determined by estimating the average depth of the waste on each of the stiffener rings and multiplying by the surface area of each of the rings (97.6 ft^2) (RPP-CALC-34573). The stiffener rings and tank wall were sprayed with the caustic circulating solution and again with the aluminate dissolution water. Because little additional waste was removed by the aluminate dissolution water, the rings were sprayed only minimally during sluicing. RPP-CALC-34573 shows the amount of waste on the stiffener rings before hard heel retrieval. The average depths of waste on the stiffener rings were estimated based on video observation and comparisons with video estimates before and after the caustic retrieval. Figure 2-4 shows photographs of the rings after completing retrieval. Table 2-1 shows the estimated depth and volume of waste remaining on the stiffener rings.

[4] AutoCAD Civil 3D is a product of Autodesk, Inc., 111 McInnis Parkway, San Rafael, California.

Figure 2-1. Section View Showing Video Camera Elevations.

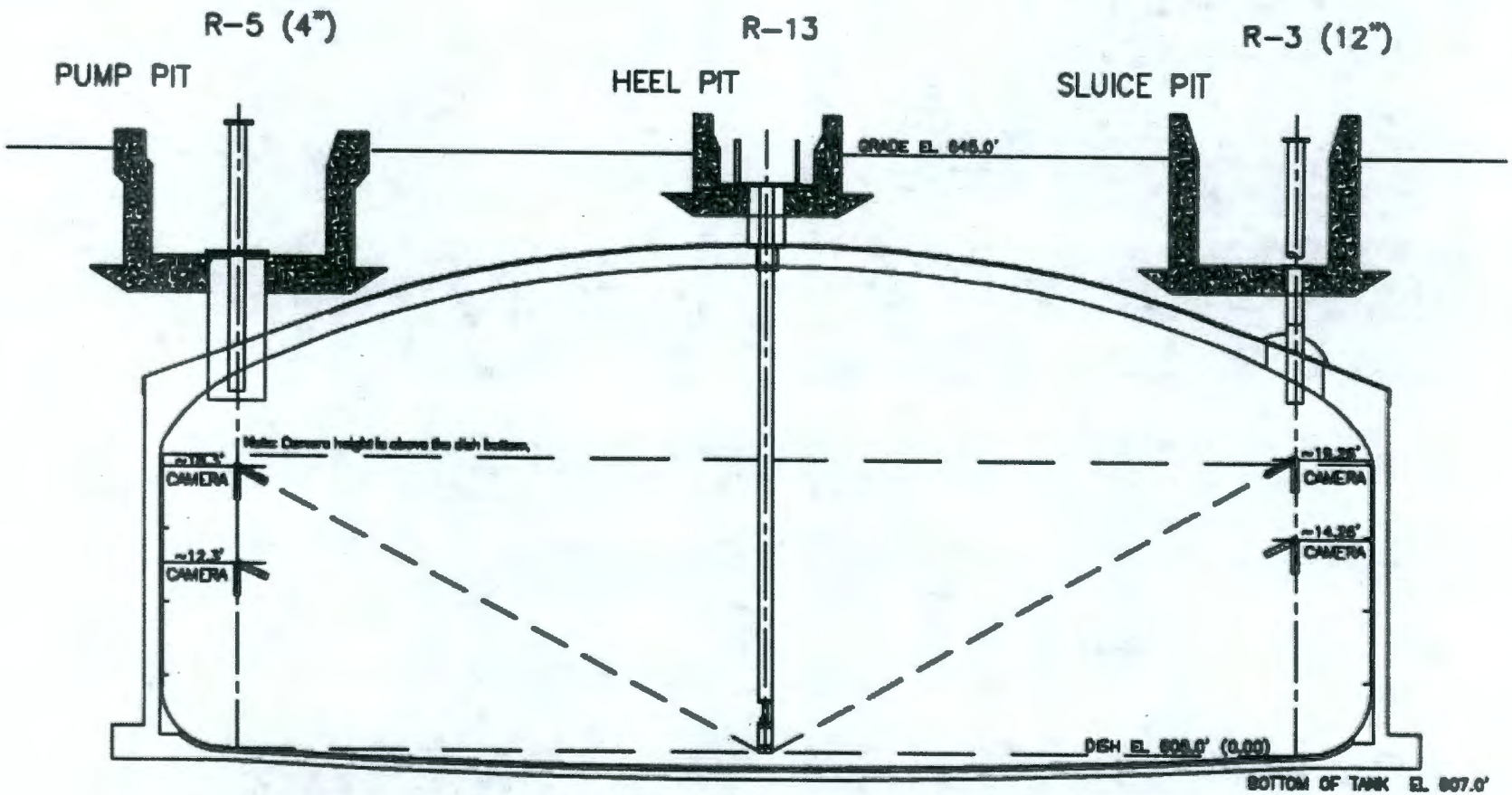
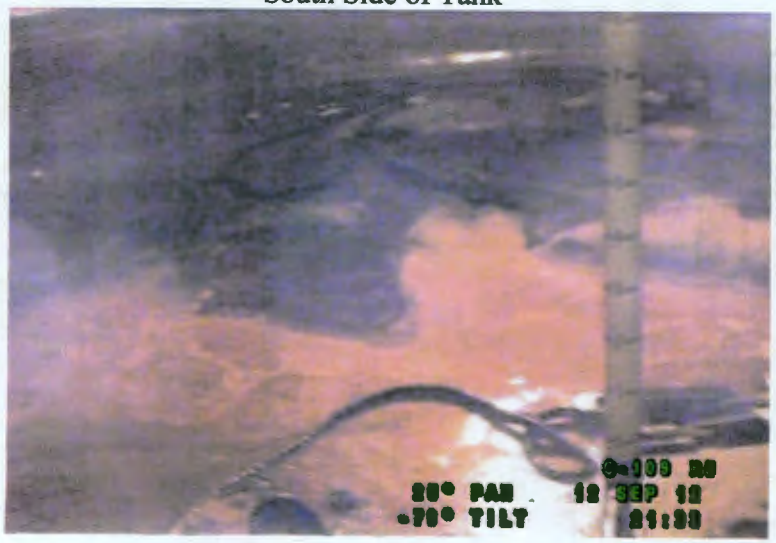


Figure 2-2. Photographs of Tank 241-C-109 after Caustic Cleaning.

Solids on West Side of Tank

Solids on East Side of Tank

South Side of Tank



North Side of Tank

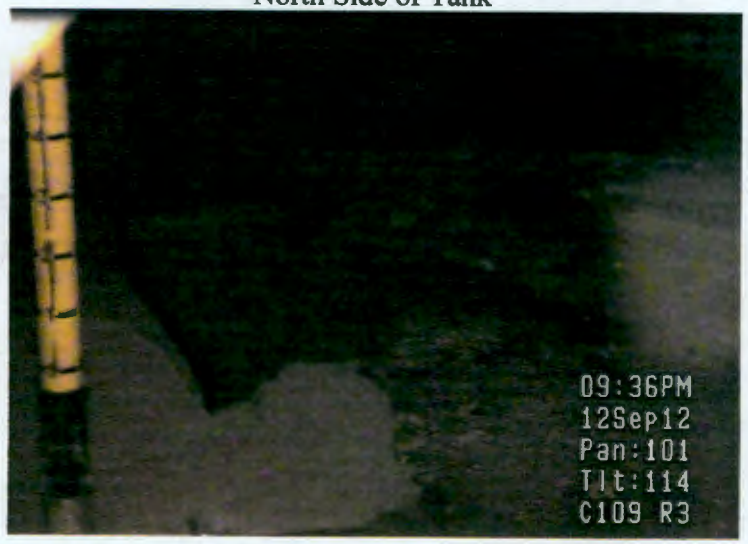
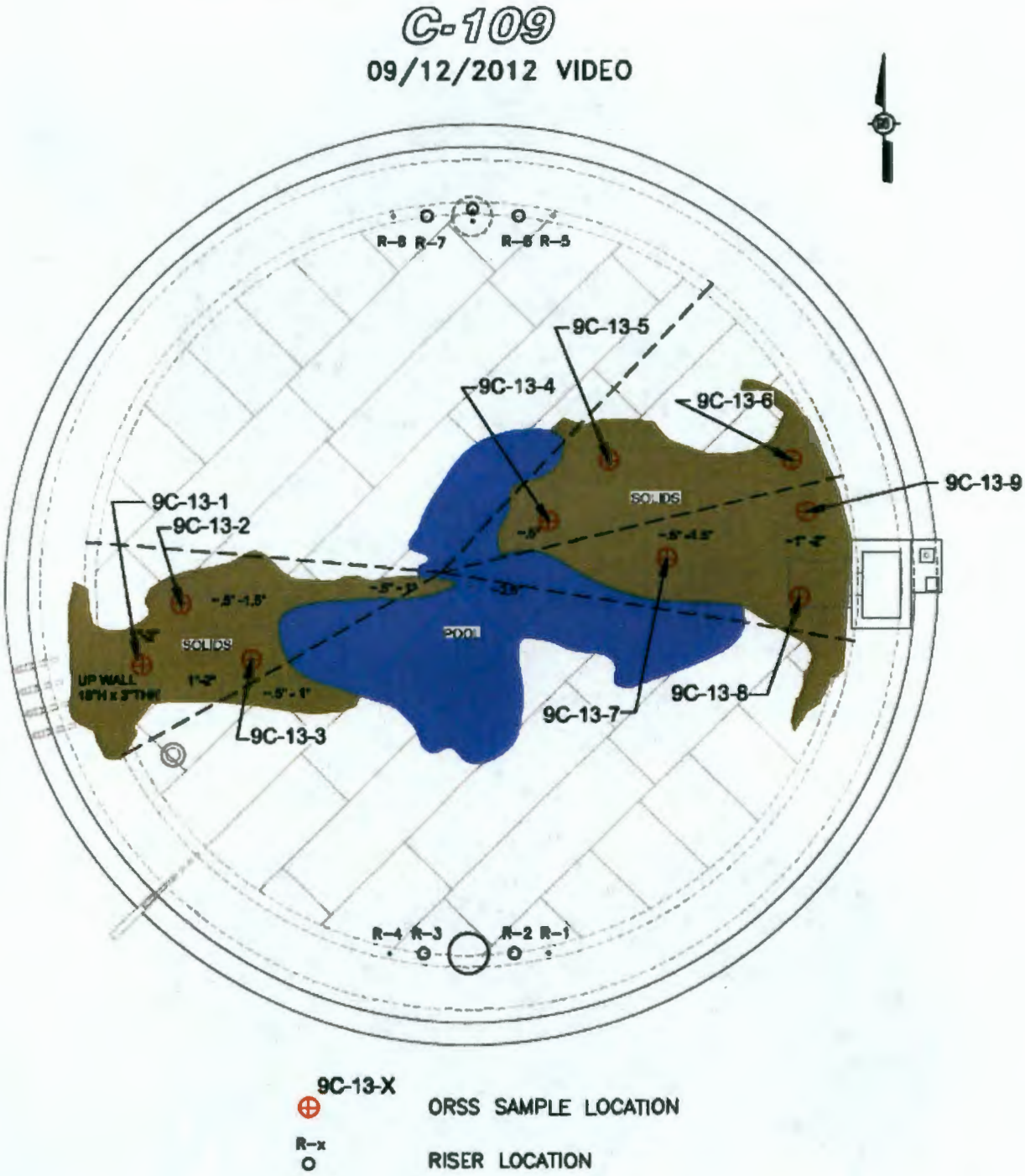


Figure 2-3. Plan View of Tank 241-C-109 Waste Residuals.



The volume of waste on the stiffener rings represents the bulk volume of waste remaining on tank surfaces. This number needs to be corrected for the porosity of the solids. This is due to the fact that the waste on the stiffener rings is estimated by apparent volume, which would inherently

include the actual volume plus a porosity correction. Since the exact porosity value is not known, a porosity of 0.17 was assumed.

Figure 2-4. Photos of Waste on Tank 241-C-109 Walls and Stiffener Rings.

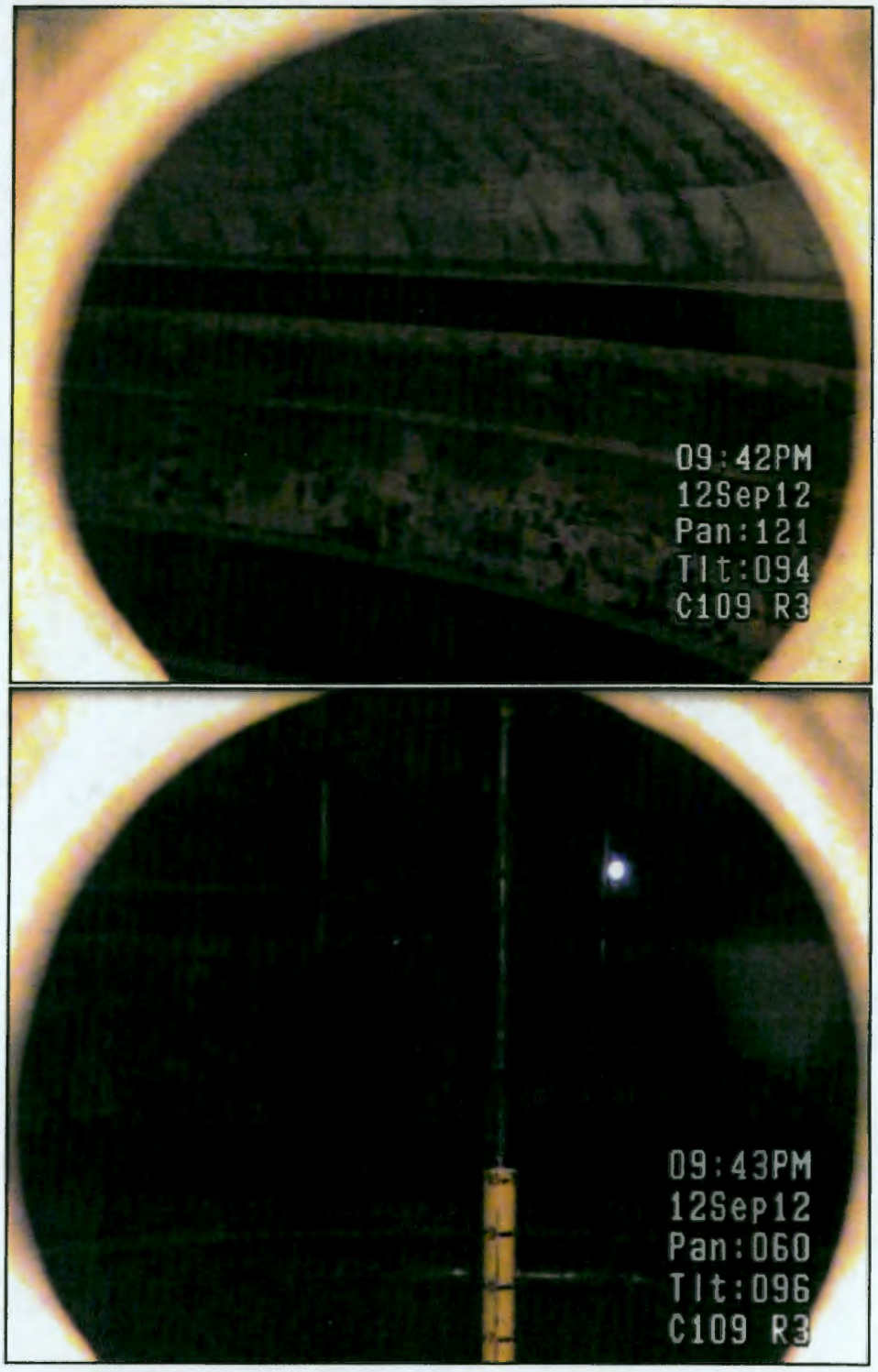


Table 2-1. Waste Estimates for Stiffener Rings.

Stiffener Ring #	Average Waste Depth (inches)	Waste Volume (ft^3)
1 (top)	0	0
2	0.75	6.1
3	1.5	12.2
4 (above knuckle)	1	8.1
Total		26.4

The total volume of waste on the stiffener rings = 26.4 ft^3 × (1 – 0.17) ~21.9 ft^3 (164 gal) at a porosity of 0.17.

The waste on the walls was also determined by estimating an average depth and multiplying by the surface area between each stiffener ring (1,060 ft^2) (RPP-CALC-34573). Figure 2-5 shows a photo of waste remaining on the tank walls. The tank walls between the third stiffener ring and bottom of the knuckle appear to be clean with negligible waste residue remaining. Some of the waste was removed on the walls between the first and third stiffener rings, but not all. Estimates are shown in Table 2-2. Because of the thin layer of waste on the tank walls, a uniform, nonporous layer is assumed.

2.1.3 Estimation of Waste in Equipment

Per RPP-23403, tank waste remaining in equipment is included in the total waste volume, but the tank equipment is not included. The estimated volume of waste in tank equipment was 1.9 ft^3 (14 gal). This estimate assumes that waste is contained in 38 ft of 3-in. hose on the tank bottom. The volume is actually less because several small hoses are contained within the 3-in hose. The previous estimate for waste remaining in equipment (RPP-CALC-53490) was determined to be high. While the hose length for the FoldTrack® was 110 ft (VI-50525, "P-2602 Foldtrack Mobile Retrieval Tool System"), only 38 ft of hose was observed on the tank bottom. The amount of waste estimated to be in other miscellaneous pipe on the tank bottom was less than a gallon.

2.2 RESIDUAL WASTE VOLUME RESULTS

The total CCMS volume of post-retrieval residual waste in tank C-109 and the waste volumes associated with the various waste components are given in Table 2-3. The best estimate for the total post-retrieval waste volume in tank C-109 is 230 ft^3 with a 95% upper confidence level (UCL) of 268 ft^3.

Figure 2-5. Tank Wall with Stiffener Rings #2, #3, and #4.

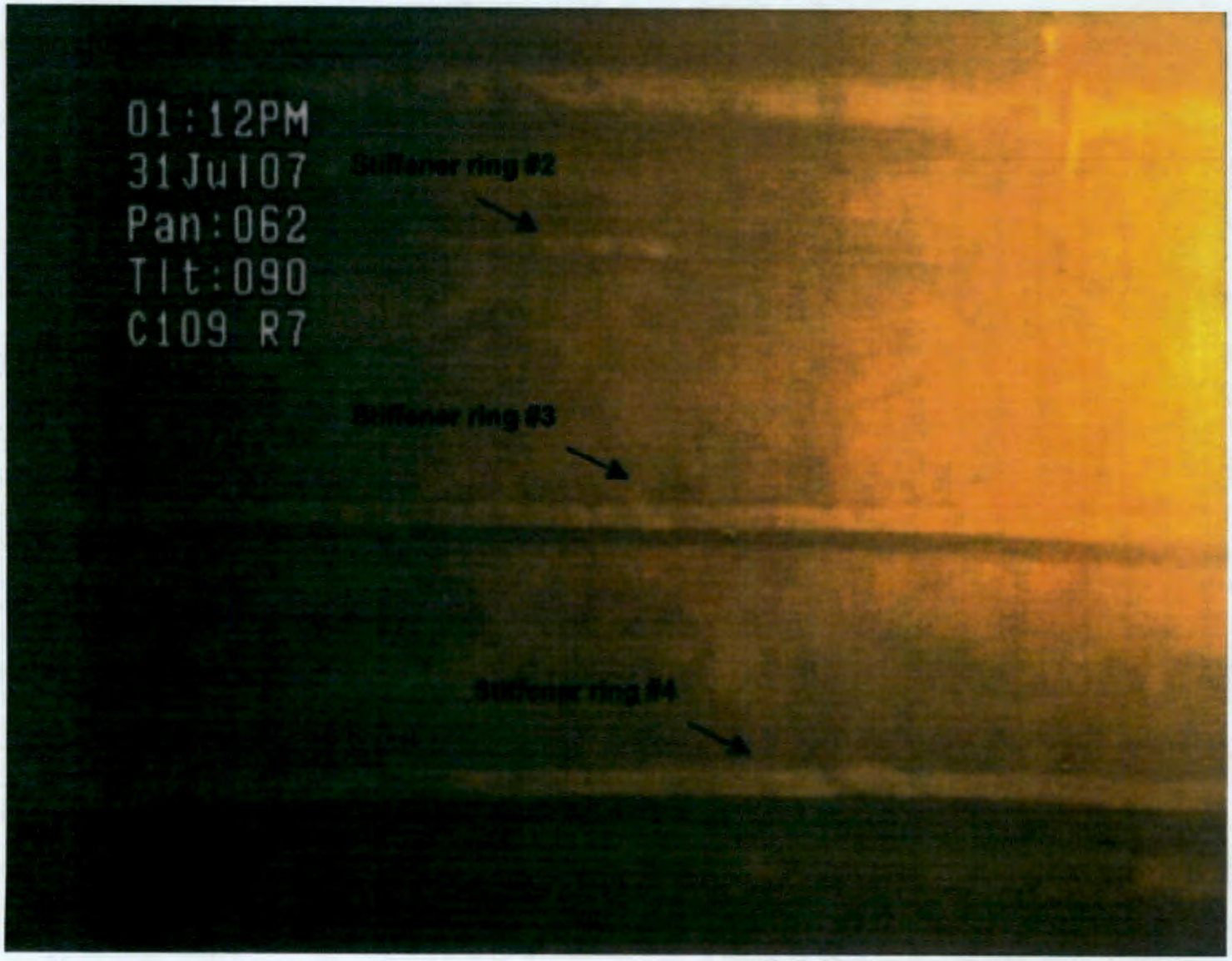


Table 2-2. Waste Estimates for Tank Walls.

Section of tank wall	Average Waste Depth (inches)	Waste Volume (ft^3)
Between 1st and 2nd ring	0.03125	2.8
Between 2nd and 3rd ring	0.125	11.0
Between 3rd and 4th ring	0	0
Below 4th ring	0	0
Total		13.8

Table 2-3. Tank 241-C-109 Total Waste Volume and Component Waste Volumes.

Component	Waste volume			95% UCL[a] (ft^3)
	m^3	gal	ft^3	
In the bottom (dish) of the tank (solids and liquids)	5.4	1,436	192	230
Waste in tank equipment[b]	0.05	14	1.9	1.9
On the stiffener ring and tank walls[c]	1.01	267	35.7	35.7
Total[d]	6.5	1,717	230	268

1 ft^3 = 7.481 gal, 1 m^3 = 264.2 gal, UCL = upper confidence level, CCMS = camera/computer-aided design computer modeling system

Notes:

[a] Per RPP-23403, *Single-Shell Tank Component Closure Data Quality Objectives*, the estimated CCMS error is calculated using: Volume at 95% upper confidence level = 1.195 × CCMS reading + 0.27 ft^3.

[b] Negligible compared to other waste components.

[c] The estimated volume for waste on the stiffener ring and on the tank wall is the upper bounding estimate.

[d] Total may not equal sum of individual volumes because of rounding.

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3.0 RESIDUAL TANK WASTE CHARACTERIZATION

This section describes the results of residual tank waste characterization for tank C-109. Presented are the average and upper bounding estimates of residual waste inventory based on laboratory analysis of waste samples taken after waste removal actions were completed. The calculated inventories are used as input to estimate the potential risk to human health that arises from the residual waste. This risk assessment is discussed in Section 5.0.

3.1 SAMPLING AND ANALYSIS OF RESIDUAL WASTE

The following documents provide requirements for sampling and analysis of the residual waste.

- RPP-23403, *Single-Shell Tank Component Closure Data Quality Objectives* – This document describes the sampling and analysis strategy developed by implementing the Data Quality Objectives (DQO) process to ensure appropriate data are collected to support SST component closure activities.

- RPP-PLAN-23827, *Sampling and Analysis Plan for Single-Shell Tanks Component Closure* – This document identifies regulatory requirements for field sampling, laboratory analysis, and data reporting for residual waste samples to ensure appropriate data are collected to support SST closure activities.

- RPP-PLAN-53814, *ORSS Sampling and Analysis Plan for Waste Solids in Tank 241-C-109 to Support Tank Closure* – This tank sampling and analysis plan (TSAP) summarizes the sampling and analysis requirements in the DQO for post-sluicing and post-heel removal solids. The TSAP provides additional guidance and clarification for satisfying the requirements. The guidance and clarification are necessary to address conditions that are specific to tank C-109.

The post-sluicing and post-heel removal sampling events, respectively, are described below. Both sampling events were conducted using the Off-Riser Sampling System (ORSS).

The ORSS consists of a remotely-operated mobile sampler and a sample carrier. This tool is designed to collect samples of solids that are not located directly under a riser. The ORSS is lowered through a 12-in.-diameter riser into the tank and then maneuvered remotely to a location specified in the TSAP to collect a waste sample. The sampler deposits the waste material into a sample jar located on the sample carrier, which is then raised into the glove bag at the top of the riser. The sample is removed from the glove bag and shipped to the 222-S Laboratory for analysis. This process is repeated until the samples specified in the TSAP are collected. A photograph of an ORSS is shown in Figure 3-1.

Samples of solids remaining in tank C-109 after modified sluicing were taken for laboratory testing to evaluate additional retrieval technologies; all analyses specified in the DQO and the sampling and analysis plan were also performed on the samples. The data are reported in RPP-RPT-50883, *Final Report for the Analysis of Waste Solids in Tank 241-C-109, 2011.*

Figure 3-1. Photograph of an Off-Riser Sampling System.

3.2 SAMPLING AT SINGLE-SHELL TANK 241-C-109

Field sampling and laboratory analysis requirements were specified in RPP-PLAN-53814. In accordance with the sampling design specified in RPP-23403, nine grab samples were taken in May 2013. The tank floor was divided into three pie-shaped regions, one on the west side of the tank and two adjacent on the east side of the tank encompassing most of the tank C-109 exposed solids. Three solid ORSS grab samples were taken from each region as shown in Figure 2-3; locations are approximate. The tank C-109 solid samples, retrieved May 7, 8, and 9, 2013 in accordance with RPP-PLAN-53814, were shipped to the 222-S Laboratory for analysis. The 2013 sample results are reported in RPP-RPT-55492, *Final Report for Tank 241-C-109 Waste Solid Samples in Support of Tank Closure*.

Descriptions of the solids samples are provided in Table 3-1 as reported in RPP-RPT-55492.

3.3 SAMPLE ANALYSES

Analysis of samples taken from tank C-109 after modified sluicing and after hard heel retrieval is presented below.

Table 3-1. Description of Post-Heel Removal Samples.

Sample Identification Number*	Date Sampled	Date Received	Solid Weight (g)	Liquid Volume (mL)	Sample Description
9C-13-1	5/8/2013	5/9/2013	109.7	0	Partially full 240-mL bottle with large white chunks of solids; no organic layer visible
9C-13-2	5/8/2013	5/8/2013	158.5	5	Partially full 240-mL bottle with tan solids, white chunks and small black specks of solids; liquid was yellow in color; no organic layer visible
9C-13-3	5/7/2013	5/8/2013	348.8	19	Full 240-mL bottle of tan solids with black specks and brown liquid; no organic layer visible
9C-13-4	5/7/2013	5/8/2013	168.8	10	Partially full 240-mL bottle with brown and white wet solids; brown liquid; no organic layer visible
9C-13-5	5/9/2013	5/9/2013	282.5	7	Partially full 240-mL bottle of tan solids with small white and light brown chunks; liquid was dark yellow/green; no organic layer visible
9C-13-6	5/9/2013	5/9/2013	196.1	13	Partially full 240-mL bottle of tan solids with small white, light brown, and dark brown specks; liquid was dark yellow/green liquid; no organic layer visible
9C-13-7	5/7/2013	5/7/2013	367.3	55	Full 240-mL bottle of tan solids and clear liquid; no organic layer visible
9C-13-8	5/8/2013	5/8/2013	192.1	0	Partially full 240-mL bottle of tan solids with white chunks; no organic layer visible
9C-13-9	5/9/2013	5/9/2013	163.4	0	Partially full 240-mL bottle of light brown solids with white chunks; no organic layer visible

* Last number in sample identification number references one of the sample locations shown in Figure B-1 in Appendix B.

The chemical and radionuclide composition of the wastes remaining in tank C-109 after modified sluicing was documented in the Best-Basis Inventory (BBI) estimate (RPP-RPT-51343). The following data were used as input for the BBI update:

- Statistical means based on the ORSS grab sample taken in April 2011 (RPP-RPT-50883)
- Tank 241-C-108 (C-108) bulk density statistical mean analytical results (see the *Means and Confidence Intervals* standard report in Appendix B-1 of RPP-RPT-45147, *Derivation of Best-Basis Inventory for Tank 241-C-108 as of January 1, 2013*) based on the ORSS grab sample taken in July 2009 (RPP-RPT-43234, *Final Report for Tank 241-C-108 Solid Samples Taken after Modified Sluicing*)

- BBI template for first decontamination cycle bismuth phosphate waste (RPP-8847, *Best-Basis Inventory Template Compositions of Common Tank Waste Layers*).

The chemical and radionuclide composition of the wastes remaining in tank C-109 after hard heel retrieval was documented in RPP-RPT-55492. The residual inventory estimates were documented in RPP-RPT-55803, *Tank 241-C-109 Residual Waste Inventory Estimates for Component Closure Risk Assessment*.

Analytical methods performed on the post-heel removal samples are identified in Table 3-2. The table also shows the corresponding analysis methods found in SW-846, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, where applicable. Sample analysis results are reported in RPP-RPT-55492. Electronic data were also loaded into the Tank Waste Information Network System (TWINS).

The primary constituents in the heel were ~40 wt% sodium fluoride phosphate (natrophosphate) and ~60 wt% gibbsite. The primary radioactive constituents in the heel were $^{90}Sr/^{90}Y$ and $^{137}Cs/^{137m}Ba$. An overview of this characterization, provided in RPP-PLAN-51371, *Process Control Plan for Tank 241-C-109 Waste Heel Retrieval*, was based on estimates detailed in TWINS, Queried 01/24/2012, [Best Basis Inventory, Best Basis Calculation Detail, Tank 241-C-109], http://twins.pnl.gov/data/datamenu.htm.

3.4 CALCULATION OF RESIDUAL INVENTORY

The residual waste inventories were computed by following the BBI process as described in RPP-7625, *Guidelines for Updating Best-Basis Inventory* and reported in RPP-RPT-55803. Two inventories were computed: an average inventory based on mean concentrations, density, and volume and an upper bounding inventory that is an estimate of an inventory at the 95% UCL. The inventories are discussed in the following sections.

3.4.1 Average Inventories

The average inventory for each waste constituent was calculated using the automated Best-Basis Inventory Maintenance (BBIM) tool (RPP-5945, *Best-Basis Inventory Maintenance Tool (BBIM): Database Description and User Guide*). This tool calculates the average inventory by finding the product of the mean concentration, the mean density, and the waste volume (i.e., inventory = concentration × density × volume). The calculations by the BBIM tool are summarized below.

As described earlier, tank C-109 solids were sampled May 2013 after the 2012 heel retrieval. The mean concentrations for the sample set after heel retrieval were estimated as follows.

The BBIM used equations from *Variance Components* (Searle et al. 1992) to estimate the mean concentration and density and the associated standard deviation for all constituents that had 50% or more of their reported values greater than the detection limit. These equations compute means by weighting results based on the variance components. Some constituents had concentrations

Table 3-2. Analytical Methods Used in Analysis of Post-Heel Removal Samples.

Analysis	SW-846 Reference Method
Inorganic Analyses	
Bulk Density – Gravimetric	Not applicable
pH	9045
Weight percent water – Thermogravimetric Analysis	Not applicable
Cyanide – Spectrophotometric	9014
Mercury – Cold Vapor Atomic Absorption	7471
Ammonia – Ion Chromatography	EPA 300.7[a]
Anions & Organic Acids – Ion Chromatography	9056
Metals – Inductively Coupled Plasma/Atomic Emission Spectrometry	6010
^{99}Tc – Inductively Coupled Plasma/Mass Spectrometry	SW-846 3050B
^{126}Sn, Antimony – Inductively Coupled Plasma/Mass Spectrometry	SW-846 3050B
Actinides – Inductively Coupled Plasma/Mass Spectrometry	SW-846 3050B
Radiochemical Analyses	
Gamma Energy Analysis	Not applicable
$^{89/90}$Sr – Separation/Beta counting	Not applicable
^{14}C – Liquid SC	Not applicable
^{79}Se – Separation/Liquid Scintillation Counting	Not applicable
^{3}H – Liquid Scintillation Counting	Not applicable
^{63}Ni – Separation/Liquid Scintillation Counting	Not applicable
^{99}Tc – Separation/Liquid Scintillation Counting	Not applicable
^{129}I – Separation/Gamma Energy Analysis	Not applicable
^{241}Am – Separation/Alpha Energy Analysis	Not applicable
$^{239/240}$Pu – Separation/Alpha Energy Analysis	Not applicable
^{241}Pu – Separation/Liquid Scintillation Counting	Not applicable
^{228}Th – Separation/Alpha Energy Analysis	Not applicable
Organic Analyses	
Volatile Organic Compound – Gas Chromatography-Mass Spectrometry	8260
Semivolatile Organic Compound – Gas Chromatography-Mass Spectrometry	8270
Polychlorinated Biphenyls – Gas Chromatography-Electron Capture Detection	8082

[a] EPA Method 300.7, *Dissolved Sodium, Ammonium, Potassium, Magnesium, and Calcium in Wet Deposition by Chemically Suppressed Ion Chromatography*, U.S. Environmental Protection Agency, Washington, District of Columbia.

Reference: SW-846, 1986, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, 3rd edition (as amended), U.S. Environmental Protection Agency, Washington, District of Columbia.

that were below the detection limits. In these cases, the analytical method detection limits were used for calculating the mean concentrations. For a constituent with a majority of the analytical results below the analytical method detection limit, a simple average of the detection limits was calculated as if they were the analytical results for the constituent. Note that in accordance with BBI protocol, the relative standard deviations for non-detected constituents were assumed to be "1" (RPP-6924, *Statistical Methods for Estimating the Uncertainty in the Best Basis Inventories*).

To calculate the average analyte inventories, the BBIM tool automatically used the mean concentrations from the samples taken after heel retrieval when available. The concentration means used by the BBIM tool to calculate the average inventories are provided in Appendix B.

The BBIM also used the Searle et al. (1992) equations to calculate the mean density and standard deviation for each set of samples. The density for the samples taken after heel retrieval was used for the inventory calculations.

3.4.2 Bounding Inventories

The 95% UCL inventory of each constituent was estimated based on a statistical method described in RPP-6924. This method is based on calculation of the average inventory (see Section 3.4.1) and a statistical uncertainty (quantified using a standard deviation) for the inventory. The standard deviation of the average inventory was calculated based on statistical uncertainties associated with the concentration, volume, and density measurements. Standard deviations for the mean concentrations (provided in Appendix B) and density were calculated using the BBIM tool. The standard deviation for waste volume was estimated as described below.

RPP-CALC-54759 provides estimates of post-retrieval residual waste volumes on the tank bottom, on the tank wall, in discarded equipment in the tank, and on the tank stiffener rings (see Table 2-3). The total waste volume was estimated at 230 ft^3. The upper bounding estimates for the waste volume components add up to 268 ft^3. The estimated error for the total volume may be represented as ± 0.165 ft^3 [(268-230)/230]. The upper bounding estimate for the volume component that makes up the bulk of the waste (waste on the tank bottom) is at the 95% UCL. Therefore, it was assumed that the error associated with the total volume is also at the 95% UCL. Using a factor of 2 for a two-sided 95% confidence level based on a normal distribution with a known variance, the relative standard deviation (RSD) for the total waste volume was estimated to be 0.083 (0.165/2). This RSD was used to approximate the RSD associated with the total volume.

The BBIM tool calculated the inventory RSD using the equation:

$$RSD^2(\hat{I}) \cong RSD^2(\overline{C}) + RSD^2(\overline{D}) + RSD^2(\hat{V})$$

where $RSD^2(\hat{I})$ is the squared inventory RSD, $RSD^2(\overline{C})$ is the squared average concentration RSD, $RSD^2(\overline{D})$ is the squared average density RSD, and $RSD^2(\hat{V})$ is the squared total volume RSD.

According to RPP-6924, the Student's t distribution (or any other probability distribution) is not applicable for determining a confidence interval for the mean inventory because there are no degrees of freedom associated with the volume measurement. The 95% UCL inventory was approximated by the equation:

$$UCL = \hat{I} + 2 \times \hat{I} \times RSD(\hat{I})$$

where $\hat{I}$ is the average inventory estimate and $RSD(\hat{I})$ is the RSD of the average inventory estimate. The factor "2 times the standard deviation of the estimate" in this equation is analogous to the factor "1.96 times the standard deviation of the mean" for a two-sided 95% confidence interval on the mean based on a normal distribution with a known variance (in accordance with the BBI process which uses a two-sided 95% confidence interval for inventory). The 95% UCL inventories were calculated using the above equation and the average inventory estimates and associated RSDs that were calculated by the BBIM tool.

3.4.3 Evaluation of Sample Data Usability

Residual waste solids were sampled after heel removal with the ORSS using an accepted sampling method described in the DQO (RPP-23403). In accordance with the DQO, three composites were prepared from samples taken for the 2013 sampling event as reported in the data package (RPP-RPT-55492). The solids RSDs in Table B-1 represent the uncertainty in the estimates due to sampling and analysis errors and to the waste variability in the tank.

The 222-S Laboratory maintains a quality assurance program to ensure data quality. The waste samples were analyzed according to quality assurance plans established by the program. In addition, the DQOs specify quality control criteria (e.g., standard recovery, matrix spike recovery, relative difference between duplicate analyses) that are specific to the closure project. The DQOs also provide direction for addressing data that do not meet the criteria. Results for most constituents satisfied the DQO criteria; those that did not meet the criteria were addressed according to the direction provided in the DQOs. Communications that were used to address data issues are included in the laboratory data report (RPP-RPT-55492).

Based on this evaluation, it was concluded that the sampling and analysis met the DQO objectives and, therefore, the sample results are acceptable for uses discussed in the DQO, including risk assessment calculations.

3.4.4 Inventory Calculation Assumptions and Clarifications

The inventories were calculated in accordance with the BBI creation rules documented in RPP-7625 and reported in RPP-RPT-55803. The calculation includes the following assumptions and clarifications.

- Inventories were generated only for constituents specified in the DQO document (RPP-23403). Inventories for BBI analytes that are not included in RPP-23403 were not calculated.

- Only data from the post-heel removal samples were used to calculate the inventories. Inventories of constituents not detected in the samples were calculated using the analytical method detection limits. Therefore, these specific inventories are considered conservative estimates.

- Concentration data are available only for solids on the bottom of the tank. Solids on the tank stiffener ring and the tank wall were not sampled and were assumed to have the same composition as the solids on the tank bottom.

- The volume estimate for the residual waste on the tank bottom includes a 99.2-ft^3 irregular pool of liquid and submerged solids (RPP-CALC-54759). The volume of the submerged solids in the liquids is not estimated; therefore, the volume of the pool is included in the total residual volume in the tank.

- Thorium concentration was measured by inductively coupled plasma (ICP)/atomic emission spectrometry and ^{232}Th was measured by ICP/mass spectrometry (MS). Analyses by ICP/MS are generally more reliable at low concentration; therefore, the thorium inventory was calculated based on the ICP/MS results.

- Uranium concentration was estimated from concentrations of uranium isotopes detected by ICP/MS (^{235}U, ^{236}U, and ^{238}U).

- Inventory of tin-126 (^{126}Sn) was estimated from sample results for tin by assuming all tin in the tank C-109 samples was ^{126}Sn and applying the specific activity for ^{126}Sn. This approach is expected to yield a conservative inventory estimate for this radionuclide.

- Plutonium and curium (except for ^{242}Cm) isotopes were calculated from the $^{239/240}Pu$ and $^{243/244}Cm$ analytical results, using the isotopic distributions ratios of tank C-109.

- In accordance with RPP-7625, the ^{137m}Ba inventory is equal to 0.944 times the ^{137}Cs inventory and the ^{90}Y inventory is equal to the ^{90}Sr inventory.

- The laboratory was not able to measure cresol (m) and cresol (p) separately; therefore, these compounds were reported as cresol (m&p). Cresol (m&p) was not detected. The inventories of the individual cresol isomers were calculated by assuming the cresol (m&p) detection limit was the upper bound for the individual isomers.

- Similarly, the laboratory was not able to distinguish xylene (m) and xylene (p). Inventories of these xylene isomers were calculated by assuming the xylene (m&p) detection limit was the upper bound for the individual isomers.

- As the name implied, tentatively identified compounds (TICs) from organic analyses were not identified with certainty. In addition, measured concentrations for these compounds are only semi-quantitative. Therefore, inventories were not computed for TICs. Only TICs that met the TIC evaluation criteria in RPP-23403 and were reported as a TIC in RPP-RPT-55492 are in Table 3-3 below. All of the reported semivolatile

organics analysis TICs had some blank contamination. The samples contained numerous alkanes and their alterations to ketones and acids.

Table 3-3. Tentatively Identified Compounds in Tank 241-C-109 Residual Solids Samples.

Laboratory Sample Number	Result Type	Tentatively Identified Compound	Result (µg/kg)	Retention Time (minutes)	Chemical Abstract Services Number	Organic: SVOA or VOA
S13T004247	Primary	3-Penten-2-ol	2.9E+03	3.45	1569-50-2	SVOA
S13T004247	Primary	3-methyl-2-Butanone	2.8E+03	3.22	563-80-4	SVOA
S13T004247	Dup	3-methyl-2-Butanone	2.6E+03	3.22	563-80-4	SVOA
S13T004247	Primary	Chloroform	4.3E+03	2.92	67-66-3	SVOA
S13T004247	Dup	Trichloromethane	4.1E+03	2.92	67-66-3	SVOA
S13T004247	Dup	1,2-Benzenedicarboxyli	2.9E+03	14.94	84-69-5	SVOA
S13T004275	Primary	Chloroform	3.8E+03	2.93	67-66-3	SVOA
S13T004302	Primary	3-Penten-2-ol	2.8E+03	3.45	1569-50-2	SVOA
S13T004302	Primary	Chloroform	3.5E+03	2.92	67-66-3	SVOA
S13T004266	Primary	1-Hexanol, 2-ethyl-	9.70E+01	16.41	104-76-7	VOA

µg/kg = microgram per kilogram SVOA = semivolatile organics analysis VOA = Volatile organic analysis

- Before compositing the samples, liquid was decanted from samples 9C-13-2 through 9C-13-7, combined, and stored in archive. Solid composite samples were prepared using equal parts of ~150 g from each sample to form composite B (9C-13-4, 9C-13-5, and 9C-13-6) and composite C (9C-13-7, 9C-13-8, and 9C-13-9) per TSAP. Because of the limited amount of sample in 9C-13-1, only ~100 g from each sample (9C-13-1, 9C-13-2, and 9C-13-3) were used to make composite A. Each composite sample was stirred with a spatula and subsampled for ammonia and volatile organic analyses. The remainder of each composite sample was homogenized with a tissue homogenizer, then a mortar and pestle, and then subsampled for the remainder of the analyses specified in the TSAP. After tissue homogenization, the composite samples still appeared somewhat heterogeneous (RPP-RPT-55492). The sample mean from all reported results for wt% water by thermogravimetric analysis is 27.5 wt%, with a range of 15 wt% to 34 wt% water.

- Bulk density sample results had a range from 1.66 g/mL to 1.79 g/mL (RPP-RPT-55492) and a sample mean of 1.74 g/mL.

3.5 INVENTORY ESTIMATES

The average and upper-bounding inventories for the residual solids are shown in Table 3-4. Note that the symbol "<" indicates the inventory was calculated based on the analytical method detection limit because the analyte was not detected in the samples. Radionuclide inventories are decay-corrected to January 1, 2008.

Table 3-4. Inventory Estimates for Selected Constituents in Tank 241-C-109. (3 sheets)

Constituent	Chemical Abstract Services Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units[1]
^{125}Sb	14234-35-6	<	5.05E+00	1.52E+01	Ci
^{126}Sn	15832-50-5	<	5.70E-04	1.71E-03	Ci
^{129}I	15046-84-1	<	1.36E-04	4.08E-04	Ci
^{137}Cs	10045-97-3		4.86E+01	6.27E+01	Ci
^{137m}Ba	NA		4.59E+01	5.85E+01	Ci
^{14}C	14762-75-5	<	6.56E-04	1.97E-03	Ci
^{152}Eu	14683-23-9	<	1.73E+00	5.19E+00	Ci
^{154}Eu	15585-10-1	<	1.46E+00	4.38E+00	Ci
^{155}Eu	14391-16-3	<	3.70E+00	1.11E+01	Ci
^{228}Th	14274-82-9		3.00E-04	3.89E-04	Ci
^{230}Th	14269-63-7	<	1.62E-02	4.86E-02	Ci
^{231}Pa	14331-85-2	<	3.70E-02	1.11E-01	Ci
^{232}Th	NA		8.49E-06	1.13E-05	Ci
^{233}U	13968-55-3	<	2.16E-01	6.48E-01	Ci
^{234}U	13966-29-5	<	5.13E-03	1.54E-02	Ci
^{235}U	15117-96-1		3.43E-04	5.08E-04	Ci
^{236}U	13982-70-2		8.23E-05	1.50E-04	Ci
^{237}Np	13994-20-2	<	7.90E-03	2.37E-02	Ci
^{238}Pu	13981-16-3		1.47E-02	2.00E-02	Ci
^{238}U	NA		8.17E-03	1.21E-02	Ci
^{239}Pu	15117-48-3		3.44E-01	5.17E-01	Ci
^{240}Pu	14119-33-6		3.74E-02	5.62E-02	Ci
^{241}Am	14596-10-2		3.23E-01	4.22E-01	Ci
^{241}Pu	14119-32-5		7.77E-01	9.23E-01	Ci
^{242}Cm	15510-73-3	<	7.36E-04	2.21E-03	Ci
^{242}Pu	NA	<	2.37E-04	7.11E-04	Ci
^{243}Cm	15757-87-6	<	5.61E-05	1.68E-04	Ci
^{244}Cm	13981-15-2	<	1.19E-03	3.57E-03	Ci
2-Butanone	78-93-3	<	2.12E-04	6.36E-04	kg
^{3}H	15086-10-9	<	5.91E-03	1.77E-02	Ci
^{60}Co	10198-40-0	<	7.10E-01	2.13E+00	Ci
^{63}Ni	13981-37-8		8.16E-01	1.00E+00	Ci
^{79}Se	15758-45-9	<	3.84E-03	1.15E-02	Ci

Table 3-4. Inventory Estimates for Selected Constituents in Tank 241-C-109. (3 sheets)

Constituent	Chemical Abstract Services Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units[1]
^{90}Sr	10098-97-2		2.66E+03	3.42E+03	Ci
^{90}Y	500784-58-7		2.66E+03	3.42E+03	Ci
^{99}Tc	14133-76-7		7.52E-03	9.45E-03	Ci
Acetate	71-50-1	<	1.28E+00	3.84E+00	kg
Acetone	67-64-1		1.15E-03	1.99E-03	kg
Ag	7440-22-4		7.15E-02	1.63E-01	kg
Al	7429-90-5		1.84E+03	2.52E+03	kg
Aroclors (Total polychlorinated biphenyl dry weight basis)	1336-36-3	<	1.14E-04	3.42E-04	kg
As	7440-38-2		8.75E-02	1.21E-01	kg
B	7440-42-8	<	1.12E-02	3.36E-02	kg
Ba	7440-39-3		1.12E-01	1.60E-01	kg
Be	7440-41-7	<	1.12E-02	3.36E-02	kg
Bi	7440-69-9		1.69E+00	2.14E+00	kg
Br	24959-67-9	<	6.84E-01	2.05E+00	kg
Ca	7440-70-2		1.34E+01	1.94E+01	kg
Cd	7440-43-9	<	1.12E-02	3.36E-02	kg
Ce	7440-45-1		4.20E+00	5.21E+00	kg
Cl	16887-00-6	<	7.30E-01	2.19E+00	kg
CN	57-12-5		3.37E-01	4.88E-01	kg
Co	7440-48-4	<	1.12E-02	3.36E-02	kg
Cr	7440-47-3		1.51E-01	2.10E-01	kg
Cu	7440-50-8		6.23E-01	9.39E-01	kg
Eu	7440-53-1	<	1.12E-02	3.36E-02	kg
F	16984-48-8		8.29E+01	1.02E+02	kg
Fe	7439-89-6		7.95E+01	1.20E+02	kg
Formate	12311-97-6	<	1.92E+00	5.76E+00	kg
Glycolate	666-14-8	<	7.30E-01	2.19E+00	kg
Hexone	108-10-1	<	1.84E-04	5.52E-04	kg
Hg	7439-97-6		1.58E-02	2.61E-02	kg
K	7440-09-7	<	2.24E-01	6.72E-01	kg
La	7439-91-0		1.03E-01	1.52E-01	kg
Li	7439-93-2		1.70E-02	2.20E-02	kg
Mg	7439-95-4		1.10E+00	1.52E+00	kg
Mn	7439-96-5		4.82E-01	7.99E-01	kg
Mo	7439-98-7		2.13E-02	3.30E-02	kg
Na	7440-23-5		1.12E+03	1.64E+03	kg
Nb	7440-03-1	<	1.79E+00	5.37E+00	kg
Nd	7440-00-8		1.31E-01	1.86E-01	kg

Table 3-4. Inventory Estimates for Selected Constituents in Tank 241-C-109. (3 sheets)

Constituent	Chemical Abstract Services Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units[1]
NH_3	7664-41-7		3.18E-02	4.03E-02	kg
Ni	7440-02-0		1.14E+01	1.68E+01	kg
NO_2	14797-65-0		3.28E+00	3.85E+00	kg
NO_3	14797-55-8		3.87E+00	4.95E+00	kg
Oxalate	338-70-5	<	1.19E+00	3.57E+00	kg
Pb	7439-92-1		4.62E+00	5.47E+00	kg
Pd	7440-05-3	<	1.01E-01	3.03E-01	kg
PO_4	14265-44-2		8.41E+02	1.27E+03	kg
Pr	7440-10-0	<	2.39E+00	7.17E+00	kg
Rb	7440-17-7	<	3.36E-01	1.01E+00	kg
Rh	7440-16-6		1.03E-01	1.28E-01	kg
Ru	7440-18-8	<	4.48E-02	1.34E-01	kg
Sb	7440-36-0	<	6.72E-02	2.02E-01	kg
Se	7782-49-2	<	6.72E-02	2.02E-01	kg
Si	7440-21-3		2.39E+01	4.39E+01	kg
Sm	7440-19-9		3.98E-01	5.04E-01	kg
Sn	7440-31-5	<	3.36E-02	1.01E-01	kg
SO_4	14808-79-8		2.45E+00	3.11E+00	kg
Sr	7440-24-6		4.21E-01	6.45E-01	kg
Ta	7440-25-7	<	2.98E+00	8.94E+00	kg
Te	13494-80-9	<	5.60E-02	1.68E-01	kg
Th	7440-29-1		7.72E-02	1.03E-01	kg
Ti	7440-32-6		5.09E-02	7.20E-02	kg
Tl	7440-28-0		7.57E-02	9.34E-02	kg
Tributyl phosphate	126-73-8	<	7.42E-03	2.23E-02	kg
Trichloroethene	79-01-6	<	1.30E-05	3.90E-05	kg
U	7440-61-1		2.45E+01	3.64E+01	kg
V	7440-62-2	<	1.12E-02	3.36E-02	kg
W	7440-33-7	<	7.33E-02	2.20E-01	kg
Xylene (m & p)	108-38-3M	<	1.80E-05	5.40E-05	kg
Xylene (o)	95-47-6	<	9.91E-06	2.97E-05	kg
Xylenes (total)	1330-20-7	<	2.19E-05	6.57E-05	kg
Y	7440-65-5		2.60E-02	3.22E-02	kg
Zn	7440-66-6		6.01E-01	7.17E-01	kg

[1] Radionuclide concentrations are decay corrected to January 1, 2008.

4.0 RETRIEVAL SYSTEM PERFORMANCE

This section discusses the tank C-109 WRS performance in terms of residual waste, retrieval duration, and water use. In addition, this section compares the achieved waste retrieval results against predicted performance.

The DOE Office of River Protection (ORP) has deployed two technologies at tank C-109: modified sluicing with the assistance from the FoldTrack® Mobile Retrieval Tool and caustic cleaning. Modified sluicing operations started on June 19, 2007 with an initial waste volume of ~63,400 gal (240 kL) of sludge, and reached its limit of technology on August 23, 2007 after 33 operating days (64 shifts). On June 2, 2008 the FoldTrack® Mobile Retrieval Tool began operations to assist in the sluicing of the remaining tank waste. The FoldTrack® continued operating until July 10, leaving an estimated 7,800 gal of sludge remaining in the tank (RPP-RPT-51343). Caustic cleaning was performed starting on March 8, 2012 and reached its limit of technology on September 12, 2012. At the conclusion of retrieval operations tank C-109 contained ~230 ft^3 (1,210 gal) of remaining waste (see RPP-CALC-54759), meeting the volume requirement provided in the Consent Decree.

4.1 WASTE RETRIEVAL PROCESS DESCRIPTION

The WRSs deployed at tank C-109 were designed to mobilize and dissolve the sludge waste so it could be transferred to a double-shell tank (DST), tank 241-AN-106 (AN-106). Descriptions of WRSs may be found in RPP-53824. The bulk WRS used supernate from the DST to break up and fluidize the waste, and transfer it to tank AN-106. Supernate from tank AN-106 was recycled continuously. The volume of supernate transferred to tank C-109 was monitored and balanced by the volume pumped out of tank C-109. The flow rate of the recycled supernate was roughly the same as the flow rate of the slurry pumped to the DST. The bulk sluicing operation directed the supernate toward the tank C-109 waste using sluicers, eroding and moving the waste toward the center transfer pump so as much pumpable material was transferred to the DST as was possible. The FoldTrack® Mobile Retrieval Tool was also used to help move waste toward the center transfer pump.

The second waste retrieval technology deployed at tank C-109 was a combination of water dissolution of sodium fluoride phosphate and caustic cleaning to remove the gibbsite waste portion. The sodium fluoride phosphate was removed first by dissolving it in water and pumping the liquid out of tank C-109. The gibbsite was then removed by adding concentrated sodium hydroxide solution to metathesize the gibbsite to sodium aluminate, then adding water to dissolve the sodium aluminate, and finally pumping the liquid out of tank C-109.

4.2 RETRIEVAL SYSTEMS PERFORMANCE

Before modified sluicing began, most of the waste in tank C-109 consisted of a soft brown sludge that was readily mobilized by the sluicers and pumped from the tank. The retrieval progressed quickly over the first few days of operation. By June 22, some of the tank bottom

was visible and lighter-colored, harder solids under the soft sludge were starting to be uncovered. By July 23, 2007, most of the soft sludge had been removed. Most of the area under and between the two sluicers had been cleared of solids; in these areas, the tank bottom was either exposed or covered by a relatively thin layer of solids. The sluicers were able to move these solids about the tank, but the solids tended to settle too quickly to be readily entrained and removed by the slurry pump. The bulk of the remaining solids were located near the tank knuckle (the section connecting the tank dish and the tank walls) on the east and west sides of the tank furthest from the sluicer installations.

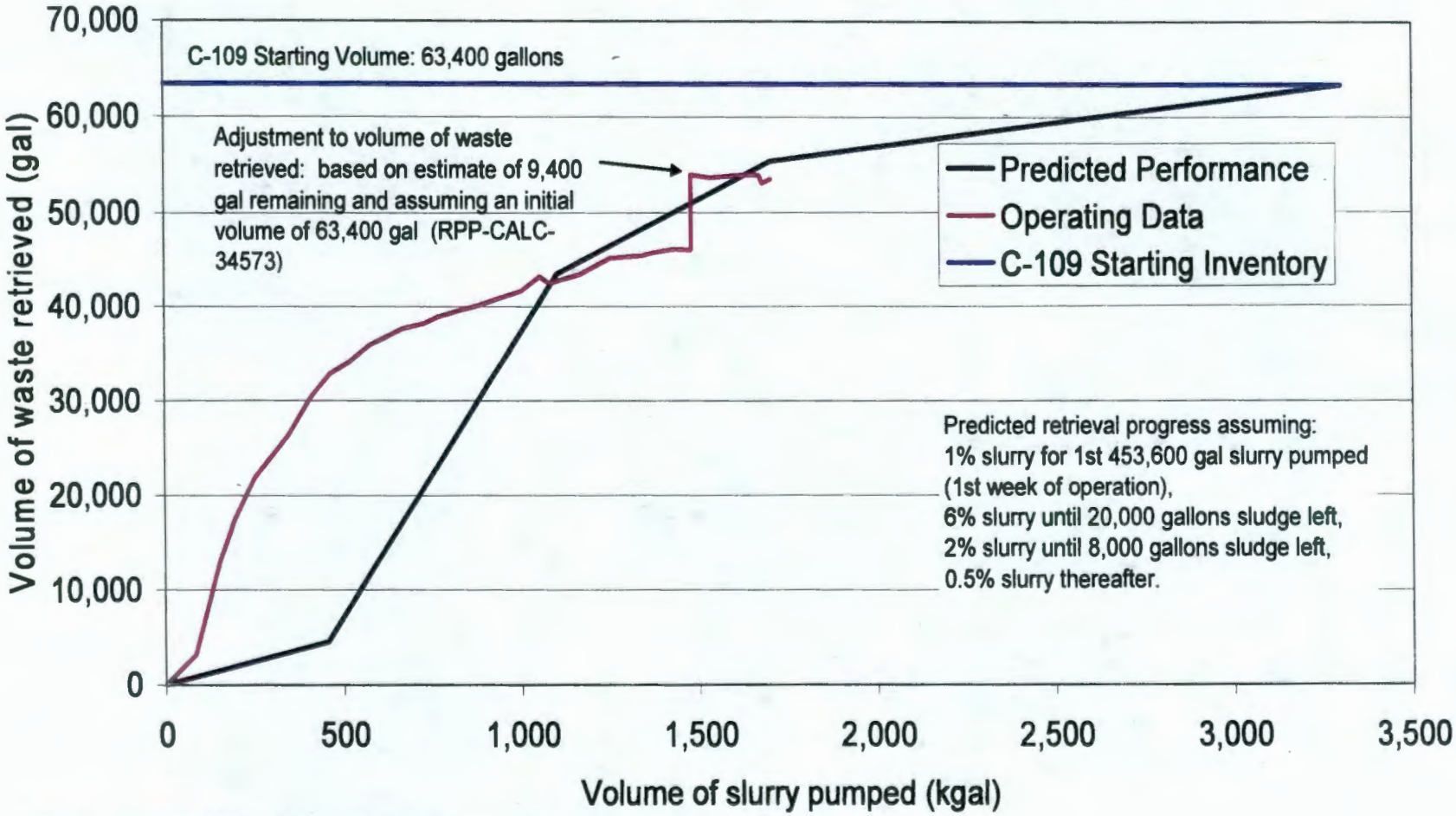
Figure 4-1 shows retrieval system performance as a function of the volume of slurry (solids plus recycled tank AN-106 supernate) transferred from tank C-109 to tank AN-106. The occasional decreases in the volume retrieved in Figure 4-1 reflect fluctuations in the ending tank C-109 liquid pool volume. It was not always possible to pump the tank C-109 liquid pool to the same level at the end of each operating period.

Retrieval system performance was tracked by trending the net waste volume increase in the receiver tank AN-106 after accounting for water additions; this is shown as the Operating Data line in Figure 4-1. This running volume balance does not distinguish between liquids and solids and does not account for solids dissolution or liquid evaporation. As the volume of waste material received by tank AN-106 approaches the starting waste volume of tank C-109, the estimate of the volume remaining in tank C-109 using the difference between these two numbers becomes increasingly sensitive to uncertainties in the starting waste volume estimate and cumulative measurement uncertainties. The running volume balance was subsequently adjusted as described below to generate an estimate of the actual volume of waste retrieved during modified sluicing of tank C-109.

On July 26, 2007, ~25,000 gal of supernatant liquid from tank AN-106 were added to tank C-109 to soak the solids. The liquid was added in 5,000-gal increments, and a level measurement was taken following the addition of each increment. The level measurement was obtained using the Enraf instrument located in riser R-1. The level measurements in tank AN-106 were also taken before and after each supernate transfer. As the liquid was added to tank C-109, the difference was calculated between the expected rise in the surface level (based on the tank dimensions) and the actual rise in surface level. The actual rise in surface level is affected by the volume of solids remaining in the bottom of the tank. This method allows the volume of the solids that become covered by liquid to be calculated, and is referred to as the "volume displacement method." Details of the calculations are documented in RPP-CALC-34573. RPP-CALC-34573 estimated that as of July 26, 2007, 9,400 gal of waste remained in tank C-109. Subsequent material balances adjusted that volume to ~9,880 gal. The bulk of the remaining waste was comprised mostly of solids that were not mobilized by sluicing and were insoluble in the tank AN-106 supernate.

Both the sluicing Operating Data and Adjusted waste retrieval volumes show the limit of technology being reached at ~1,750,000 gal of slurry pumped.

Figure 4-1. Tank 241-C-109 Modified Sluicing Waste Retrieval System Performance.



Reference: RPP-CALC-34573, *Estimate of Waste Volume and Percent Retrieved for Single-Shell Tank 241 C-109.*

The following is a discussion of the performance of the caustic cleaning process steps as specified in the tank C-109 process control plan (RPP-PLAN-51371) that demonstrates that the limit of technology was met in tank C-109.

The caustic cleaning process was divided into two parts. Each part addressed a different chemical species; sodium fluoride phosphate and gibbsite. The first process was water dissolution of sodium fluoride phosphate.

Dissolution of the natrophosphate during the heel wash step was tracked by periodic sampling of the liquid and analyzing for the fluoride concentration in the liquid. Laboratory test results indicated that the concentration of fluoride should rapidly increase initially, and then gradually reach equilibrium as the natrophosphate is dissolved. Figure 4-2 shows the sampling results as a function of the circulation/mixing time. Figure 4-3 shows the remaining solids before and after the water wash step.

Based on flowsheet estimates for the amount of fluoride in solution after dissolution is completed (RPP-RPT-51386, *Tank 241-C-109 Hard Heel Retrieval Flowsheet*), it was estimated that ~30% of the natrophosphate may have dissolved into solution (RPP-RPT-53486). Based on the predicted starting concentration, it appeared that there was little change in the fluoride concentration between the first and second sample. Also because of a pump failure, there was a prolonged period before the third sample could be taken.

Because additional circulation time for the first water wash and a second water wash appeared to be largely ineffective during the earlier retrieval of tank C-108 (see RPP-RPT-52449, *Single-Shell Tank 241-C-108 Hard Heel Retrieval Completion Report*), it was determined that the wash water would be transferred immediately after the third sample was taken. The potential for a second water wash following the metathesis reaction was included in the planning, in case additional natrophosphate dissolution was required. Photographs taken of the same in-tank locations before and after the water wash step (Figure 4-3) indicate that the water wash reduced the overall quantity of solids, and broke up many of the larger solid chunks in the tank. These observations supported the decision to initiate the metathesis reaction.

The second part of the caustic dissolution process was designed to retrieve aluminum compounds with specific emphasis on gibbsite. The process converted the aluminum compounds from a largely insoluble form to a much more soluble form by soaking in very high concentration caustic solution (50 wt% NaOH). This is a slow reaction and requires a long contact time (approximately one month) to go to completion. Once the reaction went to completion, as indicated by OH and Al sample results (Figure 4-4), water was added to dilute the hydroxide and allow the soluble form, sodium aluminate, to dissolve. The sodium aluminate dissolution is rapid. After the dissolution was complete, a sample was taken and the contents were pumped from tank C-109. The process of converting gibbsite to the sodium aluminate form was tracked by sampling and analyzing the caustic concentration. Because much of the waste heel was above the liquid level, the liquid was circulated and the waste solids were sprayed with the caustic solution. The video showed that the large piles of waste broke down and were washed below the liquid pool surface during the process.

Figure 4-2. Fluoride Concentration as a Function of Circulation Time.

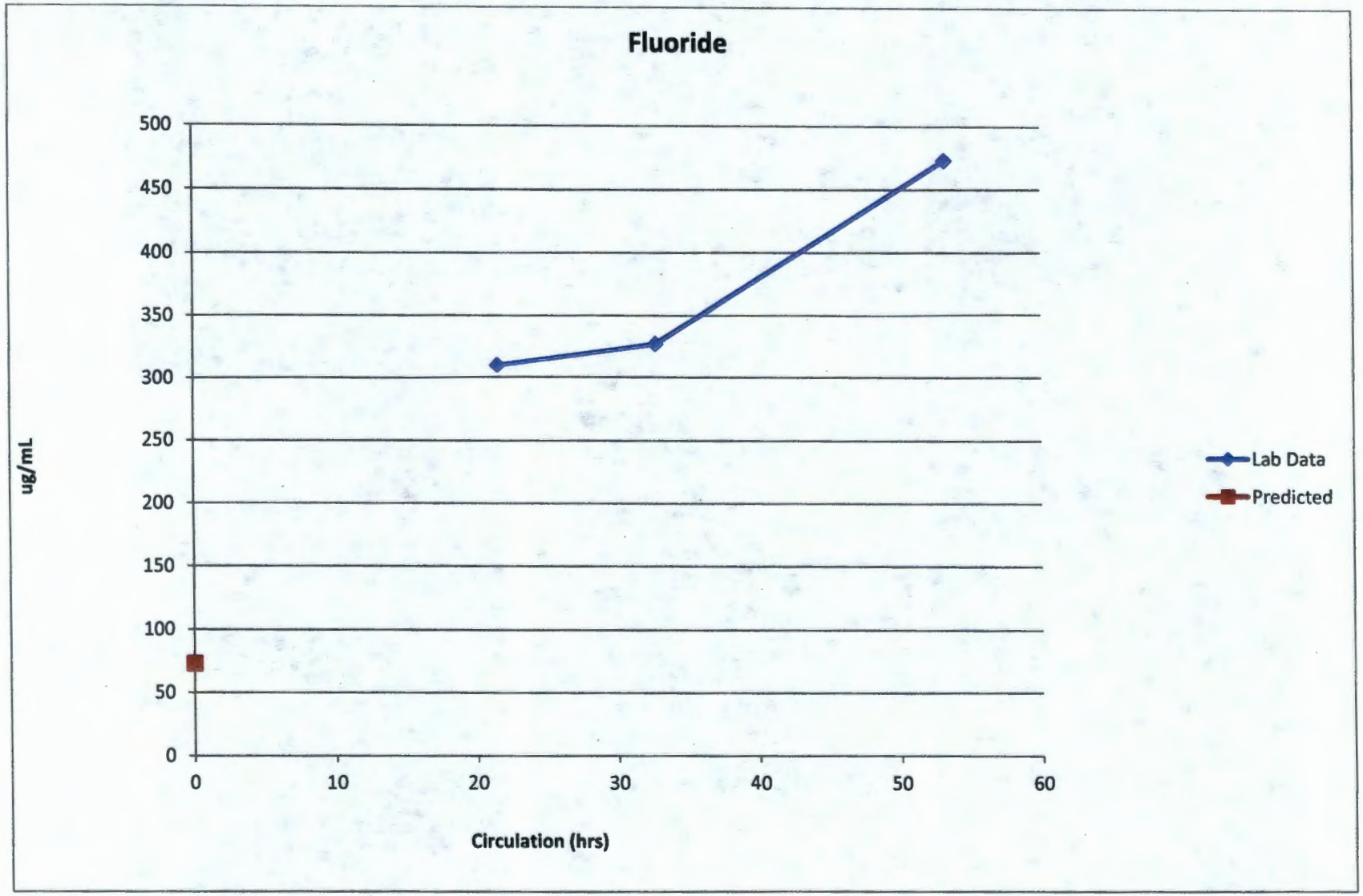


Figure 4-3. Tank 241-C-109 Remaining Solids before and after Water Wash Step.

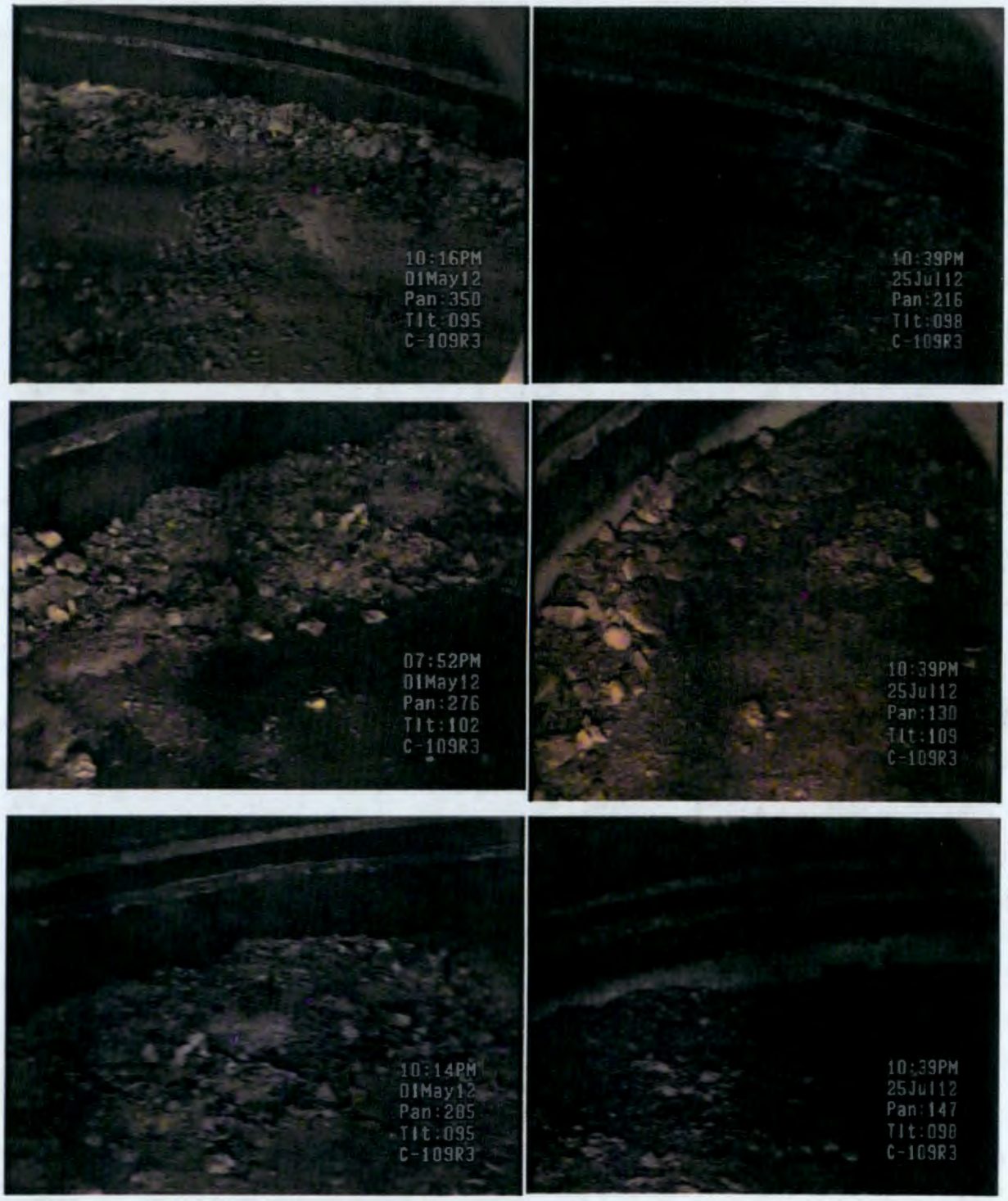
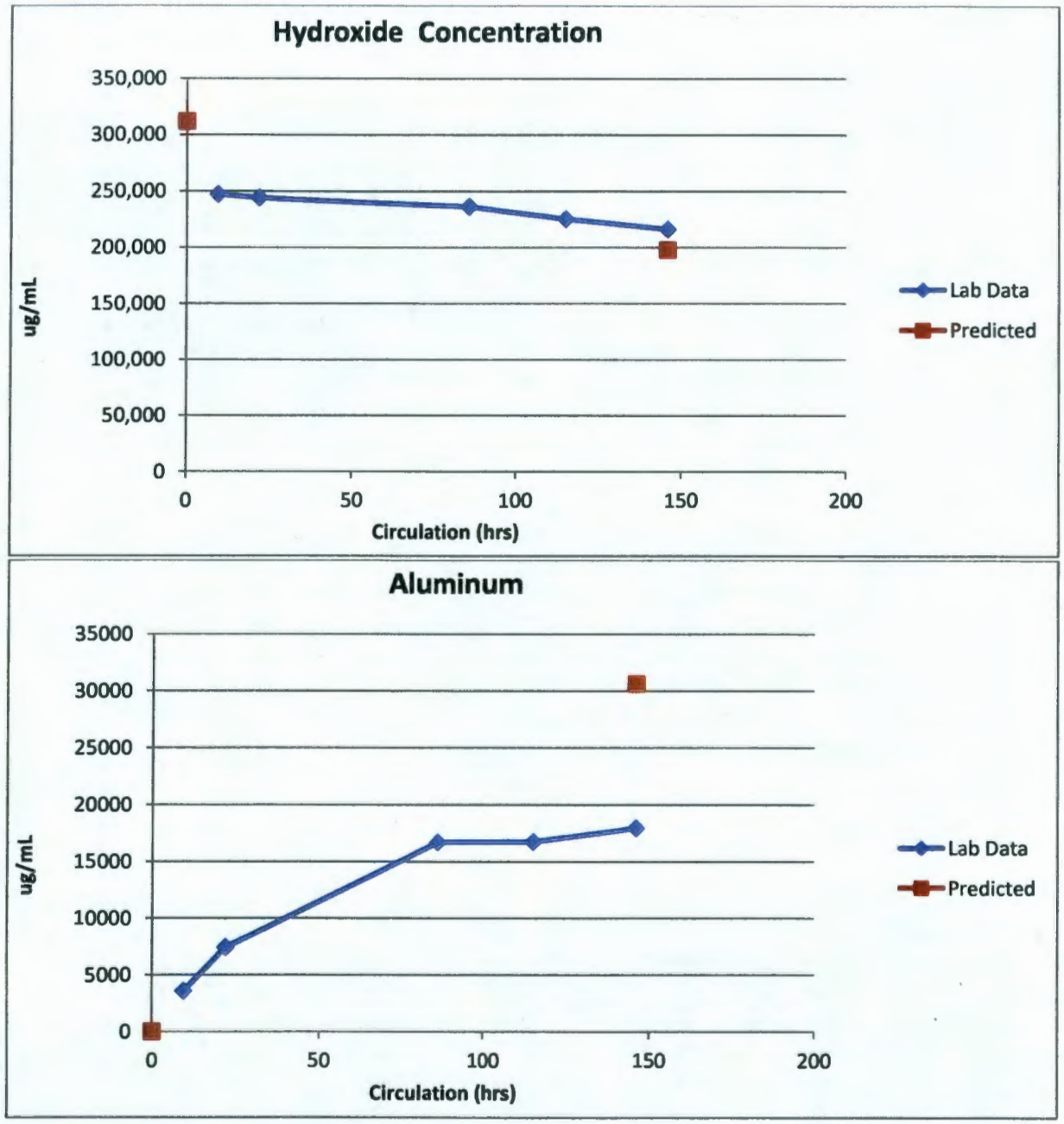


Figure 4-4. Tank 241-C-109 Sample Analysis Results during Circulation of Caustic.



On September 12, 2012, ~15,000 gal of water were added to tank C-109 and transferred to tank AN-106 to sluice remaining solids and rinse the tank. Sluicing was performed first with sluicer number 1 (in riser R-7), then with sluicer number 2 (in riser R-2). The fines were readily mobilized during the water sluicing step. The sluicers were intentionally directed toward the larger chunks and piles of waste remaining near the sides of the tank farthest from the sluicers. The pressurized water was observed to break up the chunks and continue to reduce the size of remaining waste piles.

A decision was made to deploy a second water sluicing step, with an additional ~15,000 gal (as allowed in the Process Control Plan, RPP-PLAN-51371). Visual observation at the end of the first water sluicing step showed that the majority of the remaining solids were closer to sluicer number 1 than to sluicer number 2, so the second water sluicing began with the use of sluicer number 1.

At the beginning of the second step, the slurry pump in the center of the tank was raised ~1 in. to allow sluicing under the pump intake to remove any solids that may interfere with effective retrieval. The pump was then immediately lowered to ~1 in. lower than its previous position for the remainder of this water sluicing step. Sluicing operations continued to focus on breaking up remaining waste solids and moving the resulting fine material to the slurry pump.

Reduction of the solid material remaining in tank C-109 was observed during both of the first two water sluicing steps. A decision was made to perform a third water sluicing step, using an additional ~15,000 gal of water. Sluicing operations continued to focus on breaking up remaining waste solids and moving the resulting fine material to the slurry pump. Less material break-up of the remaining consolidated solids was observed in this sluicing step than in the previous steps.

At the conclusion of the third water sluicing step, the results were evaluated to determine if a fourth water sluicing step would be effective. The recovery of waste solids had declined significantly with each of the first three water sluicing steps. Observations during the sluicing indicated that sluicing was becoming less and less effective in breaking up the remaining solids. It was concluded that an additional water sluicing step would not be effective. On September 13, 2012, the caustic cleaning retrieval process was completed. Figure 4-5 shows photographs of several areas in tank C-109 after completion of all caustic cleaning steps. Figure 2-3 shows a schematic of waste distribution at the end of caustic cleaning.

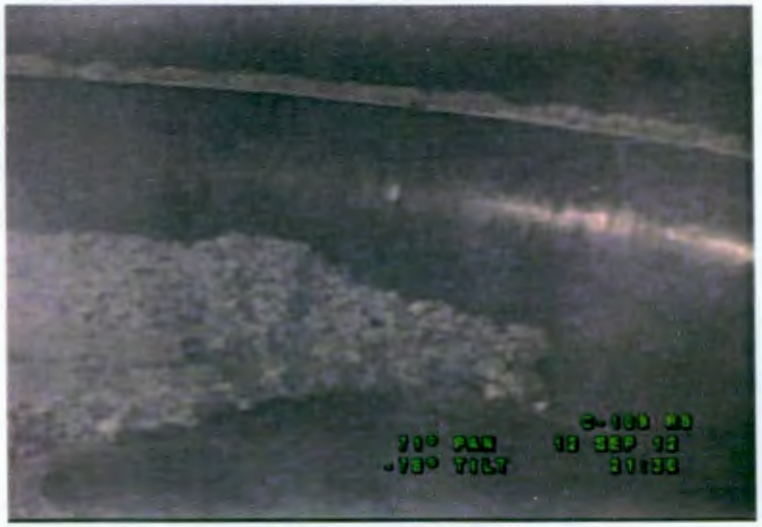
4.3 WASTE RETRIEVAL EFFICIENCY

The preliminary estimate for the tank C-109 modified sluicing rate campaign indicated that it would require 2,800,000 gal of slurry to transfer the estimated 63,400 gal of tank C-109 waste to tank AN-106. In the first 600,000 gal of the slurry pumped from tank C-109, over 38,000 gal of waste was transferred from tank C-109 to tank AN-106. Between 600,000 gal and 1,750,000 gal of slurry transferred, the retrieval rate leveled off and it was determined that the bulk of the remaining waste was comprised mostly of solids that were not mobilized by sluicing and were insoluble in the tank AN-106 supernate.

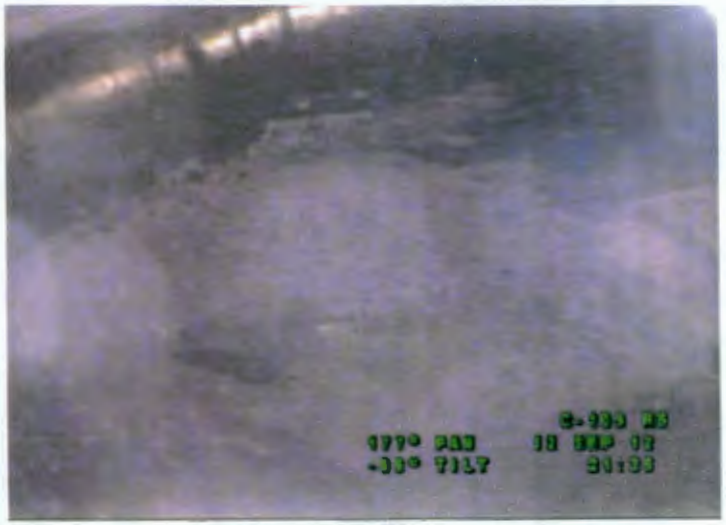
As can be seen from Figure 4-2 and Figure 4-4, the rate of waste retrieval by caustic cleaning progressed linearly as anticipated.

Figure 4-5. Photographs of Tank 241-C-109 at Completion of Caustic Cleaning.

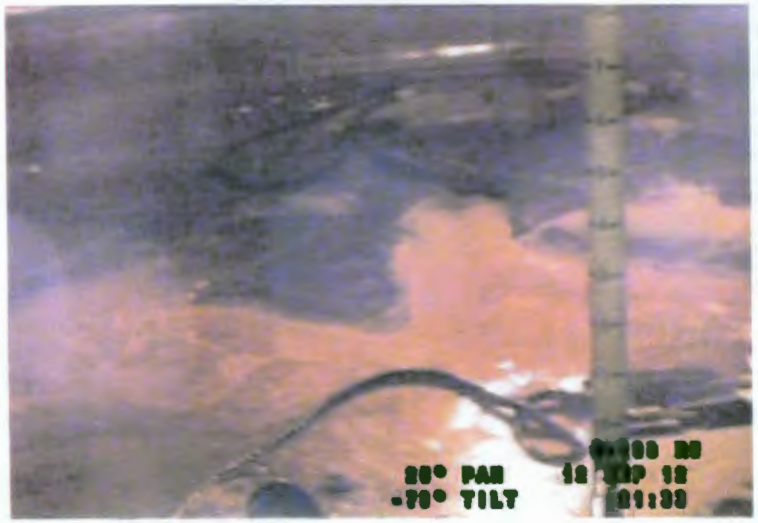
Solids on West Side of Tank



Solids on East Side of Tank



South Side of Tank



North Side of Tank

4.4 CONCLUSION

Tank C-109 was retrieved using the modified sluicing and chemical dissolution (caustic cleaning) technologies as described in RPP-21895. Prior to retrieval operations, the tank contained ~63,000 gal (238 kL, 8,422 ft^3) of waste. Modified sluicing was performed starting on June 19, 2007 and reached its limit of technology on August 23, 2007. At the conclusion of modified sluicing, tank C-109 contained ~9,900 gal (37.5 kL, 1,320 ft^3) of waste. Caustic cleaning was performed starting on May 1, 2012 and reached its limit of technology on September 12, 2012. At the conclusion of retrieval operations tank C-109 contains 1,210 gal (~230 ft^3) of remaining waste (see RPP-CALC-54759), meeting the volume requirement provided in the Consent Decree. Retrieval of tank C-109 is complete. Documentation concerning the effectiveness of the retrieval technologies employed to retrieve tank C-109 may be found in RPP-53824.

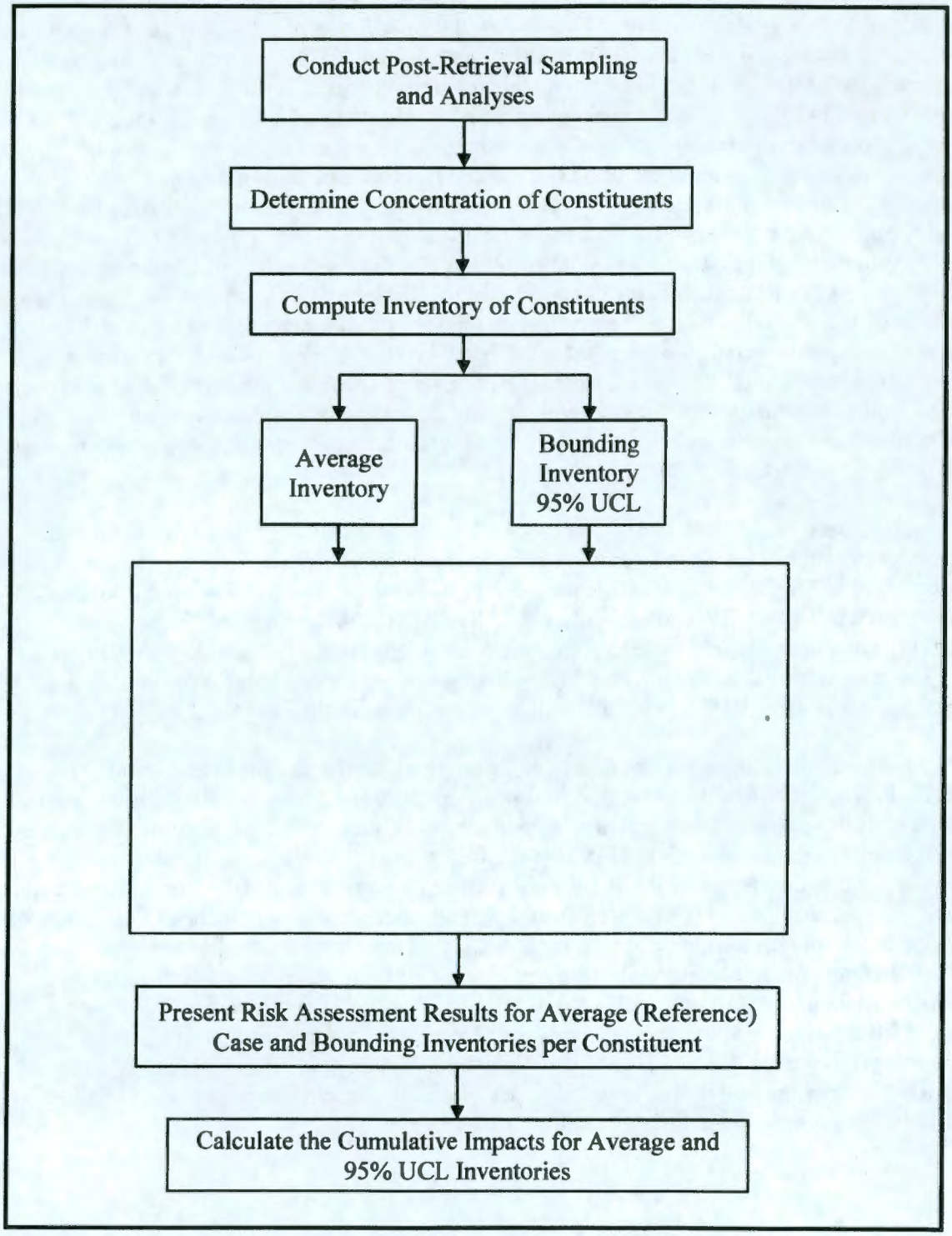
5.0 POST-RETRIEVAL SINGLE-SHELL TANK 241-C-109 RISK ASSESSMENT

The potential impacts to human health posed by the residual waste in SST C-109 were evaluated using the methodology documented in DOE/ORP-2005-01, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site*. Figure 5-1 provides a schematic of the process used for the tank C-109 risk assessment, and this methodology is described in detail in Chapter 3 of DOE/ORP-2005-01. The SST performance assessment (PA) methodology represents the current approach being used to support the assessment of long-term impacts to human health from tank residuals left in individual SSTs in RDRs. Decisions on final closure of tank C-109, all other SSTs, and ancillary facilities and equipment within Waste Management Area (WMA) C will be supported by a site-specific PA as outlined in Appendix I of the HFFACO. That single PA will evaluate whether closure conditions at WMA C will be protective of human health and the environment for all contaminants of concern, both radiological and non-radiological. The DOE intends that PA will document by reference relevant performance requirements defined by *Resource Conservation and Recovery Act of 1976*, RCW 70.105, *Federal Water Pollution Control Act* (Clean Water Act), *Safe Drinking Water Act of 1974*, and the *Atomic Energy Act of 1954*, as well as any other performance requirements that might be Applicable or Relevant and Appropriate Requirements under *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA).

The inventory used in this tank C-109 risk assessment was derived from post-retrieval residual inventory calculations (see Section 3.0). A comparison of post-retrieval inventory to the inventory used in DOE/ORP-2005-01 is provided in Appendix C for information purposes. The inventory used in DOE/ORP-2005-01 is based on RPP-RPT-23412, *Hanford Tank Waste Operations Simulator Model Data Package for the Development Run for the Refined Target Case*. The post-retrieval inventory used in this RDR provides a more accurate representation of tank residuals than RPP-RPT-23412, and will be incorporated in the WMA C PA.

Results of the potential impacts to human health were calculated using the average and 95% UCL inventories. Results show that for the groundwater pathway, the effects associated with tank C-109 are two to three orders of magnitude below current incremental lifetime cancer risk (ILCR) performance objectives (1.0E-06 to 1.0E-4) for radioactive analytes and seven to eight orders of magnitude below the ILCR performance objectives (1.0E-05) for non-radioactive analytes. The hazard indices for the tank C-109 groundwater pathway are three to four orders of magnitude below the performance objective (1.0). For all inadvertent intruder scenarios other than the suburban garden scenario (a sensitivity case) at 100 years after closure, the effects associated with tank C-109 were well below both the 100 mrem/yr performance objective for chronic exposure and the 500 mrem performance objective for acute exposure. For comparison, at 500 years after closure, the effects estimated for the suburban garden scenario are two orders of magnitude below the 100 mrem/yr performance objectives for chronic exposure. Details of these results are provided in Sections 5.2 through 5.4.

Figure 5-1. Single-Shell Tank 241-C-109 Residual Waste Inventory and Risk Assessment Process.



UCL = upper confidence level

This section also provides additional risk management information related to concentrations of constituents remaining in waste residuals within tank C-109 compared against the WAC 173-340 cleanup standards. The soil cleanup standards evaluated are developed for direct contact exposures and for groundwater protection. Selected constituent concentrations estimated for the average and 95% UCL inventories of tank residuals are specifically compared against soil direct contact cleanup levels for unrestricted land use (Method B), soil direct contact cleanup levels for industrial land use (Method C), and soil cleanup levels protective of groundwater using the fixed parameter three-phase partitioning model given in WAC 173-340-747, "Deriving Soil Concentrations for Groundwater Protection," subsection (4), "Fixed parameter three-phase partitioning model." Results of these comparisons are found in Section 5.5.1.

Section 5.5 also includes a discussion of the appropriateness of comparisons for constituent concentrations remaining in waste residuals within tank C-109 against cleanup standards protective of ecological risk found in WAC 173-340. Because footnotes in tables containing the cleanup standards protective of ecological concerns indicate these standards are not intended to be used for evaluation of sludges or wastes, specific comparisons of concentrations of constituents remaining in waste residuals within tank C-109 against the WAC 173-340 cleanup standards related to ecosystem risk are not provided.

5.1 CONSTITUENTS EVALUATED

Following retrieval, the residual waste was sampled and analyzed. This risk assessment is based on the analytical results from the post-retrieval sample (Section 3.0).

Analytical data for tank C-109 were collected and analyzed as defined by the closure DQOs. The post-retrieval samples were analyzed for 105 constituents (i.e., radionuclides, volatile organic compounds, semi-volatile organic compounds, polychlorinated biphenyls, and inorganics [including metals and conventional parameters]) in accordance with approved 222-S Laboratory procedures based on U.S. Environmental Protection Agency (EPA) approved methods. However, analytes flagged as a non-detect were evaluated at one-half the detection limit in accordance with EPA/540/1-89/002, *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A) Interim Final*. Table 5-1 presents a complete listing of the analytes evaluated, whether the analyte was detected, and whether a cancer potency factor (also called a cancer slope factor), dose factor, or reference dose is published for that analyte.

Table 5-1. List of Analytes and Available Toxicity Information. (3 sheets)

Isotope/ CAS	Analyte[a]	Detect	Available Toxicity Information[b]	Isotope/ CAS	Analyte	Detect	Available Toxicity Information
^{241}Am	Americium-241		DFR/CPF	7440-47-3	Chromium, Total*		--
^{125}Sb	Antimony-125*	U	DFR/CPF	7440-48-4	Cobalt	U	RfD/CPF
^{137m}Ba	Barium-137m*		--	7440-50-8	Copper		RfD
^{14}C	Carbon-14	U	DFR/CPF	57-12-5	Cyanide*		RfD
^{137}Cs	Cesium-137 + Daughters		DFR/CPF	7440-53-1	Europium	U	--
^{60}Co	Cobalt-60	U	DFR/CPF	16984-48-8	Fluoride		RfD
^{242}Cm	Curium-242	U	DFR/CPF	12311-97-6	Formate+A2	U	--
^{243}Cm	Curium-243	U	DFR/CPF	Glycolate	Glycolate $C_2H_3O_3$	U	--
^{244}Cm	Curium-244	U	DFR/CPF	7439-89-6	Iron		RfD
^{152}Eu	Europium-152	U	DFR/CPF	7439-91-0	Lanthanum		--
^{154}Eu	Europium-154	U	DFR/CPF	7439-92-1	Lead*		--
^{155}Eu	Europium-155	U	DFR/CPF	7439-93-2	Lithium		RfD
^{129}I	Iodine-129	U	DFR/CPF	7439-95-4	Magnesium		--
^{237}Np	Neptunium-237 + D	U	DFR/CPF	7439-96-5	Manganese		RfD
^{63}Ni	Nickel-63*		DFR/CPF	7439-97-6	Mercury*		RfD
^{238}Pu	Plutonium-238		DFR/CPF	7439-98-7	Molybdenum		RfD
^{239}Pu	Plutonium-239		DFR/CPF	108-38-3	m-Xylene	U	RfD
^{240}Pu	Plutonium-240		DFR/CPF	7440-00-8	Neodymium		--
^{241}Pu	Plutonium-241 + D		DFR/CPF	7440-02-0	Nickel*		RfD
^{242}Pu	Plutonium-242	U	DFR/CPF	7440-03-1	Niobium	U	--

Table 5-1. List of Analytes and Available Toxicity Information. (3 sheets)

Isotope/ CAS	Analyte[a]	Detect	Available Toxicity Information[b]	Isotope/ CAS	Analyte	Detect	Available Toxicity Information
^{231}Pa	Protactinium-231	U	DFR/CPF	14797-55-8	Nitrate		RfD
^{79}Se	Selenium-79*	U	DFR/CPF	14797-65-0	Nitrite		RfD
^{90}Sr	Strontium-90 + D		DFR/CPF	338-70-5	Oxalate	U	--
^{99}Tc	Technetium-99		DFR/CPF	95-47-6	o-Xylene	U	RfD
^{228}Th	Thorium-228 + D		DFR/CPF	7440-05-3	Palladium	U	--
^{230}Th	Thorium-230	U	DFR/CPF	14265-44-2	Phosphate		--
^{232}Th	Thorium-232		DFR/CPF	1336-36-3	Polychlorinated Biphenyls*	U	CPF
^{126}Sn	Tin-126	U	DFR/CPF	7440-09-7	Potassium	U	--
^{3}H	Tritium	U	DFR/CPF	7440-10-0	Praseodymium	U	--
^{233}U	Uranium-233	U	DFR/CPF	7440-16-6	Rhodium		--
^{234}U	Uranium-234	U	DFR/CPF	7440-17-7	Rubidium	U	--
^{235}U	Uranium-235 + D		DFR/CPF	7440-18-8	Ruthenium	U	--
^{236}U	Uranium-236		DFR/CPF	7440-19-9	Samarium		--
^{238}U	Uranium-238 + D		DFR/CPF	7782-49-2	Selenium*	U	RfD
^{90}Y	Yttrium-90		--	7440-21-3	Silicon		--
79-01-6	1, 1, 2-Trichloroethylene	U	RfD/CPF	7440-22-4	Silver*		RfD
78-93-3	2-Butanone(MEK)	U	RfD	7440-23-5	Sodium		--
67-64-1	2-Propanone (Acetone)		RfD	7440-24-6	Strontium		RfD
108-10-1	4-Methyl-2-pentanone (MIBK)	U	RfD	14808-79-8	Sulfate		--
71-50-1	Acetate	U	--	7440-25-7	Tantalum	U	--

Table 5-1. List of Analytes and Available Toxicity Information. (3 sheets)

Isotope/ CAS	Analyte[a]	Detect	Available Toxicity Information[b]	Isotope/ CAS	Analyte	Detect	Available Toxicity Information
7429-90-5	Aluminum		RfD	13494-80-9	Tellurium	U	--
7664-41-7	Ammonia		RfD	7440-28-0	Thallium*		RfD
7440-36-0	Antimony*	U	RfD	7440-29-1	Thorium		--
7440-38-2	Arsenic*		RfD/CPF	7440-31-5	Tin	U	RfD
7440-39-3	Barium*		RfD	7440-32-6	Titanium		--
7440-41-7	Beryllium*	U	RfD/CPF	126-73-8	Tributyl phosphate	U	RfD/CPF
7440-69-9	Bismuth		--	7440-33-7	Tungsten	U	--
7440-42-8	Boron	U	RfD	7440-61-1	Uranium		--
24959-67-9	Bromide	U	--	7440-62-2	Vanadium	U	RfD
7440-43-9	Cadmium*	U	RfD/CPF	1330-20-7	Xylenes	U	RfD
7440-70-2	Calcium		--	7440-65-5	Yttrium		--
7440-45-1	Cerium		RfD	7440-66-6	Zinc		RfD
16887-00-6	Chloride	U	--				

[a] RPP-RPT-55803, *Tank 241-C-109 Residual Waste Inventory Estimates for Component Closure Risk Assessment.*

[b] HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for Hanford Tank Waste Performance Assessments.*

CAS = Chemical Abstracts Service
CPF = Cancer potency factor
-- = No available toxicity value (dose factor, reference dose, or cancer potency factor)
DRF = Dose factor
RfD = Reference dose
U = Analyte not detected in residual wastes

Gray shaded area indicates non-detect for this analyte.

*Dangerous waste constituent per WAC 173-303-9905, "Dangerous Waste Constituents List."

5.2 RESULTS FOR INDIVIDUAL CONTAMINANTS FOR POST-RETRIEVAL SINGLE-SHELL TANK 241-C-109

Table 5-2 identifies the main contributors to the ILCR (industrial and residential scenarios), groundwater dose (all-pathways farmer scenario), and drinking water dose for radiological components of the residual waste remaining in tank C-109. Table 5-3 identifies the primary hazardous chemicals that contribute to ILCR and the Hazard Quotient. These results are provided for the average residual waste inventory for SST C-109. A more complete listing of all analytes for the same average inventory is provided in Tables D-1 and D-2 of Appendix D. A similar set of tables based on the 95% UCL inventory is provided in Tables D-3 and D-4 of Appendix D. In each of these tables, the following columns are provided.

a. **Analyte Name.**

b. **Detected in Residual Wastes** is an indicator as to whether an analyte was detected in the laboratory.

c. **Inventory** as shown here for non-detects is calculated at one-half the detection limit.

d. **WMA C Fenceline Concentration** is the maximum modeled concentration for a constituent at the WMA C fenceline over the modeling period. In the methodology used in DOE/ORP-2005-01, this concentration was estimated using cross-sectional modeling of vadose zone and groundwater flow and transport. In some cases, individual analytes may not have a corresponding concentration at the fenceline because short-lived radionuclides will decay away before the contaminant can arrive at the WMA C fenceline. Relatively immobile contaminants (i.e., K_d greater than 0.6 mg/L) will also result in a zero concentration at the fenceline as they will not reach the fenceline within 10,000 years (based on assumptions and transport modeling approach used).

e. **Peak Year** is the year in which the simulation estimates that peak concentration for a given analyte arrives at the fenceline.

f. **K_d** is the mobility factor used in the groundwater modeling for the analyte. The smaller the K_d, the more mobile the contaminant; if the K_d is zero, the contaminant moves with the groundwater.

g. **Half-life** is the duration in years for a radionuclide to decay to half its activity. Organic compounds were assumed not to decay (radionuclides only).

h. **Incremental Lifetime Cancer Risk** (groundwater) are described in HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for Hanford Tank Waste Performance Assessments* for the industrial and residential exposure scenarios [including WAC 173-340, Method B (residential)].

i. **Radiological Dose** is the estimated drinking water dose for the all-pathways farmer exposure scenario (radionuclides only).

j. **Radiological Dose – Beta/Photon** is the drinking water dose from beta/photon emitting radionuclides using equivalent dose (radionuclides only).

k. **Hazard Quotient** (groundwater) – Hazard quotients calculated for residential and industrial scenarios described in HNF-SD-WM-TI-707.

5.3 CUMULATIVE ANALYSIS RESULTS FOR SINGLE-SHELL TANK 241-C-109 AND WASTE MANAGEMENT AREA C

The cumulative analysis (i.e., sum of the risk metrics) for tank C-109 residual average and 95% UCL risk levels were calculated and are provided in this section.

- **Average Inventory**—best estimate of the residual waste inventory computed using mean sample concentrations, mean sample density, and best estimate of the residual volume.

- **95% UCL Inventory**—considered the bounding inventory. The 95% UCL of the average inventory was calculated based on uncertainties associated with the concentration, volume, and density (for solids) measurements (see Section 3.0).

The impacts for the groundwater pathway associated with each residual waste inventory are evaluated with a variety of performance metrics. The ILCRs are evaluated for radiological analytes using the average and 95% UCL inventories and industrial and residential exposure scenarios. The ILCR and hazard indices are examined for the same inventories using a residential exposure scenario.

Radiological doses using the same two inventories are also evaluated for an all-pathways farmer and a drinking water only exposure scenario. Estimated concentration levels of some selected analytes are also provided and compared against current maximum concentration levels.

A comparison of impacts from the average and the 95% UCL inventories and current performance metrics for ILCR, hazard indices, and maximum concentration limits are summarized in Table 5-4.

Table 5-2. Estimated Maximum Incremental Lifetime Cancer Risk/Radiological Dose during the Modeling Period for Primary Radionuclides Related to Average Residual Waste Inventory in Single-Shell Tank 241-C-109.

Analyte	Above Detection Limits in Residual Waste	Inventory (Ci)	Waste Management Area C Fenceline Concentration (pCi/L)	Peak Year	K_d (mL/g)[a]	Half-Life (yr)	Incremental Lifetime Cancer Risk		Radiological Dose (mrem/yr) All Pathways Farmer Scenario[b]	Radiological Dose - Beta/Photon (mrem/yr) Drinking Water Only Scenario[b]
							Industrial	Residential		
^{14}C	No	3.28E-04	<1.00E-03[c]	9.78E+03	0.00E+00	5.73E+03	NE	NE	NE	NE
^{99}Tc	Yes	7.52E-03	3.00E-02	1.05E+04	0.00E+00	2.11E+05	4.14E-10	1.01E-08	5.26E-05	1.33E-04
^{129}I	No	6.80E-05	<1.00E-03[c]	1.20E+04	2.00E-01	1.57E+07	NE	NE	NE	NE
^{234}U	No	2.57E-03	0.00E+00	DNA	6.00E-01	2.46E+05	NE	NE	NE	N/A
^{235}U	Yes	3.43E-04	0.00E+00	DNA	6.00E-01	7.04E+08	NE	NE	NE	N/A
^{236}U	Yes	8.23E-05	0.00E+00	DNA	6.00E-01	2.34E+07	NE	NE	NE	N/A
^{238}U	Yes	8.17E-03	0.00E+00	DNA	6.00E-01	4.47E+09	NE	NE	NE	N/A
Performance Objective[d]							**1-0E-6 to 1.0E-4[e]**	**1-0E-6 to 1.0E-4[e]**	**25[f]**	**4[g]**

[a] See PNNL-13895, *Hanford Contaminant Distribution Coefficient Database and Users Guide*, Rev. 1, for the basis for the K_d values listed for the radionuclides.

[b] All exposure scenarios are described in HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for Hanford Tank Waste Performance Assessments.*

[c] Simulation predicted contaminant arrives at the fenceline, but at a concentration (<0.001 pCi/L) that is much below the minimum detection limit for standard analytical methods.

[d] Performance objectives apply to the cumulative (i.e., all contaminants) for the entire waste management area.

[e] EPA/540/R/99/006, *Radiation Risk Assessment at CERCLA Sites: Q & A*, Directive 9200.4-31P.

[f] DOE O 435.1, *Radioactive Waste Management.*

[g] 65 FR 76708, "National Primary Drinking Water Regulations; Radionuclides; Final Rule."

DNA = did not arrive at fenceline within the modeling period
N/A = radionuclide is not a beta/photon emitter
NE = constituent analyzed, but this risk metric was not calculated because the analyte was predicted to have a concentration less than 0.001 pCi/L, which is well below the ability of standard laboratory methods to detect it

Shaded cell indicate nondetects in sludge or supernate, and the inventory used in the risk assessment is calculated at one-half the minimum detection limit.

Table 5-3. Estimated Maximum Value for Incremental Lifetime Cancer Risk and Hazard Quotient for Selected Non-Radiological Analytes Related to Average Residual Waste Inventory in Single-Shell Tank 241-C-109.

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[a]	Incremental Lifetime Cancer Risk Scenarios (Groundwater)[b]	Hazard Quotient (Groundwater)[b]
						WAC 173-340 Method B	
Chromium, Total*	Yes	1.51E-01	<1.00E-03[c]	1.05E+04	0.00E+00	NE	NE
Fluoride	Yes	8.29E+01	3.40E-01	1.05E+04	0.00E+00	No CPF	3.55E-04
Nitrate	Yes	3.87E+00	1.59E-02	1.05E+04	0.00E+00	No CPF	6.21E-07
Nitrite	Yes	3.28E+00	1.35E-02	1.05E+04	0.00E+00	No CPF	8.42E-06
Uranium	Yes	2.45E+01	0.00E+00	DNA	6.00E-01	NE	NE
Performance Objective[d]						**1.0E-06[e]**	**1.0[f]**

[a] See PNNL-13895, *Hanford Contaminant Distribution Coefficient Database and Users Guide*, Rev. 1, for the basis for the K_d values listed for chromium and nitrate. The K_d values listed for the organic chemical compounds are determined from the chemicals' organic carbon/water partitioning coefficient and an estimate of 0.03% for the Hanford Site sediments fraction of organic content (PNNL-13895, Rev. 1, page 11, paragraph 3).

[b] All exposure scenarios are described in HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for Hanford Tank Waste Performance Assessments*.

[c] Simulation predicted contaminant arrives at the fenceline, but at a concentration (0.001 µg/L) that is much below the minimum detection limit for standard analytical methods.

[d] Single Analyte Performance objectives apply to entire waste management area, not just a single component of the waste management area.

[e] *Washington Administrative Code* (WAC) 173-340-705, "Use of Method B," subsection (2)(c)(ii).

[f] WAC 173-340-705 (2)(c)(i).

DNA = did not arrive at fenceline within the modeling period
NE = constituent analyzed, but this risk metric was not calculated because the analyte was predicted to have a concentration less than 0.001 µg/L, which is well below the ability of standard laboratory methods to detect it
No CPF = no cancer potency factor available

* Dangerous waste constituent per WAC 173-303-9905, "Dangerous Waste Constituents List." Total Cr is assumed to be Chromium(III) insoluble salts.

Table 5-4. Comparison of Cumulative Incremental Lifetime Cancer Risk, Hazard Index, and Groundwater Concentration at Peak Waste Management Area C Fenceline for Average and 95% Upper Confidence Level Residual Waste Inventories in Single-Shell Tank 241-C-109. (2 sheets)

Metric[a]	Industrial Receptor		Residential Receptor		Performance Objective[b]
	Average Inventory	95% Upper Confidence Level Inventory	Average Inventory	95% Upper Confidence Level Inventory	
Incremental Lifetime Cancer Risk from Radioactive Analytes (unitless)					
Total without non-detects[c]	4.14E-10	5.20E-10	1.01E-08	1.27E-08	1.0E-06 to 1.0E-4[e]
Total with non-detects[d]	4.17E-10	5.31E-10	1.01E-08	1.27E-08	
Incremental Lifetime Cancer Risk from Non-Radioactive Analytes (unitless)					
Total without non-detects[c]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.0E-5[f]
Total with non-detects[d]	2.74E-13	8.21E-13	5.44E-13	1.63E-12	
Hazard Index (unitless)					
Total without non-detects[c]	5.90E-05	7.26E-05	4.06E-04	4.99E-04	1.0[f]
Total with non-detects[d]	5.90E-05	7.26E-05	4.06E-04	4.99E-04	
Radiological Dose (mrem/yr)	**All Pathways**		**Drinking Water**		**Performance Objective[b]**
	Average Inventory	**95% Upper Confidence Level Inventory**	**Average Inventory**	**95% Upper Confidence Level Inventory**	
Total without non-detects[c]	5.26E-05	6.61E-05	1.33E-04	1.68E-04	25[g] and 4[h] mrem
Total with non-detects[d]	5.50E-05	7.32E-05	1.34E-04	1.71E-04	

Table 5-4. Comparison of Cumulative Incremental Lifetime Cancer Risk, Hazard Index, and Groundwater Concentration at Peak Waste Management Area C Fenceline for Average and 95% Upper Confidence Level Residual Waste Inventories in Single-Shell Tank 241-C-109. (2 sheets)

		Waste Management Area C Fenceline Concentration[c, d]		
Analyte	**Detected In Residual Wastes**	**Average Inventory**	**95% Upper Confidence Level Inventory**	**Maximum Concentration Limit**
Technetium-99	Yes	3.00E-02 pCi/L	3.77E-02 pCi/L	900 pCi/L
Iodine-129	No	<1.00E-03 pCi/L	<1.00E-03 pCi/L	1 pCi/L
Carbon-14	No	<1.00E-03 pCi/L	1.52E-03 pCi/L	2,000 pCi/L
Chromium, Total*	Yes	<1.00E-03 µg/L	<1.00E-03 µg/L	100 µg/L

[a] Incremental lifetime cancer risks of radioactive analytes were evaluated using industrial and residential land use scenarios described in HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for Hanford Tank Waste Performance Assessments*. Incremental lifetime cancer risks and hazard indices for non-radiological analytes were evaluated using *Washington Administrative Code* (WAC) 173-340-705, "Use of Method B," subsection (4) "Multiple hazardous substances or pathways" (residential).

[b] Performance objectives apply to entire waste management area, not just a single component of the waste management area.

[c] If detected, fenceline concentration is based on an inventory that is calculated from actual laboratory results. Analytes with a fenceline concentration of less than either 0.001 pCi/L (radioactive) or 0.001 µg/L (nonradioactive), which is a value that is well below the minimum detection limit for standard analytical methods, are reported as less than 1.00E-03 pCi/L or µg/L.

[d] If not detected, fenceline concentration is based on an inventory that is calculated at half the detection limits of analytical results. Concentrations that are less than either 0.001 pCi/L (radioactive) or 0.001 µg/L (nonradioactive), which is a value that is well below the minimum detection limit for standard analytical methods, are reported as less than 1.00E-03 pCi/L or µg/L.

[e] EPA/540/R/99/006, *Radiation Risk Assessment at CERCLA Sites: Q & A*, Directive 9200.4-31P.

[f] WAC 173-340-705 (4).

[g] DOE O 435.1, *Radioactive Waste Management*.

[h] 65 FR 76708, "National Primary Drinking Water Regulations; Radionuclides; Final Rule."

Gray shaded cells are nondetects and the inventory used in the risk assessment is calculated at one-half the minimum detection limit.

* Dangerous waste constituent per WAC 173-303-9905, "Dangerous Waste Constituents List." Total Cr is assumed to be Chromium(III) insoluble salts.

Results of the Table 5-4 comparison can be summarized as follows:

Performance Metric	Comparison(s) with Performance Objective
ILCR for Radioactive Analytes (1.0E-06 to 1.0E-04 ILCR)	• Estimated ILCRs for all radionuclides are between two to three orders of magnitude below performance objective range of 1.0E-06 to 1.0E-04 ILCR.
ILCR for Non-Radiological Analytes (1.0E-05 ILCR)	• Estimated ILCRs for all non-radionuclides are seven to eight orders of magnitude lower than the upper end of the performance objective of 1.0E-05 ILCR.
Hazard Indices (1.0)	• Estimated hazard indices for all analytes are three to four orders of magnitude below performance objective of 1.0.
Radiological Dose • 25 mrem/yr All-Pathways • 4 mrem/yr Drinking Water Only	• Estimated doses for all radionuclides are between o Four and six orders of magnitude below the performance objective for the all-pathways dose of 25 mrem/yr o Three and six orders of magnitude below the performance objective for drinking water dose of 4 mrem/yr.
Maximum Concentration Limits of Key Analytes: • ^{99}Tc – 900 pCi/L • ^{129}I – 1 pCi/L • ^{14}C – 2,000 pCi/L • Cr – 100 µg/L	• Estimated concentrations for ^{99}Tc are four to five orders of magnitude below 900 pCi/L maximum contaminant level. • Predicted concentration levels of other constituents of potential concern (e.g., ^{129}I, ^{14}C, and Cr) are significantly lower than their respective maximum contaminant levels.

5.4 INADVERTENT INTRUDER

The DOE recognizes that an inadvertent intruder may be onsite and not be discovered until after exposure has occurred. The radiological dose to an inadvertent intruder is therefore estimated as a part of this risk assessment.

The scenarios considered in this assessment for radiological doses from inadvertent intrusions included: 1) a well driller scenario that was used as a reference case for acute exposure in the SST PA and 2) a rural pasture scenario that was used as a reference case for chronic exposure in the SST PA. This assessment of doses from inadvertent intrusions also evaluated chronic exposure scenarios that included: 1) a suburban gardener scenario and 2) a commercial farmer scenario that were used as sensitivity cases for chronic exposure in the SST PA.

A summary of doses calculated for each of the intruder scenarios for the average and 95% UCL inventories remaining at SST C-109 at 100 years and 500 years after closure for tank C-109 are provided in Table 5-5. A summary of doses calculated for each of the intruder scenarios for the average and 95% UCL inventories at 100-year intervals between 100 and 1,000 years after closure for tank C-109 are provided in Table 5-6. Tables and plots of doses related to individual radioactive analytes are provided in Tables D-5 through D-8 and Figures D-1 through D-4 in Appendix D.

Table 5-5. Comparison of Intruder Doses at 100 and 500 years after Closure from Residual Waste for Single-Shell Tank 241-C-109.

Years after Closure[1]	Inventory	SST PA Reference Case		SST PA Sensitivity Cases	
		Well Driller[2] (mrem)	Rural Pasture[3] (mrem/yr)	Suburban Garden[3] (mrem/yr)	Commercial Farm[3] (mrem/yr)
100	Average	0.69	16	230	3.27E-03
	95% UCL	0.91	21	295	4.39E-03
500	Average	0.044	0.013	0.28	3.36E-04
	95% UCL	0.082	0.023	0.52	6.21E-04

PA = performance assessment SST = single-shell tank UCL = upper confidence level

Notes:
[1] Site closure is assumed to occur on January 1, 2032.
[2] Performance Objective (Acute Exposure) – 500 mrem.
[3] Performance Objective (Chronic Exposure) – 100 mrem/yr.

A review of detailed results and plots in Appendix D (Tables D-5 through D-8 and Figures D-1 through D-4) resulted in the following observations about key analytes for inadvertent intruder impacts:

Inadvertent Intrusion Scenario	Key Radionuclides			
	^{137}Cs	^{90}Sr	^{239}Pu	^{241}Am
Well Driller	Primary contributor to dose up to ~220 yrs after closure	Secondary contributor to dose up to ~200 yrs after closure	Primary contributors to dose after ~220 yrs after closure	
Rural Pasture	Secondary contributor to dose up to ~220 yrs after closure	Primary contributor to dose up to ~420 yrs after closure	Secondary contributors to dose between ~220 and ~420 yrs after closure; primary contributor to dose after ~420 yrs post-closure	
Suburban Gardener	Secondary contributor to dose up to ~180 yrs after closure	Primary contributor to dose up to ~400 yrs after closure	Secondary contributors to dose between ~180 and ~400 yrs after closure; primary contributor to dose after ~400 yrs post-closure	
Commercial Farm	Primary contributors to dose up to ~180 yrs after closure		Secondary contributors to dose up to ~180 yrs after closure; primary contributors to dose after ~180 years post-closure	

Table 5-6. Potential Future Impact from Inadvertent Intrusion into Residual Waste for Average and 95% Upper Confidence Level Inventories.

Years After Closure[1]	100	200	300	400	500	600	700	800	900	1,000
Inadvertent Intrusion Acute Dose[2] (mrem) – Well Driller Scenario										
Average Inventory	0.69	0.11	0.052	0.046	0.044	0.042	0.042	0.041	0.040	0.040
95% Upper Confidence Level Inventory	0.91	0.16	0.092	0.084	0.082	0.081	0.080	0.080	0.080	0.079
Inadvertent Intrusion Acute Dose[3] (mrem/yr) – Rural Pasture Scenario										
Average Inventory	16	1.4	0.13	0.022	0.013	0.012	0.011	0.011	0.011	0.011
95% Upper Confidence Level Inventory	21	1.8	0.17	0.036	0.023	0.022	0.022	0.021	0.021	0.021
Inadvertent Intrusion Chronic Dose[3] (mrem/yr) – Suburban Gardener Scenario										
Average Inventory	230	20	2.0	0.42	0.28	0.26	0.26	0.25	0.25	0.24
95% Upper Confidence Level Inventory	295	26	2.7	0.70	0.52	0.50	0.49	0.49	0.48	0.48
Inadvertent Intrusion Chronic Dose[3] (mrem/yr) – Commercial Farm Scenario										
Average Inventory	3.3E-03	6.4E-04	3.9E-04	3.5E-04	3.4E-04	3.3E-04	3.2E-04	3.1E-04	3.1E-04	3.0E-04
95% Upper Confidence Level Inventory	4.4E-03	1.0E-03	6.8E-04	6.3E-04	6.2E-04	6.1E-04	6.0E-04	6.0E-04	6.0E-04	5.9E-04

[1] Site closure is assumed to occur on January 1, 2032.

[2] Performance Objective (Acute Exposure) – 500 mrem.

[3] Performance Objective (Chronic Exposure) – 100 mrem/yr.

At 100 years after closure (see Table 5-5 and 5-6), doses for the well driller scenario were estimated to be about 0.14% and 0.18% of the 500 mrem acute exposure performance objective for the average and the 95% UCL inventories, respectively. At 100 years after closure, doses with the rural pasture scenario were estimated to be about 16% and 21% of the 100 mrem/yr chronic exposure performance objective for the average and 95% UCL inventories, respectively. However, doses resulting from chronic exposure in the suburban garden scenario were about 230% and 295% higher than the 100 mrem/yr chronic exposure performance objective for the average and 95% UCL inventories, respectively (see Table 5-5). Doses resulting from the commercial farmer were well below (e.g., 0.003% and 0.04%) the 100 mrem/yr chronic exposure performance objective for the average and 95% UCL inventories, respectively (see Table 5-5).

By 500 years after closure (see Tables 5-5 and 5-6), the estimated doses for the well driller scenario for the average and 95% UCL inventories was about 0.008% and 0.02% of the acute exposure performance objective of 500 mrem, respectively. At 500 years after closure, doses for all inadvertent intruder scenarios used to evaluate the doses from chronic exposure were well below the chronic exposure performance objective of 100 mrem/yr. The highest estimated dose at 500 yrs after closure was for the suburban gardener scenario using the 95% UCL inventory which yielded a dose that was estimated to be ~0.52% of the 100 mrem/yr performance objective (see Table 5-5).

5.5 COMPARISON OF TANK RESIDUALS WITH MODEL TOXICS CONTROL ACT SOIL CLEANUP LEVELS

This section provides additional risk management information related to concentrations of constituents remaining in waste residuals within tank C-109 compared against the *Model Toxics Control Act* (MTCA) WAC 173-340 cleanup standards. In this section, specific comparisons are made between the concentrations of constituents remaining in tank C-109 against the MTCA cleanup standards for soil direct contact unrestricted land use (Method B), industrial land use (Method C), and soil concentrations protective of groundwater using the fixed parameter three-phase partitioning model given in WAC 173-340-747(4).

Per WAC 173-340-740, "Unrestricted Land Use Soil Cleanup Standards," for soil cleanup levels based on human exposure via direct contact or other exposure pathways where contact with the soil is required to complete the pathway, the point of compliance shall be established in the soils throughout the site from the ground surface to 15 ft below the ground surface. Under a closure configuration, waste residuals left in tank C-109 and other SSTs in WMA C would be expected to be below 15 ft below ground surface.

Implicit in the use of the fixed parameter three-phase partitioning model given in WAC 173-340-747 deriving soil cleanup levels for groundwater protection is the assumption that constituents of interest are found in soils and are immediately available to be leached by infiltrating precipitation. Under a closure configuration, constituents associated with waste residuals left in tank C-109 and other SSTs in WMA C would be contained within a grout-filled tank, a steel tank liner, and an underlying concrete pad below the liner and would not be immediately available for leaching by infiltrating water.

5.5.1 WAC 173-340 Direct Contact and Soil Concentrations Protective of Groundwater

Table 5-7 contains the average and 95% UCL concentrations of detected constituents estimated in residual waste for tank C-109 on a mass basis for comparison against WAC 173-340 cleanup levels for soil direct contact unrestricted land use (Method B), industrial land use (Method C), and soil concentration protective of groundwater. Table 5-7 also provides Hanford Site-specific 90th percentile background concentrations, and identifies analytes that are dangerous waste constituents per WAC 173-303-9905, "Dangerous Waste Constituents List". A more detailed list of background concentrations and references is provided in Table D-11 of Appendix D.

Ratios of the average and 95% UCL concentrations to cleanup levels for soil direct contact (Method B and Method C) and soil concentrations protective of groundwater are provided in Tables 5-8 and 5-9, respectively. The ratios are obtained by dividing the analyte concentration by the soil direct contact cleanup level or the soil concentration protective of groundwater. The level of exceedance (ratio) corresponds to the level of residual waste concentration remaining in tank C-109 above or below the cleanup level. A level of exceedance greater than 1 corresponds to a residual waste concentration greater than the cleanup level. Tables 5-8 and 5-9 also identify analytes that are dangerous waste constituents per WAC 173-303-9905 and analytes with concentrations that exceed 90th percentile background concentrations. Expanded lists of non-radioactive analytes that were not detected are provided in Tables D-9 and D-10 in Appendix D.

The results for waste residual concentrations estimated for the average residual waste inventory from detected analytes are briefly summarized below.

- For direct contact under an unrestricted land use scenario, only aluminum, arsenic, fluoride, and uranium are above the cleanup levels, with only arsenic having a concentration more than 10 times the soil cleanup level. Arsenic is listed as a dangerous constituent per WAC 173-303-9905.

- For direct contact under an industrial land use scenario, all constituents are reported at concentrations less than the soil cleanup level.

- For soil concentrations protective of groundwater, arsenic, cyanide, fluoride, iron, nickel, nitrate, nitrite, thallium, and uranium are all above the concentration predicted by the MTCA fixed parameter three-phase model, with arsenic being greater than 100 times above the concentration protective of groundwater. Arsenic, cyanide, nickel, and thallium are listed as dangerous constituents per WAC 173-303-9905.

Table 5-7. Average and 95% Upper Limit Concentrations of Selected Constituents Estimated for Waste Residuals within Tank 241-C-109, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (2 sheets)

Analyte	Average Concentration (mg/kg)[a]	95% Upper Confidence Level Concentration (mg/kg)[b]	Soil Cleanup Level (mg/kg) – Direct Contact Method B	Soil Cleanup Level (mg/kg) – Direct Contact Method C	Soil Concentrations (mg/kg) – Protective of Groundwater	Lognormal 90 Percentile Background Value (mg/kg)	Above Detection Limits
2-Propanone (Acetone)	1.01E-01	1.71E-01	7.20E+04	3.15E+06	2.89E+01	--	Yes
Aluminum	1.62E+05	2.14E+05	8.00E+04	3.50E+06	4.80E+05	1.18E+07[e]	Yes
Arsenic*	7.72E+00	1.03E+01	6.67E-01	8.75E+01	3.41E-02	6.47E+03[e]	Yes
Barium*	9.85E+00	1.37E+01	1.60E+04	7.00E+05	1.65E+03	1.32E+05[e]	Yes
Chromium, Total*	1.33E+01	1.79E+01	1.20E+05	5.25E+06	2.00E+03	--	Yes
Copper	5.50E+01	8.08E+01	3.20E+03	1.40E+05	2.84E+02	2.20E+04[e]	Yes
Cyanide*	2.97E+01	4.17E+01	4.80E+01	2.10E+03	9.70E-01	--	Yes
Fluoride	7.32E+03	8.47E+03	4.80E+03	2.10E+05	2.88E+03	2.81E+03[e]	Yes
Iron	7.02E+03	1.03E+04	5.60E+04	2.45E+06	5.64E+03	3.26E+07[e]	Yes
Lead*	4.08E+02	4.34E+02	--	1.00E+03	3.00E+03	1.02E+04[e]	Yes
Lithium	1.50E+00	1.85E+00	1.60E+02	7.00E+03	1.92E+02	1.33E+04[g]	Yes
Manganese	4.26E+01	6.91E+01	1.12E+04	4.90E+05	5.01E+02	5.12E+05[e]	Yes
Mercury*	1.39E+00	2.24E+00	2.40E+01	1.05E+03	2.09E+00	1.30E+01[g]	Yes
Molybdenum	1.88E+00	2.84E+00	4.00E+02	1.75E+04	3.23E+01	4.70E+02[g]	Yes
Nickel*	1.01E+03	1.45E+03	1.60E+03	7.00E+04	1.30E+02	1.91E+04[g]	Yes
Nitrate[c]	3.42E+02	4.16E+02	5.68E+05	2.49E+07	1.80E+02	5.20E+04[e]	Yes

Table 5-7. Average and 95% Upper Limit Concentrations of Selected Constituents Estimated for Waste Residuals within Tank 241-C-109, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (2 sheets)

Analyte	Average Concentration (mg/kg)[a]	95% Upper Confidence Level Concentration (mg/kg)[b]	Soil Cleanup Level (mg/kg) – Direct Contact Method B	Soil Cleanup Level (mg/kg) – Direct Contact Method C	Soil Concentrations (mg/kg) – Protective of Groundwater	Lognormal 90 Percentile Background Value (mg/kg)	Above Detection Limits
Nitrite[d]	2.89E+02	2.95E+02	2.40E+04	1.05E+06	1.32E+01	--	Yes
Silver*	6.31E+00	1.42E+01	4.00E+02	1.75E+04	1.36E+01	1.67E+02[g]	Yes
Strontium	3.71E+01	5.54E+01	4.80E+04	2.10E+06	6.76E+03	--	Yes
Sulfate	2.16E+02	2.60E+02	--	--	1.00E+03	2.37E+05[e]	Yes
Thallium*	6.68E+00	7.72E+00	--	--	2.28E-01	1.85E+02[g]	Yes
Uranium	2.16E+03	3.12E+03	2.40E+02	1.05E+04	2.70E+02	3.21E+03[f]	Yes
Zinc	5.31E+01	5.75E+01	2.40E+04	1.05E+06	5.97E+03	6.78E+04[e]	Yes

[a] Mean Concentrations taken from Table A-1, Appendix A of RPP-RPT-55803, *Tank 241-C-109 Residual Waste Inventory Estimates for Component Closure Risk Assessment.*

[b] 95% Upper Confidence Level Concentration = Mean Concentration + (1.96 × Mean Concentration × Relative Standard Deviation). Mean Concentrations and Relative Standard Deviation provided in Table A-1 in Appendix A of RPP-RPT-55803.

[c] As nitrate, not nitrogen in nitrate; to convert to nitrogen in nitrate divide this number by 4.43.

[d] As nitrite, not nitrogen in nitrite; to convert to nitrogen in nitrite divide this number by 3.29.

[e] DOE/RL-92-24, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*, Rev. 4, Volume 1.

[f] DOE/RL-96-12, *Hanford Site Background: Part 2, Soil Background for Radionuclides.*

[g] ECF-HANFORD-11-0038, *Soil Background for Interim Use at the Hanford Site.*

* Dangerous waste constituent per WAC 173-303-9905, "Dangerous Waste Constituents List." Total Cr is assumed to be Chromium(III), insoluble salts.

-- = Value is not available

Table 5-8. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for Average Concentrations of Selected Constituents above Detection in 241-C-109 Tank Residual Wastes.

Analyte	Average Concentration (mg/kg)[a]	Ratio of Average Concentrations in Tank 241-C-109 Residual Wastes to Soil Cleanup Standards				
		Soil Direct Contact (Method B)	Soil Direct Contact (Method C)	Soil Concentrations Protective of Groundwater	Above Detection Limits	Above 90 Percentile Background
2-Propanone (Acetone)	1.01E-01	1.40E-06	3.21E-08	3.49E-03	Yes	--
Aluminum	1.62E+05	2.03E+00	4.63E-02	3.37E-01	Yes	No
Arsenic*	7.72E+00	1.16E+01	8.82E-02	2.27E+02	Yes	No
Barium*	9.85E+00	6.16E-04	1.41E-05	5.98E-03	Yes	No
Chromium, Total*	1.33E+01	1.11E-04	2.53E-06	6.65E-03	Yes	--
Copper	5.50E+01	1.72E-02	3.93E-04	1.94E-01	Yes	No
Cyanide*	2.97E+01	6.19E-01	1.41E-02	3.06E+01	Yes	--
Fluoride	7.32E+03	1.53E+00	3.49E-02	2.54E+00	Yes	Yes
Iron	7.02E+03	1.25E-01	2.87E-03	1.24E+00	Yes	No
Lead*	4.08E+02	--	4.08E-01	1.36E-01	Yes	No
Lithium	1.50E+00	9.38E-03	2.14E-04	7.81E-03	Yes	No
Manganese	4.26E+01	3.80E-03	8.69E-05	8.51E-02	Yes	No
Mercury*	1.39E+00	5.79E-02	1.32E-03	6.66E-01	Yes	No
Molybdenum	1.88E+00	4.70E-03	1.07E-04	5.82E-02	Yes	No
Nickel*	1.01E+03	6.31E-01	1.44E-02	7.75E+00	Yes	No
Nitrate[b]	3.42E+02	6.02E-04	1.38E-05	1.90E+00	Yes	No
Nitrite[c]	2.89E+02	1.20E-02	2.75E-04	2.19E+01	Yes	--
Silver*	6.31E+00	1.58E-02	3.61E-04	4.64E-01	Yes	No
Strontium	3.71E+01	7.73E-04	1.77E-05	5.49E-03	Yes	--
Sulfate	2.16E+02	--	--	2.16E-01	Yes	No
Thallium*	6.68E+00	--	--	2.93E+01	Yes	No
Uranium	2.16E+03	9.00E+00	2.06E-01	8.00E+00	Yes	No
Zinc	5.31E+01	2.21E-03	5.06E-05	8.89E-03	Yes	No

[a] Mean Concentrations taken from Table A-1, Appendix A of RPP-RPT-55803, *Tank 241-C-109 Residual Waste Inventory Estimates for Component Closure Risk Assessment.*

[b] As nitrate, not nitrogen in nitrate; to convert to nitrogen in nitrate divide this number by 4.43.

[c] As nitrite, not nitrogen in nitrite; to convert to nitrogen in nitrite divide this number by 3.29.

* Dangerous waste constituent per WAC 173-303-9905, "Dangerous Waste Constituents List." Total Cr is assumed to be Chromium (III), insoluble salts.

-- = Value is not available

Table 5-9. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for 95% Upper Confidence Level Concentrations of Selected Constituents above Detection in 241-C-109 Tank Residual Wastes.

Analyte	95 % Upper Confidence Level Concentration (mg/kg)[a]	Ratio of 95% Upper Confidence Level Concentrations in Tank 241-C-109 Residual Wastes to Soil Cleanup Standards				
		Soil Direct Contact (Method B)	Soil Direct Contact (Method C)	Soil Concentrations Protective of Groundwater	Above Detection Limits	Above 90 Percentile Background
2-Propanone (Acetone)	1.71E-01	2.37E-06	5.42E-08	5.91E-03	Yes	--
Aluminum	2.14E+05	2.68E+00	6.12E-02	4.46E-01	Yes	No
Arsenic*	1.03E+01	1.55E+01	1.18E-01	3.03E+02	Yes	No
Barium*	1.37E+01	8.55E-04	1.95E-05	8.30E-03	Yes	No
Chromium, Total*	1.79E+01	1.49E-04	3.40E-06	8.93E-03	Yes	--
Copper	8.08E+01	2.52E-02	5.77E-04	2.84E-01	Yes	No
Cyanide*	4.17E+01	8.70E-01	1.99E-02	4.31E+01	Yes	--
Fluoride	8.47E+03	1.76E+00	4.03E-02	2.94E+00	Yes	Yes
Iron	1.03E+04	1.85E-01	4.22E-03	1.83E+00	Yes	No
Lead*	4.34E+02	--	4.34E-01	1.45E-01	Yes	No
Lithium	1.85E+00	1.16E-02	2.65E-04	9.64E-03	Yes	No
Manganese	6.91E+01	6.17E-03	1.41E-04	1.38E-01	Yes	No
Mercury*	2.24E+00	9.34E-02	2.14E-03	1.07E+00	Yes	No
Molybdenum	2.84E+00	7.10E-03	1.62E-04	8.79E-02	Yes	No
Nickel*	1.45E+03	9.07E-01	2.07E-02	1.11E+01	Yes	No
Nitrate[b]	4.16E+02	7.32E-04	1.67E-05	2.31E+00	Yes	No
Nitrite[c]	2.95E+02	1.23E-02	2.81E-04	2.23E+01	Yes	--
Silver*	1.42E+01	3.55E-02	8.11E-04	1.04E+00	Yes	No
Strontium	5.54E+01	1.15E-03	2.64E-05	8.20E-03	Yes	--
Sulfate	2.60E+02	--	--	2.60E-01	Yes	No
Thallium*	7.72E+00	--	--	3.39E+01	Yes	No
Uranium	3.12E+03	1.30E+01	2.97E-01	1.15E+01	Yes	No
Zinc	5.75E+01	2.40E-03	5.48E-05	9.63E-03	Yes	No

[a] 95% Upper Confidence Level Concentration = Mean Concentration + (1.96 × Mean Concentration × Relative Standard Deviation). Mean Concentrations and Relative Standard Deviation provided in Table A-1, Appendix A of RPP-RPT-55803, *Tank 241-C-109 Residual Waste Inventory Estimates for Component Closure Risk Assessment.*

[b] As nitrate, not nitrogen in nitrate; to convert to nitrogen in nitrate divide this number by 4.43.

[c] As nitrite, not nitrogen in nitrite; to convert to nitrogen in nitrite divide this number by 3.29.

* Dangerous waste constituent per WAC 173-303-9905, "Dangerous Waste Constituents List." Total Cr is assumed to be Chromium(III), insoluble salts.

-- = Value is not available

The results for waste residual concentrations estimated in the 95% UCL residual waste inventory are briefly summarized below.

- For direct contact under an unrestricted land use scenario, aluminum, arsenic, fluoride, and uranium are above the cleanup levels, with arsenic having a concentration more than 10 times the cleanup level. Arsenic is listed as a dangerous constituent per WAC 173-303-9905.

- For direct contact under an industrial land use scenario, all constituents are reported at concentrations less than the soil cleanup level.

- For soil concentrations protective of groundwater, arsenic, cyanide, fluoride, iron, mercury, nickel, nitrate, nitrite, silver, thallium, and uranium are all above the concentration predicted by the MTCA fixed parameter three-phase model, with arsenic being greater than 100 times above the concentration protective of groundwater. Arsenic, cyanide, mercury, nickel, silver, and thallium are listed as dangerous constituents per WAC 173-303-9905.

5.5.2 WAC 173-340 Ecological Risk

WAC 173-340-900, "Tables" includes the following tables:

- Table 749-2, Priority Contaminants of Ecological Concern for Sites that Qualify for the Simplified Terrestrial Ecological Evaluation Procedure

- Table 749-3, Ecological Indicator Soil Concentrations (mg/kg) for Protection of Terrestrial Plants and Animals.

Each of these tables contains a footnote stating that it is not intended for the purpose of evaluating sludges or waste, as follows (key statement bolded for this report).

- Table 749-2, footnote a: "Caution on misusing these chemical concentration numbers. These values have been developed for use at sites where a site-specific terrestrial ecological evaluation is not required. They are not intended to be protective of terrestrial ecological receptors at every site. Exceedances of the values in this table do not necessarily trigger requirements for cleanup action under this chapter. **The table is not intended for purposes such as evaluating sludges or wastes.**
  This list does not imply that sampling must be conducted for each of these chemicals at every site. Sampling should be conducted for those chemicals that might be present based on available information, such as current and past uses of chemicals at the site."

- Table 749-3, footnote a: "Caution on misusing ecological indicator concentrations. Exceedances of the values in this table do not necessarily trigger requirements for cleanup action under this chapter. Natural background concentrations may be substituted for ecological indicator concentrations provided in this table. **The table is not intended for purposes such as evaluating sludges or wastes.**

This list does not imply that sampling must be conducted for each of these chemicals at every site. Sampling should be conducted for those chemicals that might be present based on available information, such as current and past uses of chemicals at the site."

Because of the limitations stated above, comparisons between the concentrations of waste constituents remaining in tank C-109 have not been made against Table 749-2 [under WAC 173-340-7492, "Simplified Terrestrial Ecological Evaluation Procedures," subsection (1) "Purpose"] or Table 749-3 [under WAC 173-340-7493, "Site-Specific Terrestrial Ecological Evaluation Procedures," subsection (2) "Problem formulation step," (i) "The chemicals of ecological concern"].

5.6 RISK ASSESSMENT SUMMARY

Cumulative analysis results of the risk assessment performed to examine impacts from post-retrieval inventories for SST C-109 are summarized as follows.

- The impacts estimated for residual waste left in SST C-109, using either the average or the 95% UCL inventory, are orders of magnitude below the various performance objectives identified for the groundwater pathway.
- Total ILCRs estimated for all radionuclides are two to three orders of magnitude below the upper end of the performance objective range 1.0E-06 to 1.0E-04 ILCR.
- Total ILCRs estimated for all detectable non-radionuclides are seven to eight orders of magnitude below the performance objective of 1.0E-05 ILCR.
- Total hazard indices estimated for all detectable analytes are three to four orders of magnitude below the performance objective of 1.0.
- Estimated doses for all detectable radionuclides are between:
    - Four and six orders of magnitude below the performance objective for the all-pathways dose of 25 mrem/yr
    - Three and six orders of magnitude below the performance objective for drinking water dose of 4 mrem/yr.

Following are conclusions about the impacts from key analytes identified in the residual wastes within SST C-109 for each of the performance metrics evaluated.

- **Total ILCR for Radionuclides:** For both the average and 95% UCL inventory, ^{99}Tc and ^{14}C are the primary contributors to the total ILCR for all radionuclides with the industrial land use and residential land use scenarios. The contribution from all other detectable radionuclides, including ^{129}I and the uranium isotopes, was not detectable in residual waste samples, arrived at the WMA C fenceline within the 10,000-year period of interest

below concentrations of 1.0E-03 pCi/L, or did not arrive at the WMA C fenceline within the 10,000-year period of interest.

- **Total ILCR for Nonradionuclides:** For both the average and 95% UCL inventory, the contribution from non-radioactive analytes detectable in residual waste samples arrived at the WMA C fenceline within the 10,000-year period of interest below concentrations of 1.0E-03 mg/L, or did not arrive at the WMA C fenceline within the 10,000-year period of interest.

- **Hazard Indices:** The contribution from non-radioactive analytes detectable in residual waste samples arrived at the WMA C fenceline within the 10,000-year period of interest below concentrations of 1.0E-03 mg/L, or did not arrive at the WMA C fenceline within the 10,000-year period of interest.

- **All-Pathways Dose:** ^{99}Tc and ^{14}C are the primary contributors to the total all-pathways dose estimated for the all-pathways farmer scenario. The contribution from all other radionuclides, including ^{129}I and the uranium isotopes, was not detectable in residual waste samples, arrived at the WMA C fenceline below concentrations of 1.0E-03 pCi/L, or did not arrive at the WMA C fenceline within the 10,000-year period of interest.

- **Drinking Water Dose (Target Organ):** ^{99}Tc, with a maximum dose rate of 5.3E-05 mrem/yr, contributed the majority of the EPA maximum contaminant level for beta/photon emitters (4 mrem/yr target organ dose). The contribution to dose from all other radionuclides, including ^{14}C, ^{129}I ,and the uranium isotopes, was not detectable in residual waste samples, arrived at the WMA C fenceline below concentrations of 1.0E-03 pCi/L, or did not arrive at the WMA C fenceline within the 10,000-year period of interest.

- **Intruder Dose:** Doses calculated from inadvertent intrusion are primarily attributable to doses from ^{90}Sr, ^{137}Cs, ^{239}Pu, and ^{241}Am. The relative contribution and timing of doses from these radionuclides to the total doses estimated during the 1,000-year period of analysis depends on the scenario considered. In general, dose contributions from ^{90}Sr and ^{137}Cs typically account for the majority of the dose during the first 200 to 400 years. Doses from ^{239}Pu and ^{241}Am contribute the majority of the dose realized after 200 to 400 years, and in the cases of the commercial farm and well driller, are the primary and secondary contributors to the total dose estimated after 200 years. For both average and 95% UCL inventories estimated for SST C-109, none of the inadvertent intruder evaluations produce results that exceed the performance objectives for either acute exposure or chronic exposure after ~120 years following closure.

As additional risk management information, concentrations of constituents remaining in waste residuals within tank C-109 are compared against the MTCA cleanup standards. For MTCA Method B and Method C soil cleanup levels based on human exposure via direct contact or other exposure pathways where contact with the soil is required to complete the pathway, the point of compliance shall be established in the soils throughout the site from the ground surface to

15 ft below the ground surface. Under a closure configuration, waste residuals left in tank C-109 and other SSTs in WMA C would be expected to be below 15 ft below ground surface.

For MTCA soil cleanup levels protective of groundwater, the assumption is that constituents of interest are found in soils and are immediately available to be leached by infiltrating precipitation. Under a closure configuration, constituents associated with waste residuals left in tank C-109 and other SSTs in WMA C would be contained within a grout-filled tank, a steel tank liner, and an underlying concrete pad below the liner and would not be immediately available for leaching by infiltrating water.

Following are conclusions about the comparison of tank C-109 waste residual concentrations against MTCA cleanup levels.

- **MTCA Method B Unrestricted Land Use:** For both the average and 95% UCL inventory, aluminum, arsenic, fluoride, and uranium are above the cleanup levels. Arsenic is listed as a dangerous constituent per WAC 173-303-9905.

- **MTCA Method C Industrial Land Use:** For both the average and 95% UCL inventory, all constituents are reported at concentrations less than the soil cleanup level.

- **MTCA Soil Concentrations Protective of Groundwater:** For both the average and 95% UCL inventory, arsenic, cyanide, fluoride, iron, nickel, nitrate, nitrite, thallium, and uranium are greater than the soil cleanup level. For the 95% UCL, mercury and silver are also above the soil cleanup level. Arsenic, cyanide, mercury, nickel, silver, and thallium are listed as dangerous constituents per WAC 173-303-9905.

Table 5-10 provides a comparison of the inventory used in DOE/ORP-2005-01 against the inventory for detected analytes calculated using post-retrieval samples for the average inventory and the 95% UCL inventories. For the purpose of this comparison, Table 5-10 includes inventories calculated from the laboratory's minimum detection limit for an analyte. Inventories calculated from one half of the laboratory's minimum detection limit are included in the risk assessment analysis. The following observations are made from the comparison of the Hanford Tank Waste Operations Simulator (HTWOS) and post-retrieval inventories.

- Comparison of the HTWOS estimated inventories and post-retrieval inventories for analytes important for assessment of groundwater impacts are as follows:

    - Post-retrieval inventories for ^{99}Tc are approximately two orders of magnitude less than the HTWOS estimate for ^{99}Tc

    - Post-retrieval inventories for chromium are approximately one order of magnitude less than the HTWOS estimate for chromium

    - Post-retrieval inventories for fluoride, nitrate, and nitrite are approximately one to two orders of magnitude below those in the HTWOS estimates.

- Comparison of the HTWOS estimated inventories and post-retrieval inventories for analytes important to assessing inadvertent intruder impacts are as follows:
    - Post-retrieval inventories for ^{90}Sr are approximately 3 and 4 times less than HTWOS estimates for ^{90}Sr
    - Post-retrieval inventories for ^{137}Cs are two orders of magnitude less than the HTWOS inventory estimates for ^{137}Cs
    - Post-retrieval inventories for ^{232}Th are approximately six orders of magnitude greater than the HTWOS estimates for ^{232}Th
    - Post-retrieval inventories for the plutonium isotopes are approximately 2 times less than to an order of magnitude less than those in the HTWOS estimate
    - Post-retrieval inventories for ^{241}Am are approximately 4 and 5 times less than those in the HTWOS estimate
    - Post-retrieval inventories for the uranium isotopes are approximately one order of magnitude less than estimated in the HTWOS inventory.

Table 5-10. Comparison of Hanford Tank Waste Operations Simulator Predicted Inventory Used in DOE/ORP-2005-01 with the Average and 95% Upper Confidence Level Post-Retrieval Inventories.

	Analyte	Units	DOE/ORP-2005-01[a] (HTWOS Predicted)	Average Post-Retrieval Inventory[b]	95% UCL Inventory[b]	Detected in Residual Wastes	Ratio Average/ HTWOS	Ratio Bounding/ HTWOS
Analytes Important for Groundwater Impacts	^{14}C	Ci	1.30E-04	6.56E-04	1.97E-03	No	N/A	N/A
	^{99}Tc	Ci	4.96E-01	7.52E-03	9.45E-03	Yes	1.52E-02	1.91E-02
	Chromium, Total	Kg	1.68E+00	1.51E-01	2.10E-01	Yes	8.99E-02	1.25E-01
	Fluoride	Kg	1.00E+01	8.29E+01	1.02E+02	Yes	8.29E+00	1.02E+01
	Nitrate	Kg	1.61E+02	3.87E+00	4.95E+00	Yes	2.40E-02	3.07E-02
	Nitrite	Kg	1.03E+02	3.28E+00	3.85E+00	Yes	3.18E-02	3.74E-02
Analytes Important for Inadvertent Intruder	^{90}Sr	Ci	8.45E+03	2.66E+03	3.42E+03	Yes	3.15E-01	4.05E-01
	^{137}Cs	Ci	5.74E+03	4.86E+01	6.27E+01	Yes	8.47E-03	1.09E-02
	^{232}Th	Ci	2.46E-12	8.49E-06	1.13E-05	Yes	3.45E+06	4.60E+06
	^{233}U	Ci	4.80E-06	2.16E-01	6.48E-01	No	N/A	N/A
	^{234}U	Ci	5.16E-02	5.13E-03	1.54E-02	No	N/A	N/A
	^{235}U	Ci	2.07E-03	3.43E-04	5.08E-04	Yes	1.66E-01	2.46E-01
	^{236}U	Ci	7.56E-04	8.23E-05	1.50E-04	Yes	1.09E-01	1.99E-01
	^{238}U	Ci	4.88E-02	8.17E-03	1.21E-02	Yes	1.67E-01	2.48E-01
	^{237}Np	Ci	3.52E-03	7.90E-03	2.37E-02	No	N/A	N/A
	^{238}Pu	Ci	5.46E-02	1.47E-02	2.00E-02	Yes	2.69E-01	3.66E-01
	^{239}Pu	Ci	2.17E+00	3.44E-01	5.17E-01	Yes	1.59E-01	2.39E-01
	^{240}Pu	Ci	3.72E-01	3.74E-02	5.62E-02	Yes	1.01E-01	1.51E-01
	^{241}Pu	Ci	1.89E+00	7.77E-01	9.23E-01	Yes	4.12E-01	4.90E-01
	^{241}Am	Ci	1.67E+00	3.23E-01	4.22E-01	Yes	1.93E-01	2.53E-01
	^{242}Cm	Ci	9.94E-03	7.36E-04	2.21E-03	No	N/A	N/A
	^{243}Cm	Ci	4.93E-04	5.61E-05	1.68E-04	No	N/A	N/A
	^{244}Cm	Ci	1.11E-02	1.19E-03	3.57E-03	No	1.07E-01	3.20E-01

[a] Inventories for contaminants having the greatest impact for groundwater or inadvertent intruder pathway.

[b] Includes inventories in sludge calculated from one half of the laboratory's minimum detection limit for an analyte.

Reference: DOE/ORP-2005-01, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site.*

HTWOS = Hanford Tank Waste Operations Simulator
N/A = Not applicable because the inventory in both supernate and sludge was calculated from one half of the laboratory's minimum detection limit for that analyte.
UCL = upper confidence level

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6.0 OPPORTUNITIES AND ACTIONS BEING TAKEN TO REFINE OR DEVELOP TANK WASTE RETRIEVAL TECHNOLOGIES, BASED ON LESSONS LEARNED

This section discusses aspects of the tank C-109 waste retrieval operations, provides recommendations for further actions, and addresses opportunities to refine waste retrieval technologies based on lessons learned from the tank C-109 retrieval operation. The format of this section is to provide brief discussions of the major Lessons-Learned topic areas. Some of the lessons learned are derived from retrieval of other tanks.

There are opportunities to improve future waste retrieval operations by looking at the ways to modify equipment, make operational changes (e.g., operating sequencing and conditions), plan work, and enhance the design and fabrication of equipment. All RDRs have a Lessons Learned section and it must be recognized that several of the previously identified lessons learned have been incorporated in the formulation and operation of subsequent tank waste retrieval operations, and in the tank C-109 retrieval operation.

Improvements implemented during the retrieval of the tank C-109 waste heel include the following.

- A 10,000-gal presoak was added in an attempt to remove supernate and soften the waste before initiating formal retrieval operations.
- Enough water was added to tank C-109 (70% contingency) to ensure water was added for all of estimated natrophosphate to dissolve (remain at less than 70% sodium saturation) (RPP-RPT-51386).
- A second water wash was planned after metathesis and aluminate dissolution, if needed to remove additional natrophosphate.
- Additional caustic was added to ensure the caustic concentration remained above 9 Molar during the metathesis process (RPP-RPT-51386).
- Based on tank C-109 results and observations, following transfer of the caustic/dissolution water, the tank was sluiced to remove additional fine solids that were not dissolved into solution or transferred after the aluminate dissolution.
- Based on tank C-109 recommendations, the tank walls and stiffener rings were washed with caustic solution during caustic circulation and with water added for aluminate dissolution.
- The tank C-109 hard heel caustic cleaning process was performed during the summer months. Higher temperatures of the wash water and caustic appear to have increased reaction rates. Working during the summer also eliminated potential flushing and water addition controls and requirements to prevent freezing.

- During sluicing it was found that higher flows were effective in breaking down solids. To keep the average flow rate of water into the tank below the average flow rate out, the rate of flow was increased to ~90 gpm for 5 minutes and then decreased to ~30 gpm. This was found to be more effective than maintaining a constant flow rate of ~60 gpm.

- In a lesson learned during sluicing operations in tank 241-C-104, an in-tank obstruction limited the ability to lower the slurry pump. The Articulated Mast System was successfully used to move the obstruction and permit the slurry pump to be lowered. While this tool was not needed in tank C-109, it may be useful in future retrieval operations.

6.1 SLUICING OPERATION

The in-tank cameras, as installed, did provide the necessary visibility to operate the retrieval system safely. During the sluicing operations, positioning the sluice stream across the tank resulted in buildup of solids on the light. Future considerations need to be made that address this operational aspect.

Addressing potential impacts is advisable when there are significant changes from the planned process (such as extended downtimes). Such changes may require additional process samples and/or even more time needed to evaluate the process.

The tank C-109 supernatant soak performed between July 26 and August 13, 2007 (after ~1,500,000 gal of slurry had been pumped) in an attempt to soften the solids had no measurable effect on the retrieval efficiency. The final days of operations show no net waste retrieval; this was also supported by visual observations of the retrieval operations.

6.2 SLUICER EQUIPMENT

Modified sluicing performed well for bulk retrieval of tank C-109 sludge. By using two sluicers, sludge could be mobilized throughout most of the tank.

The FoldTrack® Mobile Retrieval Tool was used to assist in the sluicing of the remaining tank C-109 waste and some additional waste was removed. The FoldTrack® Mobile Retrieval Tool remained in the tank at the completion of waste retrieval.

Opportunistic water sluicing was added following the sodium aluminate dissolution transfer. The added water sluicing step allowed recovery of additional waste.

6.3 CAUSTIC CLEANING OPERATION

Lesson Learned WRPS-IB-12-005, *Caustic Addition Process Improvements* on caustic addition to tank C-108 was determined to be applicable to tank C-109. Since the caustic addition process

sometimes takes longer than planned, sufficient manpower and resources were allocated for caustic addition to tank C-109.

6.4 WASTE CIRCULATION

Another lesson learned from retrieval of tank C-108 that was applicable to tank C-109 retrieval was that during circulation pre-start activities, low temperatures in the pump pit made it difficult to begin circulation. Due to the cold temperatures in January and the strict temperature limits of 50% sodium hydroxide solution, project delays on retrieval of tank C-108 were incurred while attempts were made to heat up the boxes into acceptable operating temperatures. Using caustic during the warm summer/fall months for tank C-109 helped to mitigate such a delay.

During initial caustic circulation activities of tank C-108, the slurry pump had high amperage readings resulting from pumping heavier (higher specific gravity) solution. At first, the project was not sure about operating the pump at the higher amp level. After discussions with the vendor and based on operating experience, the pump was operated safely at the higher amp levels. After the solution was circulated for some time, the pump amps would drop into normal operating ranges. Preparation for such incidents would enable continuity in the pump operation and startup.

A water flush at the slurry pump was done after high pump amp readings were experienced during initial caustic circulation startup on tank C-108. Adding the water diluted the liquid and/or heated the solution near the pump, allowing the pump to circulate the solution successfully. The recommendation is to pump the caustic solution before it cools and/or use small flush volumes prior to beginning circulation of the solution.

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7.0 LEAK DETECTION, MONITORING, AND MITIGATION

The LDMM program was implemented to protect the workers, public, and environment from leaks of radioactive liquid waste. The LDMM program included technologies and methods used prior to, during, and after waste retrieval to detect leaks, reduce the potential for a leak to occur by minimizing hydrostatic head, or minimize leak volumes by minimizing tank liquid volume. In addition, if a leak had occurred, the LDMM program would have quantified liquid waste release volumes.

The operational history and decades of waste and liquid level monitoring indicate that tank C-109 had not leaked and was sound before starting retrieval (HNF-EP-0182, *Waste Tank Summary Report for Month Ending July 31, 2013*, Rev. 304). Additionally, there was no evidence of a leak during retrieval of waste from tank C-109.

The following sections describe the LDMM requirements, leak detection monitoring implementation, mitigative approach, chronology, and results. The major results for the LDMM program during tank C-109 waste retrieval were as follows.

a. Drywell moisture and gamma logging showed no evidence of leaks during the tank C-109 waste retrieval.

b. Modified static level monitoring demonstrated no evidence to indicate leakage during retrieval.

c. Material balance calculations showed no evidence of leaks during the tank C-109 waste retrieval.

Retrieval of tank C-109 was performed under work plan RPP-21895 Revision 5.

7.1 REQUIREMENTS

Details of the LDMM program are presented in RPP-21895. The leak detection and monitoring (LDM) system requirements are contained in the safety basis controls given in HNF-SD-WM-TSR-006, *Tank Farms Technical Safety Requirements*, specifically Technical Safety Requirement (TSR) Limiting Condition for Operation Section 3.1.1, "Transfer Leak Detection Systems." Material balances during transfers are required by the TSR Administrative Control Section 5.11, "Transfer Control," and RPP-12711, *Temporary Waste Transfer Line Management Program Plan*. The primary procedures governing notification and reporting of leaks are TFC-OPS-OPER-C-24, "Occurrence Reporting and Processing of Operations Information" and TFC-ESHQ-ENV_FS-C-01, "Environmental Notification." Table 7-1 presents the tank C-109 LDM functions and requirements.

Table 7-1. Tank 241-C-109 Leak Detection and Monitoring Functions and Requirements.

Function	Requirement	Basis	Key Elements
Detect leaks during waste removal from SST	The leak detection and monitoring (LDM) system shall be capable of detecting liquid waste releases during all waste removal operations.	*Washington Administrative Code* (WAC) 173-303	Utilize LDM technologies to detect loss of liquid from a tank; see Section 7.2.
Monitor leaks from SST during waste removal	The waste retrieval system (WRS) shall be capable of providing data to support quantifying leak volumes from the tanks in the event a release is detected during waste retrieval operations	WAC 173-303	Utilize both ex-tank LDM technologies and process data that will allow estimate of leak volume and migration rate to be developed to the extent practical in the event of a leak.
Mitigate leaks during SST waste retrieval	The integrated retrieval and LDM system shall be designed and operated to mitigate leaks as the primary means of minimizing environmental impacts from leaks during waste retrieval if they occur.	WAC 173-303	Leak mitigation strategy described in Section 7.3.
WRS secondary containment and leak detection.	For ex-tank equipment and piping, the WRS shall incorporate secondary containment and leak-detection design features in accordance with 40 CFR 265.193 and DOE O 435.1.	40 CFR 265 WAC 173-303 DOE O 435.1 RPP-13033 HNF-SD-WM-TSR-006	Provide for safe and compliant transfer of waste to the receiver double-shell tank.

CFR = *Code of Federal Regulations* DOE = U.S. Department of Energy SST = single-shell tank

References:
40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," Subpart J—Tank Systems, §265.193 Containment and detection of releases.
DOE O 435.1, *Radioactive Waste Management.*
HNF-SD-WM-TSR-006, *Tank Farms Technical Safety Requirements.*
RPP-13033, *Tank Farms Documented Safety Analysis.*
WAC 173-303, "Dangerous Waste Regulations."

7.2 LEAK DETECTION AND TANK MONITORING

During retrieval of waste from tank C-109, LDM was accomplished by the use of high-resolution resistivity (HRR), drywell monitoring, visual inspection, leak detectors, Enraf gauges in tank AN-106, radiological monitoring, and material balances as shown in Table 7-2 and discussed in Sections 7.2.1 through 7.2.4. In-tank process control parameters were used to supplement ex-tank methods to provide a comprehensive approach to leak detection.

Table 7-2. Leak Detection and Monitoring Methods for Each Waste Retrieval System Component.

Component	Leak Detection and Monitoring Method
Single-shell tank 241-C-109	Drywells, liquid level indicators, visual inspection, material balance
Double-shell tank 241-AN-106	Liquid level indicators, annulus leak detectors, radiation monitoring for annulus exhaust air
Ancillary equipment (hose-in-hose transfer line)	Secondary containment, leak detectors, radiation monitoring

7.2.1 Drywell Logging and High-Resolution Resistivity

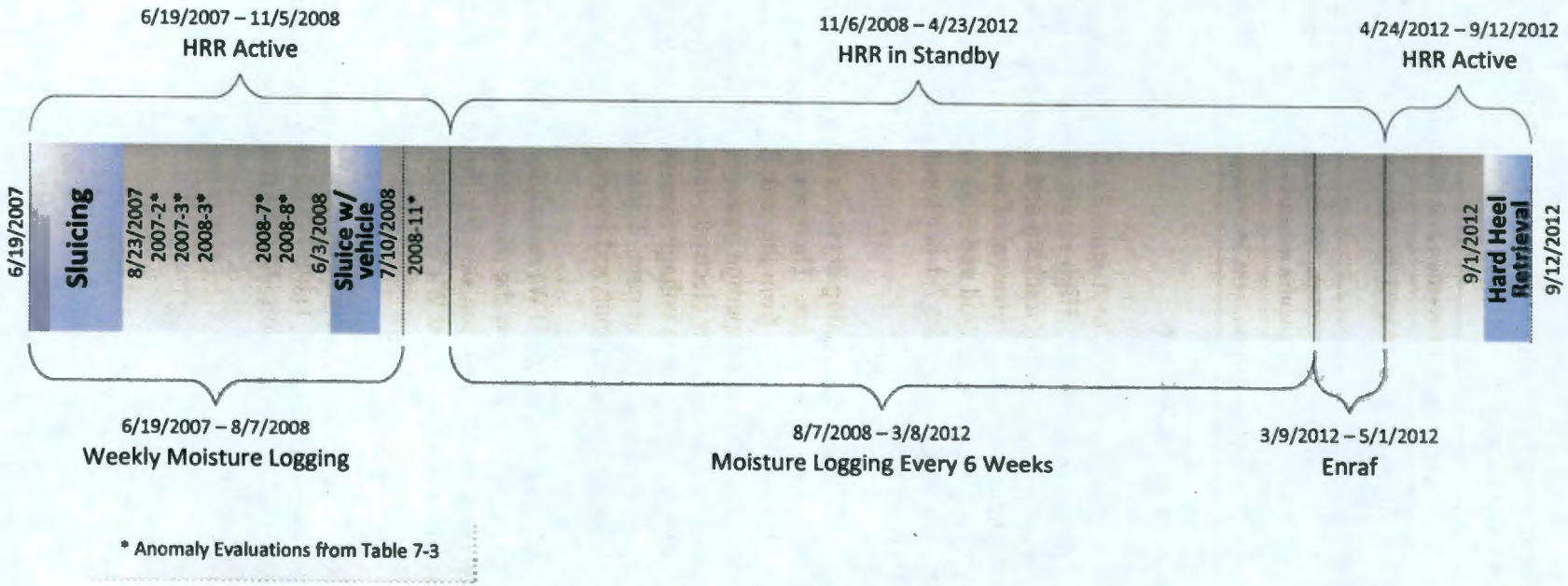
During the sluicing retrieval of tank C-109 (June 19, 2007 to August 23, 2007), moisture logging with gamma scans was the primary leak detection method. High-resolution resistivity was a demonstration leak detection method, but anomalous result tracking and reporting was required. High-resolution resistivity was used throughout the active retrieval of tank C-109. In August 2008, HRR became the primary leak detection method and moisture logging frequency was decreased from weekly to once every six weeks. Figure 7-1 is a timeline of the leak detection monitoring used for tank C-109 retrieval.

The basic resistivity measurement concept utilizes the existing drywells and a tank electrode (normally the tank thermocouple) as measurement electrodes. There are reference transmitters and receiver electrodes located a nominal 1,500 ft or more from the tank farm. Power is applied to a drywell-reference transmitter electrode pair and an amperage measurement obtained. Concurrently, a voltage measurement is obtained at another electrode-reference receiver electrode pair. Soil resistivity is calculated by dividing the voltage measured across the receiver electrode pair by the current measured across the transmitter pair. These measurements are repeated continuously and the subsequent resistivity data analyzed for changes with time.

Ideally, drywell-to-tank (WTT) and drywell-to-drywell (WTW) resistivity measurements are available to review. When the waste level in the tank is low the thermocouple may not be in contact with the waste, so the WTT data was not used. When sluicing finished in tank C-109, the thermocouple tree was not in contact with the waste and WTW resistivity measurements were relied on for leak determinations.

During the first phase deployment of HRR on tank C-109, encompassing sluicing retrieval and in-tank vehicle, several anomalous results were evaluated. Table 7-3 identifies the anomalies and provides a description of each anomaly and its resolution. During sluicing retrieval, a leak determination was made for each day of operation.

Figure 7-1. Tank 241-C-109 Leak Detection Monitoring Timeline.



HRR = high-resolution resistivity

Honeywell Enraf is a product of Honeywell Process Solutions, Strahlenbergerstr. 110-112, 63067 Offenbach, Germany.

Table 7-3. High-Resolution Resistivity Anomaly Evaluations during and after Sluicing.

Number	Date	Anomaly Description	Resolution/Comments
2007-2	11/21/07	High drywell-to-drywell (WTW) and drywell-to-tank (WTT) exceedance values.	No leak indicated. Too few data points for calculating the values.
2007-3	12/6/07	Slow trend change in WTW data.	Ground resistance change with temperature. No leak indicated. No active retrieval.
2008-3	1/22/08	Slightly high WTW exceedance values associated with well 30-09-02.	No leak indicated. No active retrieval.
2008-7	4/17/08	High exceedance values on tanks 241-C-108 and 241-C-109 WTT and WTW data pairs.	No leak indicated electrical interference. No active retrieval.
2008-8	5/5/08	High exceedance values on tanks 241-C-108 and 241-C-109 WTT and WTW data pairs (similar to 2008-7).	No leak indicated electrical interference. No active retrieval.
2008-11	8/26/08	High exceedance values for both WTT and WTW data pairs.	No leak indicated. An electrical spike from high-resolution resistivity equipment work.

For a short time prior to the second phase hard heel retrieval, level measurements were used for leak detection while the waste was being preconditioned by soaking. Hard heel dissolution began March 8, 2012. Due to concurrent retrieval activities and limitations of the HRR equipment capacity, only WTW measurements were available to be monitored. During most of the hard heel retrieval period, the tank thermocouple was not in contact with the waste and the WTT measurement was not used. The WTW HRR data was reviewed every day during hard heel retrieval; no leaks were indicated.

Subsequent to tank C-109 retrieval, additional drywell logging was performed by a subcontractor (RPP-RPT-56540, *241-C-109 Tank Waste Retrieval Project Final Report of Drywell Monitoring Data*). None of the drywells around tank C-109 show evidence of significant changes in either gamma activity or subsurface moisture. Available data from these drywells provide no evidence of any leak or contaminant movement associated with tank retrieval operations.

7.2.2 Single-Shell Tank 241-C-109

7.2.2.1 Liquid Level Monitoring. The overall waste retrieval operating strategy for tank C-109 was to reduce the tank liquid inventory and minimize liquid additions during waste retrieval operations. Liquid levels were monitored to evaluate liquid inventories and indicate potential leaks in the system to implement this strategy.

7.2.2.2 Visual Inspection. Before initiating waste retrieval operations, a visual assessment and documentation of in-tank conditions in tank C-109 were performed using an in-tank video camera. Throughout waste retrieval, the closed-circuit television system was used to identify the waste surface condition, qualitatively assess the amount of liquid in the tank, observe any significant changes, and implement the mitigation strategy of minimizing liquid pools.

Observations of the waste surface in tank C-109 indicated that the surface level decrease corresponded with waste retrieval activities.

7.2.2.3 Material Balance. Process control measurements were used periodically to perform a material balance and determine the change in tank C-109 waste inventory. Once determined, the change in waste inventory was compared to the anticipated change (gallons of slurry produced and/or released per gallon of water added, adjusted for changes in the central pool and interstitial liquid volumes).

During retrieval operations, material balances were performed during transfers by Operations for tank leak detection and mitigation for the portion of the system between the portable valve pit and tank AN-106, inclusive. Radiation surveys were required for the portion of the transfer line where volume material balance could not be performed. The frequency of material balance measurements and radiation surveys met the requirements of HNF-IP-1266, *Tank Farms Operations Administrative Controls*.

7.2.3 Double-Shell Tank 241-AN-106

7.2.3.1 Liquid Level Monitoring. The waste level in the DST was monitored using an Enraf, and annulus leak detector probes were used to provide indication of leaks, as described in Section 4.0 of OSD-T-151-00031, *Operating Specifications for Tank Farm Leak Detection and Single-Shell Tank Intrusion Detection.*

Daily liquid level measurements were recorded for the receiving DST. The Enraf gauge was capable of measuring liquid level changes to a precision of 0.1 inch.

During waste retrieval there was no evidence of a release from tank AN-106 based on results of liquid level monitoring. The tank AN-106 liquid level increase corresponded with the material balance results for tank C-109.

7.2.3.2 Leak Detection. Tank AN-106 was monitored for leaks in the inner shell by a conductivity probe leak detection system installed in the tank annulus during tank construction. Slots cut in the concrete that support the tank at the bottom were designed to drain any leakage to the annulus floor. Enraf assemblies in the annulus would have activated an audible alarm and an annunciator panel light in the event of liquid leaking to the annulus so that mitigation could have begun. Throughout the tank C-109 waste retrieval campaign, no leaks were detected by any of the leak detectors in tank AN-106.

7.2.3.3 Radiation Monitoring. A continuous air monitor operated to detect airborne radionuclides entrained in the ventilation exhaust stream of the annulus of tank AN-106. Detection of radiation exceeding a set limit in the annulus of the DST would have activated an audible alarm and an annunciator panel light, initiating mitigative action.

The continuous air monitor for the tank AN-106 annulus detected no radiation levels above background during retrieval that could have been attributed to leak-induced airborne radionuclides.

7.2.4 Ancillary Equipment

Leak detectors were installed in the valve pits to detect the presence of liquid through conductivity, which would have activated alarms and shut down the WRS.

In accordance with RPP-12711, the hose-in-hose transfer line system underwent radiation monitoring and was equipped with leak detectors as part of the leak detection program.

7.3 MITIGATION

Leak mitigation was accomplished through design features and the operational strategy developed for the retrieval system. Mitigation included actions that reduced the chance of a leak and the environmental impact of a leak should one have occurred. Potential leaks were proactively prevented and minimized throughout the waste retrieval operations.

The leak mitigation strategy (i.e., reduction of leak loss potential) was to minimize the liquid volume within the tank during waste retrieval operations. Conditions to control leak potential involved the following:

a. In-tank liquid levels during retrieval were lower than liquid levels present before interim stabilization

b. Retrieval from the center out

c. Liquid removed between waste retrieval campaigns

d. Leak assessment protocols were in accordance with procedures

e. Drywell surveys were conducted.

Conditions to control leak minimization included the following:

a. Liquid addition minimized and liquid pools removed as practical

b. Retrieval from the center out

c. Equipment handling controls to minimize potential for dropping equipment that could have penetrated tank bottom

d. Maintaining a benchmark waste level.

7.3.1 Single-Shell Tank 241-C-109

A summary of the tank C-109 mitigation actions to minimize or prevent a leak were as follows.

a. Minimizing the addition of water to the retrieval tank to the extent practical.

b. During bulk removal, waste was retrieved to the extent practical by working from the center of the tank outwards. In the center-out waste retrieval strategy, mobilized waste and interstitial liquids drain quickly into a central pool and could have been rapidly pumped from the tank had a leak been detected.

c. Waste sluicing activities were performed only while a video camera was in place to observe the sluicing operation and the waste surface.

d. Equipment handling controls were used to minimize the potential for dropping equipment into the tank, which could have penetrated the tank bottom during installation.

e. A benchmark level was maintained to ensure a low head of introduced liquid. The waste level did not exceed this benchmark.

The mitigative approach was implemented to ensure that potential leakage from tank C-109 was monitored at all times. Key mitigative actions which would have been taken in the event of a leak are described in the Tank Waste Retrieval Work Plan (RPP-21895), Sections 4.6.2 and 4.6.3.

7.4 CONCLUSION

Based on the available data (presented in Sections 7.2 and 7.3), no evidence of a tank leak occurred during tank C-109 waste retrieval operations. The tank C-109 LDMM program focused on a mitigation strategy to successfully control potential leaks. This strategy included the following.

a. Minimize residual tank waste.

b. Minimize in-tank water use.

c. Minimize standing liquid pools in the tank.

d. Control and monitor additions of water.

e. Visually monitor tank conditions and retrieval operations.

f. Retrieve from the center of the tank out to minimize water accumulation around the tank knuckle.

The goal of the LDMM program for tank C-109 as set forth in RPP-21895 was achieved.

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APPENDIX A

SINGLE-SHELL TANK 241-C-109 INVENTORY PRE- AND POST-SLUICING TECHNOLOGY RETRIEVAL

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APPENDIX A

SINGLE-SHELL TANK 241-C-109 INVENTORY PRE- AND POST-SLUICING TECHNOLOGY RETRIEVAL

Table A-1. Single-Shell Tank 241-C-109 Best-Basis Inventory Pre-Retrieval Inventory and Post-Sluicing Operations. (2 sheets)

Constituent Name	BBI April 2005[a]	BBI October 2011[b]			Constituent Name	BBI April 2005[a]	BBI October 2011[b]	
Volume (Kgal)	63	4.7						
Analyte	Inventory	Inventory	Unit		Analyte	Inventory	Inventory	Unit
Al	2.52E+04	9.36E+03	Kg		^{99}Tc	3.49E+01	2.00E-01	Ci
Bi	1.05E+03	7.10E+00	Kg		^{106}Ru	5.44E-05	2.54E-13	Ci
Ca	6.12E+03	2.52E+01	Kg		^{113m}Cd	2.62E-01	3.71E-03	Ci
Cl	3.01E+02	2.14E+00	Kg		^{125}Sb	1.12E-01	2.21E-05	Ci
CN	1.99E+03	N/A	Kg		^{126}Sn	1.33E-02	4.08E-04	Ci
Cr	8.54E-01	8.54E-01	Kg		^{129}I	2.87E-02	3.99E-05	Ci
F	7.01E+02	4.46E+02	Kg		^{134}Cs	5.59E-04	1.20E-08	Ci
Fe	6.99E+03	7.11E+01	Kg		^{137}Cs	1.73E+05	9.05E+02	Ci
Hg	2.35E+00	2.94E-02	Kg		^{137m}Ba	1.63E+05	8.54E+02	Ci
K	1.88E+02	2.47E+01	Kg		^{151}Sm	1.09E+03	7.66E+00	Ci
La	2.59E+00	3.46E-01	Kg		^{152}Eu	1.78E-01	2.06E-04	Ci
Mn	7.83E+01	3.93E-01	Kg		^{154}Eu	4.05E+00	1.24E-02	Ci
Na	3.76E+04	3.90E+03	Kg		^{155}Eu	5.60E+00	4.11E-03	Ci
Ni	4.94E+03	4.69E+01	Kg		^{226}Ra	1.21E-05	4.93E-07	Ci
NO_2	1.32E+04	1.97E+02	Kg		^{227}Ac	5.90E-05	7.49E-06	Ci
NO_3	1.96E+04	1.11E+02	Kg		^{228}Ra	5.56E-11	1.31E-11	Ci
Oxalate	5.60E+02	3.58E+01	Kg		^{229}Th	6.82E-09	1.56E-09	Ci
Pb	8.95E+02	9.39E+00	Kg		^{231}Pa	8.33E-05	3.15E-05	Ci
PO_4	2.68E+04	4.48E+03	Kg		^{232}Th	5.42E-11	1.31E-11	Ci
Si	2.24E+03	7.12E+01	Kg		^{232}U	6.80E-05	5.66E-07	Ci
SO_4	3.16E+03	2.30E+01	Kg		^{233}U	1.44E-04	4.90E-08	Ci
Sr	1.34E+02	8.40E-01	Kg		^{234}U	1.55E+00	1.64E-02	Ci
TIC as CO_3	1.00E+04	4.92E+02	Kg		^{235}U	6.21E-02	6.13E-04	Ci

Table A-1. Single-Shell Tank 241-C-109 Best-Basis Inventory Pre-Retrieval Inventory and Post-Sluicing Operations. (2 sheets)

Constituent Name	BBI April 2005[a]	BBI October 2011[b]			Constituent Name	BBI April 2005[a]	BBI October 2011[b]	
Volume (Kgal)	63	4.7						
Analyte	Inventory	Inventory	Unit		Analyte	Inventory	Inventory	Unit
TOC	8.15E+02	7.55E+01	Kg		^{236}U	2.27E-02	2.29E-04	Ci
U_{TOTAL}	4.38E+03	4.31E+01	Kg		^{237}Np	1.06E-01	2.51E-03	Ci
Zr	1.11E+01	1.06E+01	Kg		^{238}Pu	1.65E+00	3.06E-02	Ci
^{3}H	1.23E+00	2.34E-02	Ci		^{238}U	1.46E+00	1.44E-02	Ci
^{14}C	1.65E-02	1.79E-02	Ci		^{239}Pu	6.54E+01	7.39E-01	Ci
^{59}Ni	3.67E+00	9.71E-04	Ci		^{240}Pu	1.12E+01	8.04E-02	Ci
^{60}Co	8.74E-01	3.65E-03	Ci		^{241}Am	5.01E+01	4.52E-01	Ci
^{63}Ni	3.29E+02	1.31E-01	Ci		^{241}Pu	5.69E+01	1.12E-01	Ci
^{79}Se	3.44E-03	2.23E-04	Ci		^{242}Cm	2.98E-01	7.62E-05	Ci
^{90}Sr	2.53E+05	5.44E+03	Ci		^{242}Pu	1.01E-03	1.12E-06	Ci
^{90}Y	2.53E+05	5.44E+03	Ci		^{243}Am	7.26E-03	4.56E-05	Ci
^{93m}Nb	2.00E-01	1.17E-01	Ci		^{243}Cm	1.48E-02	7.89E-07	Ci
^{93}Zr	2.26E-01	1.27E-01	Ci		^{244}Cm	1.64E-03	1.68E-05	Ci

BBI = Best-Basis Inventory TIC = total inorganic carbon TOC = total organic carbon

[a] RPP-21895, 2012, *241-C-103 and 241-C-109 Tanks Waste Retrieval Work Plan*, Rev. 5, Washington River Protection Solutions, LLC, Richland, Washington.

[b] RPP-RPT-51343, 2011, *Derivation of Best-Basis Inventory for Tank 241-C-109 as of October 1, 2011*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

APPENDIX B

MEAN CONCENTRATIONS AND RELATIVE STANDARD DEVIATIONS FOR TANK 241-C-109 RESIDUAL SOLIDS

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APPENDIX B

MEAN CONCENTRATIONS AND RELATIVE STANDARD DEVIATIONS FOR TANK 241-C-109 RESIDUAL SOLIDS

A summary of concentrations estimated for selected radioactive and non-radioactive analytes in residual waste solids left in single-shell tank 241-C-109 following final retrieval is provided in this appendix.

Waste concentrations provided in this appendix in Table B-1 were taken from Table A.1 in RPP-RPT-55803, *Tank 241-C-109 Residual Waste Inventory Estimates for Component Closure Risk Assessment*. These calculated concentrations were developed from sampling of waste solids in single-shell tank 241-C-109. Tank 241-C-109 solids were sampled twice: first after completion of modified sluicing which removed the bulk of the solids, and again after heel retrieval which further removed a comparatively small amount of waste. The mean concentrations for each sample set were estimated as follows.

Equations from *Variance Components* (Searle et al. 1992) were used in the automated Best-Basis Inventory Maintenance (BBIM) tool [RPP-5945, *Best-Basis Inventory Maintenance Tool (BBIM): Database Description and User Guide*] to estimate the mean concentration and density and the associated standard deviation for all constituents that had 50% or more of their reported values greater than the detection limit. These equations compute means by weighting results based on the variance components. Some constituents had concentrations that were below the detection limits. In these cases, the detection limits were used for calculating the mean concentrations. For a constituent with a majority of results below the detection limit, a simple average of the detection limits was calculated. Note that in accordance with Best-Basis Inventory protocol, the relative standard deviations for non-detected constituents were assumed to be "1" (RPP-6924, *Statistical Methods for Estimating the Uncertainty in the Best Basis Inventories*).

To calculate the average analyte inventories provided in Table B-1, the BBIM tool automatically used the mean concentrations from the samples taken after heel retrieval when available. Otherwise, the adjusted mean concentrations of analytes from the samples taken after modified sluicing were used.

Table B-1. Inventory Estimates for Selected Constituents in Tank 241-C-109 Residual Solids. (4 Sheets)

Constituent	Chemical Abstract Services Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units[1]
^{125}Sb	14234-35-6	<	5.05E+00	1.52E+01	Ci
^{126}Sn	15832-50-5	<	5.70E-04	1.71E-03	Ci
^{129}I	15046-84-1	<	1.36E-04	4.08E-04	Ci
^{137}Cs	10045-97-3		4.86E+01	6.27E+01	Ci
^{137m}Ba	N/A		4.59E+01	5.85E+01	Ci
^{14}C	14762-75-5	<	6.56E-04	1.97E-03	Ci
^{152}Eu	14683-23-9	<	1.73E+00	5.19E+00	Ci
^{154}Eu	15585-10-1	<	1.46E+00	4.38E+00	Ci
^{155}Eu	14391-16-3	<	3.70E+00	1.11E+01	Ci
^{228}Th	14274-82-9		3.00E-04	3.89E-04	Ci
^{230}Th	14269-63-7	<	1.62E-02	4.86E-02	Ci
^{231}Pa	14331-85-2	<	3.70E-02	1.11E-01	Ci
^{232}Th	N/A		8.49E-06	1.13E-05	Ci
^{233}U	13968-55-3	<	2.16E-01	6.48E-01	Ci
^{234}U	13966-29-5	<	5.13E-03	1.54E-02	Ci
^{235}U	15117-96-1		3.43E-04	5.08E-04	Ci
^{236}U	13982-70-2		8.23E-05	1.50E-04	Ci
^{237}Np	13994-20-2	<	7.90E-03	2.37E-02	Ci
^{238}Pu	13981-16-3		1.47E-02	2.00E-02	Ci
^{238}U	N/A		8.17E-03	1.21E-02	Ci
^{239}Pu	15117-48-3		3.44E-01	5.17E-01	Ci
^{240}Pu	14119-33-6		3.74E-02	5.62E-02	Ci
^{241}Am	14596-10-2		3.23E-01	4.22E-01	Ci
^{241}Pu	14119-32-5		7.77E-01	9.23E-01	Ci
^{242}Cm	15510-73-3	<	7.36E-04	2.21E-03	Ci
^{242}Pu	N/A	<	2.37E-04	7.11E-04	Ci
^{243}Cm	15757-87-6	<	5.61E-05	1.68E-04	Ci
^{244}Cm	13981-15-2	<	1.19E-03	3.57E-03	Ci
2-Butanone	78-93-3	<	2.12E-04	6.36E-04	kg

Table B-1. Inventory Estimates for Selected Constituents in Tank 241-C-109 Residual Solids. (4 Sheets)

Constituent	Chemical Abstract Services Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units[1]
^{3}H	15086-10-9	<	5.91E-03	1.77E-02	Ci
^{60}Co	10198-40-0	<	7.10E-01	2.13E+00	Ci
^{63}Ni	13981-37-8		8.16E-01	1.00E+00	Ci
^{79}Se	15758-45-9	<	3.84E-03	1.15E-02	Ci
^{90}Sr	10098-97-2		2.66E+03	3.42E+03	Ci
^{90}Y	500784-58-7		2.66E+03	3.42E+03	Ci
^{99}Tc	14133-76-7		7.52E-03	9.45E-03	Ci
Acetate	71-50-1	<	1.28E+00	3.84E+00	kg
Acetone	67-64-1		1.15E-03	1.99E-03	kg
Ag	7440-22-4		7.15E-02	1.63E-01	kg
Al	7429-90-5		1.84E+03	2.52E+03	kg
Aroclors (Total PCB dry weight basis)	1336-36-3	<	1.14E-04	3.42E-04	kg
As	7440-38-2		8.75E-02	1.21E-01	kg
B	7440-42-8	<	1.12E-02	3.36E-02	kg
Ba	7440-39-3		1.12E-01	1.60E-01	kg
Be	7440-41-7	<	1.12E-02	3.36E-02	kg
Bi	7440-69-9		1.69E+00	2.14E+00	kg
Br	24959-67-9	<	6.84E-01	2.05E+00	kg
Ca	7440-70-2		1.34E+01	1.94E+01	kg
Cd	7440-43-9	<	1.12E-02	3.36E-02	kg
Ce	7440-45-1		4.20E+00	5.21E+00	kg
Cl	16887-00-6	<	7.30E-01	2.19E+00	kg
CN	57-12-5		3.37E-01	4.88E-01	kg
Co	7440-48-4	<	1.12E-02	3.36E-02	kg
Cr	7440-47-3		1.51E-01	2.10E-01	kg
Cu	7440-50-8		6.23E-01	9.39E-01	kg
Eu	7440-53-1	<	1.12E-02	3.36E-02	kg
F	16984-48-8		8.29E+01	1.02E+02	kg
Fe	7439-89-6		7.95E+01	1.20E+02	kg

Table B-1. Inventory Estimates for Selected Constituents in Tank 241-C-109 Residual Solids. (4 Sheets)

Constituent	Chemical Abstract Services Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units[1]
Formate	12311-97-6	<	1.92E+00	5.76E+00	kg
Glycolate	666-14-8	<	7.30E-01	2.19E+00	kg
Hexone	108-10-1	<	1.84E-04	5.52E-04	kg
Hg	7439-97-6		1.58E-02	2.61E-02	kg
K	7440-09-7	<	2.24E-01	6.72E-01	kg
La	7439-91-0		1.03E-01	1.52E-01	kg
Li	7439-93-2		1.70E-02	2.20E-02	kg
Mg	7439-95-4		1.10E+00	1.52E+00	kg
Mn	7439-96-5		4.82E-01	7.99E-01	kg
Mo	7439-98-7		2.13E-02	3.30E-02	kg
Na	7440-23-5		1.12E+03	1.64E+03	kg
Nb	7440-03-1	<	1.79E+00	5.37E+00	kg
Nd	7440-00-8		1.31E-01	1.86E-01	kg
NH_3	7664-41-7		3.18E-02	4.03E-02	kg
Ni	7440-02-0		1.14E+01	1.68E+01	kg
NO_2	14797-65-0		3.28E+00	3.85E+00	kg
NO_3	14797-55-8		3.87E+00	4.95E+00	kg
Oxalate	338-70-5	<	1.19E+00	3.57E+00	kg
Pb	7439-92-1		4.62E+00	5.47E+00	kg
Pd	7440-05-3	<	1.01E-01	3.03E-01	kg
PO_4	14265-44-2		8.41E+02	1.27E+03	kg
Pr	7440-10-0	<	2.39E+00	7.17E+00	kg
Rb	7440-17-7	<	3.36E-01	1.01E+00	kg
Rh	7440-16-6		1.03E-01	1.28E-01	kg
Ru	7440-18-8	<	4.48E-02	1.34E-01	kg
Sb	7440-36-0	<	6.72E-02	2.02E-01	kg
Se	7782-49-2	<	6.72E-02	2.02E-01	kg
Si	7440-21-3		2.39E+01	4.39E+01	kg
Sm	7440-19-9		3.98E-01	5.04E-01	kg

Table B-1. Inventory Estimates for Selected Constituents in Tank 241-C-109 Residual Solids. (4 Sheets)

Constituent	Chemical Abstract Services Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units[1]
Sn	7440-31-5	<	3.36E-02	1.01E-01	kg
SO_4	14808-79-8		2.45E+00	3.11E+00	kg
Sr	7440-24-6		4.21E-01	6.45E-01	kg
Ta	7440-25-7	<	2.98E+00	8.94E+00	kg
Te	13494-80-9	<	5.60E-02	1.68E-01	kg
Th	7440-29-1		7.72E-02	1.03E-01	kg
Ti	7440-32-6		5.09E-02	7.20E-02	kg
Tl	7440-28-0		7.57E-02	9.34E-02	kg
Tributyl phosphate	126-73-8	<	7.42E-03	2.23E-02	kg
Trichloroethene	79-01-6	<	1.30E-05	3.90E-05	kg
U	7440-61-1		2.45E+01	3.64E+01	kg
V	7440-62-2	<	1.12E-02	3.36E-02	kg
W	7440-33-7	<	7.33E-02	2.20E-01	kg
Xylene (m & p)	108-38-3M	<	1.80E-05	5.40E-05	kg
Xylene (o)	95-47-6	<	9.91E-06	2.97E-05	kg
Xylenes (total)	1330-20-7	<	2.19E-05	6.57E-05	kg
Y	7440-65-5		2.60E-02	3.22E-02	kg
Zn	7440-66-6		6.01E-01	7.17E-01	kg

N/A = not available

PCB = polychlorinated biphenyl

[1] Radionuclide concentrations are decay corrected to January 1, 2008.

REFERENCES

RPP-5945, 2000, *Best-Basis Inventory Maintenance Tool (BBIM): Database Description and User Guide*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-6924, 2010, *Statistical Methods for Estimating the Uncertainty in the Best Basis Inventories*, Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-55803, 2013, *Tank 241-C-109 Residual Waste Inventory Estimates for Component Closure Risk Assessment*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

Searle, S. R., G. Casella, and C. E. McCulloch, 1992, *Variance Components*, John Wiley and Sons, Inc., New York, New York.

APPENDIX C

COMPARISON OF SINGLE-SHELL TANK 241-C-109 FINAL INVENTORY TO SINGLE-SHELL TANK 241-C-109 INVENTORY USED IN DOE/ORP-2005-01, *INITIAL SINGLE-SHELL TANK SYSTEM PERFORMANCE ASSESSMENT FOR THE HANFORD SITE*

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APPENDIX C

COMPARISON OF SINGLE-SHELL TANK 241-C-109 FINAL INVENTORY TO SINGLE-SHELL TANK 241-C-109 INVENTORY USED IN DOE/ORP-2005-01, *INITIAL SINGLE-SHELL TANK SYSTEM PERFORMANCE ASSESSMENT FOR THE HANFORD SITE*

Table C-1. Comparison of Single-Shell Tank 241-C-109 Final Inventory to Single-Shell Tank 241-C-109 Inventory Used in DOE/ORP-2005-01.

Analyte	Units	DOE/ORP-2005-01, Rev. 0	RPP-RPT-55803, Rev. 0 Average Inventory	RPP-RPT-55803, Rev. 0 Upper Bounding Inventory
Tritium	Ci	9.24E-03	5.91E-03	1.77E-02
C-14	Ci	1.30E-04	6.56E-04	1.97E-03
I-129	Ci	4.28E-04	1.36E-04	4.08E-04
Tc-99	Ci	4.96E-01	7.52E-03	9.45E-03
Cr	kg	1.68E+00	1.51E-01	2.10E-01
F	kg	1.00E+01	8.29E+01	1.02E+02
NO_2	kg	1.03E+02	3.28E+00	3.85E+00
NO_3	kg	1.61E+02	3.87E+00	4.95E+00
U	kg	1.46E+02	2.45E+01	3.64E+01

REFERENCES

DOE/ORP-2005-01, 2006, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site*, Rev. 0, U.S. Department of Energy, Office of River Protection, Richland, Washington.

RPP-RPT-55803, 2013, *Tank 241-C-109 Residual Waste Inventory Estimates for Component Closure Risk Assessment*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

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APPENDIX D

RISK ASSESSMENT INFORMATION FOR RESIDUAL WASTES REMAINING IN SINGLE-SHELL TANK 241-C-109

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APPENDIX D

RISK ASSESSMENT INFORMATION FOR RESIDUAL WASTES REMAINING IN SINGLE-SHELL TANK 241-C-109

This appendix provides risk assessment information related to post-retrieval inventories estimated to remain in single-shell tank (SST) 241-C-109 (C-109). The potential risk impacts to human health posed by the residual waste in SST C-109 were evaluated using the methodology documented in DOE/ORP-2005-01, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site*. The process used for the SST C-109 risk assessment, and this methodology, is described in detail in Chapter 3 of DOE/ORP-2005-01. The SST performance assessment methodology represents the current approach being used to support the assessment of long-term impacts to human health from tank residuals left in individual SSTs in retrieval data reports. Decisions on final closure of tank C-109, all other SSTs, and ancillary facilities and equipment within Waste Management Area C will be supported by a site-specific performance assessment as outlined in Appendix I of the *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1989).

The risk assessment-related information for post-retrieval inventories estimated to remain in SST C-109 and contained in this appendix are as follows:

- Summary of incremental lifetime cancer risk, radiological dose, and drinking water dose for radionuclide contaminants of potential concern estimated in the average post-retrieval inventory for SST C-109 (see Table D-1)

- Summary of maximum value for incremental lifetime cancer risk and hazard index for non-radionuclide contaminants of potential concern estimated in the average post-retrieval inventory for SST C-109 (see Table D-2)

- Summary of incremental lifetime cancer risk, radiological dose, and drinking water dose for radionuclide contaminants of potential concern estimated in the 95% upper confidence level (UCL) post-retrieval inventory for SST C-109 (see Table D-3)

- Summary of maximum value for incremental lifetime cancer risk and hazard index for non-radionuclide contaminants of potential concern estimated in the 95% UCL post-retrieval inventory for SST C-109 (see Table D-4)

- Tables and plots of doses from a well driller scenario for radioactive contaminants of concern found within the average and 95% UCL inventory estimated for SST C-109 (see Table D-5 and Figure D-1)

- Tables and plots of doses from a rural pasture scenario for radioactive contaminants of concern found within the average and 95% UCL inventories estimated for SST C-109 (see Table D-6 and Figure D-2)

- Tables and plots of doses from a suburban gardener scenario for radioactive contaminants of concern found within the average and 95% UCL inventories estimated for SST C-109 (see Table D-7 and Figure D-3)

- Tables and plots of doses from a commercial farm scenario for radioactive contaminants of concern found within the average and 95% UCL inventories estimated for SST C-109 (see Table D-8 and Figure D-4).

Table D-9 provides a comparison of the average and 95% UCL concentrations for waste residuals within tank C-109 against *Washington Administrative Code* 173-340, "Model Toxics Control Act – Cleanup" cleanup levels for soil direct contact unrestricted land use (Method B), industrial land use (Method C), and soil concentrations protective of groundwater.

Tables D-10 and D-11 provide additional risk management information related to average and 95% UCL concentrations of constituents remaining in waste residuals within tank C-109 compared against the *Washington Administrative Code* 173-340 cleanup standards. See Section 5.5 for additional discussion.

Table D-12 provides information on background concentration levels at the Hanford Site that have been developed for selected constituents. This is provided to bring additional perspective in the concentration levels of constituents remaining in residual wastes within tank C-109.

Table D-1. Incremental Lifetime Cancer Risk, Radiological Dose, and Drinking Water Dose per Radionuclide Contaminant of Potential Concern for the Average Inventory for Single-Shell Tank 241-C-109. (3 sheets)

Analyte Name	Above Detection Limits in Residual Wastes	Inventory (Ci)	Waste Management Area C Fenceline Concentration	Peak Year	K_d (mL/g)[a]	Half-Life (yr)	Incremental Cancer Risk (Groundwater)[b]		Radiological Dose (mrem/yr) All-Pathway Farmer Scenario[b]	Radiological Dose - Beta/Photon (mrem/yr) Drinking Water Only Scenario[b]
							Industrial	Residential		
Americium-241	Yes	3.23E-01	0.00E+00	DNA	3.00E+00	4.33E+02	NE	NE	NE	NE
Antimony-125	No	2.53E+00	0.00E+00	DNA	1.00E+00	2.73E+00	NE	NE	NE	NE
Barium-137m	Yes	4.59E+01	0.00E+00	DNA	0.00E+00	4.86E-06	NE	NE	NE	NE
Carbon-14	No	3.28E-04	<1.00E-03	9.78E+03	0.00E+00	5.73E+03	NE	NE	NE	NE
Cesium-137 + Daughters	Yes	4.86E+01	0.00E+00	DNA	2.50E+01	3.00E+01	NE	NE	NE	NE
Cobalt-60	No	3.55E-01	0.00E+00	DNA	1.00E-01	5.27E+00	NE	NE	NE	NE
Curium-242	No	3.68E-04	0.00E+00	DNA	3.00E+00	4.46E-01	NE	NE	NE	NE
Curium-243	No	2.81E-05	0.00E+00	DNA	3.00E+00	2.85E+01	NE	NE	NE	NE
Curium-244	No	5.95E-04	0.00E+00	DNA	3.00E+00	1.81E+01	NE	NE	NE	NE
Europium-152	No	8.65E-01	0.00E+00	DNA	1.00E+00	1.33E+01	NE	NE	NE	NE
Europium-154	No	7.30E-01	0.00E+00	DNA	1.00E+00	8.59E+00	NE	NE	NE	NE
Europium-155	No	1.85E+00	0.00E+00	DNA	1.00E+00	4.68E+00	NE	NE	NE	NE
Iodine-129	No	6.80E-05	<1.00E-03	1.20E+04	2.00E-01	1.57E+07	NE	NE	NE	NE
Neptunium-237 + D	No	3.95E-03	0.00E+00	DNA	2.00E+00	2.14E+06	NE	NE	NE	NE
Nickel-63	Yes	8.16E-01	0.00E+00	DNA	4.80E+01	1.00E+02	NE	NE	NE	NE
Plutonium-238	Yes	1.47E-02	0.00E+00	DNA	3.00E+00	8.77E+01	NE	NE	NE	NE
Plutonium-239	Yes	3.44E-01	0.00E+00	DNA	3.00E+00	2.41E+04	NE	NE	NE	NE

Table D-1. Incremental Lifetime Cancer Risk, Radiological Dose, and Drinking Water Dose per Radionuclide Contaminant of Potential Concern for the Average Inventory for Single-Shell Tank 241-C-109. (3 sheets)

Analyte Name	Above Detection Limits in Residual Wastes	Inventory (Ci)	Waste Management Area C Fenceline Concentration	Peak Year	K_d (mL/g)[a]	Half-Life (yr)	Incremental Cancer Risk (Groundwater)[b]		Radiological Dose (mrem/yr) All-Pathway Farmer Scenario[b]	Radiological Dose - Beta/Photon (mrem/yr) Drinking Water Only Scenario[b]
							Industrial	Residential		
Plutonium-240	Yes	3.74E-02	0.00E+00	DNA	3.00E+00	6.56E+03	NE	NE	NE	NE
Plutonium-241 + D	Yes	7.77E-01	0.00E+00	DNA	3.00E+00	1.44E+01	NE	NE	NE	NE
Plutonium-242	No	1.19E-04	0.00E+00	DNA	3.00E+00	3.74E+05	NE	NE	NE	NE
Protactinium-231	No	1.85E-02	0.00E+00	DNA	5.50E+02	3.28E+04	NE	NE	NE	NE
Selenium-79	No	1.92E-03	0.00E+00	DNA	3.10E+00	8.05E+05	NE	NE	NE	NE
Strontium-90 + D	Yes	2.66E+03	0.00E+00	DNA	1.61E+01	2.81E+01	NE	NE	NE	NE
Technetium-99	Yes	7.52E-03	3.00E-02	1.05E+04	0.00E+00	2.11E+05	4.14E-10	1.01E-08	5.26E-05	1.33E-04
Thorium-228 + D	Yes	3.00E-04	0.00E+00	DNA	3.00E+00	1.91E+00	NE	NE	NE	NE
Thorium-230	No	8.10E-03	0.00E+00	DNA	3.00E+00	7.54E+04	NE	NE	NE	NE
Thorium-232	Yes	8.49E-06	0.00E+00	DNA	3.00E+00	1.41E+10	NE	NE	NE	NE
Tin-126	No	2.85E-04	0.00E+00	DNA	1.00E+00	2.46E+05	NE	NE	NE	NE
Tritium	No	2.96E-03	0.00E+00	DNA	0.00E+00	1.23E+01	NE	NE	NE	NE
Uranium-233	No	1.08E-01	0.00E+00	DNA	6.00E-01	1.59E+05	NE	NE	NE	N/A
Uranium-234	No	2.57E-03	0.00E+00	DNA	6.00E-01	2.46E+05	NE	NE	NE	N/A
Uranium-235 + D	Yes	3.43E-04	0.00E+00	DNA	6.00E-01	7.04E+08	NE	NE	NE	N/A
Uranium-236	Yes	8.23E-05	0.00E+00	DNA	6.00E-01	2.34E+07	NE	NE	NE	N/A
Uranium-238 + D	Yes	8.17E-03	0.00E+00	DNA	6.00E-01	4.47E+09	NE	NE	NE	N/A

Table D-1. Incremental Lifetime Cancer Risk, Radiological Dose, and Drinking Water Dose per Radionuclide Contaminant of Potential Concern for the Average Inventory for Single-Shell Tank 241-C-109. (3 sheets)

Analyte Name	Above Detection Limits in Residual Wastes	Inventory (Ci)	Waste Management Area C Fenceline Concentration	Peak Year	K_d (mL/g)[a]	Half-Life (yr)	Incremental Cancer Risk (Groundwater)[b]		Radiological Dose (mrem/yr) All-Pathway Farmer Scenario[b]	Radiological Dose - Beta/Photon (mrem/yr) Drinking Water Only Scenario[b]
							Industrial	Residential		
Yttrium-90	Yes	2.66E+03	0.00E+00	DNA	0.00E+00	7.31E-03	NE	NE	NE	NE
Performance Objectives[c]							**1-0E-6 to 1.0E-4[d]**	**1-0E-6 to 1.0E-4[d]**	**25[e]**	**4[f]**

[a] See PNNL-13895, *Hanford Contaminant Distribution Coefficient Database and Users Guide*, Rev. 1, and Section 4.3 of PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments* for the basis for the K_d values listed for the radionuclides.

[b] All exposure scenarios are described in HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for Hanford Tank Waste Performance Assessments.*

[c] Performance objectives apply to the cumulative (i.e., all contaminants) for the entire waste management area.

[d] EPA/540/R/99/006, *Radiation Risk Assessment at CERCLA Sites: Q & A*, Directive 9200.4-31P.

[e] DOE O 435.1, *Radioactive Waste Management.*

[f] 65 FR 76708, "National Primary Drinking Water Regulations; Radionuclides; Final Rule."

DNA = Did not arrive at fenceline within the 10,000-year modeling period.
N/A = Radionuclide is not a beta/photon emitter.
NE = Incremental cancer risk for industrial and residential scenarios or radiological dose evaluated for the all-pathways farmer and drinking water only scenarios not evaluated because radiological constituent had no estimated initial inventory or did not arrive in concentrations greater than at the fenceline within the 10,000-year modeling period. In the Decision Management Tool (DMT) that is used to implement the calculational methodology documented in DOE/ORP-2005-01, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site* for this Retrieval Data Report, calculated concentrations less than 1.00E-21 pCi/L are considered to be effectively zero. This risk metric may have also not been calculated because the radioactive analyte was predicted to have a concentration less than 0.001 pCi/L, which is well below the ability of standard laboratory analytical methods to detect it.

Table D-2. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index per Nonradionuclide Contaminant of Potential Concern using Average Post-Retrieval Inventory for Single-Shell Tank 241-C-109. (5 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[b]	Incremental Lifetime Cancer Risk (Groundwater)[c]	Hazard Quotient (Groundwater)[c]
						WAC 173-340 Method B	
Aluminum	Yes	1.84E+03	0.00E+00	DNA	1.00E+00	NE	NE
Ammonia	Yes	3.18E-02	<1.00E-03	1.05E+04	9.30E-04	NE	NE
Antimony[a]	No	3.36E-02	0.00E+00	DNA	1.00E+00	NE	NE
Arsenic[a]	Yes	8.75E-02	0.00E+00	DNA	3.90E+01	NE	NE
Barium[a]	Yes	1.12E-01	0.00E+00	DNA	6.00E+01	NE	NE
Beryllium[a]	No	5.60E-03	0.00E+00	DNA	7.00E+01	NE	NE
Bismuth	Yes	1.69E+00	6.94E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Boron	No	5.60E-03	0.00E+00	DNA	3.00E+00	NE	NE
Bromide	No	3.42E-01	1.40E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Cadmium[a]	No	5.60E-03	0.00E+00	DNA	1.26E+00	NE	NE
Calcium	Yes	1.34E+01	0.00E+00	DNA	4.00E+00	NE	NE
Cerium	Yes	4.20E+00	1.72E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Chloride	No	3.65E-01	1.50E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Chromium, Total[a]	Yes	1.51E-01	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Cobalt	No	5.60E-03	<1.00E-03	1.20E+04	1.00E-01	NE	NE
Copper	Yes	6.23E-01	0.00E+00	DNA	3.50E+01	NE	NE
Cyanide[a]	Yes	3.37E-01	0.00E+00	DNA	9.90E+00	NE	NE

Table D-2. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index per Nonradionuclide Contaminant of Potential Concern using Average Post-Retrieval Inventory for Single-Shell Tank 241-C-109. (5 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[b]	Incremental Lifetime Cancer Risk (Groundwater)[c]	Hazard Quotient (Groundwater)[c]
						WAC 173-340 Method B	
Europium	No	5.60E-03	0.00E+00	DNA	5.00E+01	NE	NE
Fluoride	Yes	8.29E+01	3.40E-01	1.05E+04	0.00E+00	No CPF	3.55E-04
Formate+A2	No	9.60E-01	3.94E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Iron	Yes	7.95E+01	0.00E+00	DNA	2.50E+01	NE	NE
Lanthanum	Yes	1.03E-01	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Lead[a]	Yes	4.62E+00	0.00E+00	DNA	5.20E+00	NE	NE
Lithium	Yes	1.70E-02	0.00E+00	DNA	3.00E+02	NE	NE
Magnesium	Yes	1.10E+00	0.00E+00	DNA	4.50E+00	NE	NE
Manganese	Yes	4.82E-01	0.00E+00	DNA	1.00E+00	NE	NE
Mercury[a]	Yes	1.58E-02	0.00E+00	DNA	5.20E+00	NE	NE
Molybdenum	Yes	2.13E-02	0.00E+00	DNA	4.00E+00	NE	NE
Neodymium	Yes	1.31E-01	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Nickel[a]	Yes	1.14E+01	0.00E+00	DNA	4.80E+01	NE	NE
Niobium	No	8.95E-01	0.00E+00	DNA	1.00E+02	NE	NE
Nitrate	Yes	3.87E+00	1.59E-02	1.05E+04	0.00E+00	No CPF	6.21E-07
Nitrite	Yes	3.28E+00	1.35E-02	1.05E+04	0.00E+00	No CPF	8.42E-06
Oxalate	No	5.95E-01	2.44E-03	1.05E+04	0.00E+00	No CPF	No Rfd

Table D-2. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index per Nonradionuclide Contaminant of Potential Concern using Average Post-Retrieval Inventory for Single-Shell Tank 241-C-109. (5 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[b]	Incremental Lifetime Cancer Risk (Groundwater)[c]	Hazard Quotient (Groundwater)[c]
						WAC 173-340 Method B	
o-Xylene	No	4.96E-06	<1.00E-03	1.20E+04	7.23E-02	NE	NE
Palladium	No	5.05E-02	0.00E+00	DNA	5.00E+01	NE	NE
Phosphate	Yes	8.41E+02	3.45E+00	1.05E+04	0.00E+00	No CPF	No Rfd
Potassium	No	1.12E-01	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Praseodymium	No	1.20E+00	4.91E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Rhodium	Yes	1.03E-01	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Rubidium	No	1.68E-01	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Ruthenium	No	2.24E-02	0.00E+00	DNA	1.00E+00	NE	NE
Samarium	Yes	3.98E-01	0.00E+00	DNA	1.00E+00	NE	NE
Selenium[a]	No	3.36E-02	0.00E+00	DNA	5.00E+00	NE	NE
Silicon	Yes	2.39E+01	0.00E+00	DNA	3.00E+01	NE	NE
Silver[a]	Yes	7.15E-02	0.00E+00	DNA	2.70E+00	NE	NE
Sodium	Yes	1.12E+03	4.60E+00	1.05E+04	0.00E+00	No CPF	No Rfd
Strontium	Yes	4.21E-01	0.00E+00	DNA	1.61E+01	NE	NE
Sulfate	Yes	2.45E+00	1.01E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Tantalum	No	1.49E+00	6.12E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Tellurium	No	2.80E-02	<1.00E-03	1.05E+04	0.00E+00	NE	NE

Table D-2. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index per Nonradionuclide Contaminant of Potential Concern using Average Post-Retrieval Inventory for Single-Shell Tank 241-C-109. (5 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[b]	Incremental Lifetime Cancer Risk (Groundwater)[c]	Hazard Quotient (Groundwater)[c]
						WAC 173-340 Method B	
Thallium[a]	Yes	7.57E-02	0.00E+00	DNA	7.10E+01	NE	NE
Thorium	Yes	7.72E-02	0.00E+00	DNA	1.00E+00	NE	NE
Tin	No	1.68E-02	0.00E+00	DNA	2.50E+02	NE	NE
Titanium	Yes	5.09E-02	0.00E+00	DNA	1.00E+03	NE	NE
Tungsten	No	3.67E-02	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Uranium	Yes	2.45E+01	0.00E+00	DNA	6.00E-01	NE	NE
Vanadium	No	5.60E-03	0.00E+00	DNA	5.00E+01	NE	NE
Yttrium	Yes	2.60E-02	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Zinc	Yes	6.01E-01	0.00E+00	DNA	6.20E+01	NE	NE
1, 1, 2-Trichloroethylene	No	6.50E-06	<1.00E-03	1.20E+04	2.82E-02	NE	NE
2-Butanone (MEK)[a]	No	1.06E-04	<1.00E-03	1.05E+04	1.35E-03	NE	NE
2-Propanone (Acetone)[a]	Yes	1.15E-03	<1.00E-03	1.05E+04	1.73E-04	NE	NE
4-Methyl-2-pentanone (MIBK)	No	9.20E-05	<1.00E-03	1.20E+04	4.02E-02	NE	NE
Acetate $C_2H_3O_2^-$	No	6.40E-01	2.63E-03	1.05E+04	3.00E-04	No CPF	No Rfd
Glycolate $C_2H_3O_3$	No	3.65E-01	1.50E-03	1.05E+04	0.00E+00	No CPF	No Rfd
m-Xylene	No	9.00E-06	<1.00E-03	1.20E+04	5.88E-02	NE	NE
Polychlorinated Biphenyls (high risk)[a]	No	5.70E-05	0.00E+00	DNA	9.27E+01	NE	NE

Table D-2. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index per Nonradionuclide Contaminant of Potential Concern using Average Post-Retrieval Inventory for Single-Shell Tank 241-C-109. (5 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[b]	Incremental Lifetime Cancer Risk (Groundwater)[c]	Hazard Quotient (Groundwater)[c]
						WAC 173-340 Method B	
Tributyl phosphate	No	3.71E-03	<1.00E-03	1.20E+04	5.67E-01	NE	NE
Xylenes	No	1.10E-05	<1.00E-03	1.20E+04	5.88E-02	NE	NE
Performance Objective[d]						**1.0E-06[e]**	**1.0[f]**

[a] Dangerous waste constituent per *Washington Administrative Code* (WAC) 173-303-9905, "Dangerous Waste Constituents List."

[b] See PNNL-13895, *Hanford Contaminant Distribution Coefficient Database and Users Guide*, Rev. 1, for the basis for the K_d values listed for chromium and nitrate. The K_d values listed for the organic chemical compounds are determined from the chemicals' organic carbon/water partitioning coefficient and an estimate of 0.03% for the Hanford Site sediments fraction of organic content (PNNL-13895, Rev. 1, page 11, paragraph 3).

[c] All exposure scenarios are described in HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for Hanford Tank Waste Performance Assessments*.

[d] Single Analyte Performance objectives apply to entire waste management area, not just a single component of the waste management area.

[e] WAC 173-340-705, "Use of Method B," subpart (2)(c)(ii).

[f] WAC 173-340-705 (2)(c)(i).

DNA = Did not arrive at fenceline within the 10,000-year modeling period.

NE = Incremental cancer risk or hazard quotient calculated under WAC 173-340, "Model Toxics Control Act – Cleanup," Method B not evaluated because hazardous chemical constituent had no estimated initial inventory or did not arrive in concentrations greater than zero at the fenceline within the 10,000-year modeling period. In the Decision Management Tool (DMT) that is used to implement the calculational methodology documented in DOE/ORP-2005-01, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site* for this Retrieval Data Report, calculated concentrations less than 1.00E-21 µg/L are considered to be effectively zero. The risk metric may have also not been calculated because the chemical analyte was predicted to have a concentration less than 0.001 µg/L, which is well below the ability of standard laboratory analytical methods to detect it.

No CPF = No cancer potency factor available.

No Rfd = No reference dose available.

Table D-3. Incremental Lifetime Cancer Risk, Radiological Dose, and Drinking Water for Single-Shell Tank 241-C-109 Dose per Radionuclide Contaminant of Potential Concern for the 95% Upper Confidence Level Inventory. (3 sheets)

Analyte Name	Above Detection Limits in Residual Wastes	Inventory (Ci)	Waste Management Area C Fenceline Concentration	Peak Year	K_d (mL/g)[a]	Half-Life (yr)	Incremental Cancer Risk (Groundwater)[b]		Radiological Dose (mrem/yr) All-Pathway Farmer Scenario[b]	Radiological Dose - Beta/Photon (mrem/yr) Drinking Water Only Scenario[b]
							Industrial	Residential		
Americium-241	Yes	4.22E-01	0.00E+00	DNA	3.00E+00	4.33E+02	NE	NE	NE	NE
Antimony-125	No	7.60E+00	0.00E+00	DNA	1.00E+00	2.73E+00	NE	NE	NE	NE
Barium-137m	Yes	5.85E+01	0.00E+00	DNA	0.00E+00	4.86E-06	NE	NE	NE	NE
Carbon-14	No	9.85E-04	1.52E-03	9.78E+03	0.00E+00	5.73E+03	1.18E-11	8.52E-11	7.35E-06	3.04E-06
Cesium-137 + Daughters	Yes	6.27E+01	0.00E+00	DNA	2.50E+01	3.00E+01	NE	NE	NE	NE
Cobalt-60	No	1.07E+00	0.00E+00	DNA	1.00E-01	5.27E+00	NE	NE	NE	NE
Curium-242	No	1.11E-03	0.00E+00	DNA	3.00E+00	4.46E-01	NE	NE	NE	NE
Curium-243	No	8.40E-05	0.00E+00	DNA	3.00E+00	2.85E+01	NE	NE	NE	NE
Curium-244	No	1.79E-03	0.00E+00	DNA	3.00E+00	1.81E+01	NE	NE	NE	NE
Europium-152	No	2.60E+00	0.00E+00	DNA	1.00E+00	1.33E+01	NE	NE	NE	NE
Europium-154	No	2.19E+00	0.00E+00	DNA	1.00E+00	8.59E+00	NE	NE	NE	NE
Europium-155	No	5.55E+00	0.00E+00	DNA	1.00E+00	4.68E+00	NE	NE	NE	NE
Iodine-129	No	2.04E-04	<1.00E-03	1.20E+04	2.00E-01	1.57E+07	NE	NE	NE	NE
Neptunium-237 + D	No	1.19E-02	0.00E+00	DNA	2.00E+00	2.14E+06	NE	NE	NE	NE
Nickel-63	Yes	1.00E+00	0.00E+00	DNA	4.80E+01	1.00E+02	NE	NE	NE	NE
Plutonium-238	Yes	2.00E-02	0.00E+00	DNA	3.00E+00	8.77E+01	NE	NE	NE	NE
Plutonium-239	Yes	5.17E-01	0.00E+00	DNA	3.00E+00	2.41E+04	NE	NE	NE	NE

Table D-3. Incremental Lifetime Cancer Risk, Radiological Dose, and Drinking Water for Single-Shell Tank 241-C-109 Dose per Radionuclide Contaminant of Potential Concern for the 95% Upper Confidence Level Inventory. (3 sheets)

Analyte Name	Above Detection Limits in Residual Wastes	Inventory (Ci)	Waste Management Area C Fenceline Concentration	Peak Year	K_d (mL/g)[a]	Half-Life (yr)	Incremental Cancer Risk (Groundwater)[b]		Radiological Dose (mrem/yr) All-Pathway Farmer Scenario[b]	Radiological Dose - Beta/Photon (mrem/yr) Drinking Water Only Scenario[b]
							Industrial	Residential		
Plutonium-240	Yes	5.62E-02	0.00E+00	DNA	3.00E+00	6.56E+03	NE	NE	NE	NE
Plutonium-241 + D	Yes	9.23E-01	0.00E+00	DNA	3.00E+00	1.44E+01	NE	NE	NE	NE
Plutonium-242	No	3.56E-04	0.00E+00	DNA	3.00E+00	3.74E+05	NE	NE	NE	NE
Protactinium-231	No	5.55E-02	0.00E+00	DNA	5.50E+02	3.28E+04	NE	NE	NE	NE
Selenium-79	No	5.75E-03	0.00E+00	DNA	3.10E+00	8.05E+05	NE	NE	NE	NE
Strontium-90 + D	Yes	3.42E+03	0.00E+00	DNA	1.61E+01	2.81E+01	NE	NE	NE	NE
Technetium-99	Yes	9.45E-03	3.77E-02	1.05E+04	0.00E+00	2.11E+05	5.20E-10	1.27E-08	6.61E-05	1.68E-04
Thorium-228 + D	Yes	3.89E-04	0.00E+00	DNA	3.00E+00	1.91E+00	NE	NE	NE	NE
Thorium-230	No	2.43E-02	0.00E+00	DNA	3.00E+00	7.54E+04	NE	NE	NE	NE
Thorium-232	Yes	1.13E-05	0.00E+00	DNA	3.00E+00	1.41E+10	NE	NE	NE	NE
Tin-126	No	8.55E-04	0.00E+00	DNA	1.00E+00	2.46E+05	NE	NE	NE	NE
Tritium	No	8.85E-03	0.00E+00	DNA	0.00E+00	1.23E+01	NE	NE	NE	NE
Uranium-233	No	3.24E-01	0.00E+00	DNA	6.00E-01	1.59E+05	NE	NE	NE	N/A
Uranium-234	No	7.70E-03	0.00E+00	DNA	6.00E-01	2.46E+05	NE	NE	NE	N/A
Uranium-235 + D	Yes	5.08E-04	0.00E+00	DNA	6.00E-01	7.04E+08	NE	NE	NE	N/A
Uranium-236	Yes	1.50E-04	0.00E+00	DNA	6.00E-01	2.34E+07	NE	NE	NE	N/A
Uranium-238 + D	Yes	1.21E-02	0.00E+00	DNA	6.00E-01	4.47E+09	NE	NE	NE	N/A

Table D-3. Incremental Lifetime Cancer Risk, Radiological Dose, and Drinking Water for Single-Shell Tank 241-C-109 Dose per Radionuclide Contaminant of Potential Concern for the 95% Upper Confidence Level Inventory. (3 sheets)

Analyte Name	Above Detection Limits in Residual Wastes	Inventory (Ci)	Waste Management Area C Fenceline Concentration	Peak Year	K_d (mL/g)[a]	Half-Life (yr)	Incremental Cancer Risk (Groundwater)[b]		Radiological Dose (mrem/yr) All-Pathway Farmer Scenario[b]	Radiological Dose - Beta/Photon (mrem/yr) Drinking Water Only Scenario[b]
							Industrial	Residential		
Yttrium-90	Yes	3.42E+03	0.00E+00	DNA	0.00E+00	7.31E-03	NE	NE	NE	NE
Performance Objectives[c]							**1-0E-6 to 1.0E-4[d]**	**1-0E-6 to 1.0E-4[d]**	**25[e]**	**4[f]**

[a] See PNNL-13895, *Hanford Contaminant Distribution Coefficient Database and Users Guide*, Rev. 1, and Section 4.3 of PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments* for the basis for the K_d values listed for the radionuclides.

[b] All exposure scenarios are described in HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for Hanford Tank Waste Performance Assessments.*

[c] Performance objectives apply to the cumulative (i.e., all contaminants) for the entire waste management area.

[d] EPA/540/R/99/006, *Radiation Risk Assessment at CERCLA Sites: Q & A*, Directive 9200.4-31P.

[e] DOE O 435.1, *Radioactive Waste Management.*

[f] 65 FR 76708, "National Primary Drinking Water Regulations; Radionuclides; Final Rule."

DNA = Did not arrive at fenceline within the 10,000-year modeling period.
N/A = Radionuclide is not a beta/photon emitter.
NE = Incremental cancer risk for industrial and residential scenarios or radiological dose evaluated for the all-pathways farmer and drinking water only scenarios not evaluated because radiological constituent had no estimated initial inventory or did not arrive in concentrations greater than at the fenceline within the 10,000-year modeling period. In the Decision Management Tool (DMT) that is used to implement the calculational methodology documented in DOE/ORP-2005-01, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site* for this Retrieval Data Report, calculated concentrations less than 1.00E-21 pCi/L are considered to be effectively zero. This risk metric may have also not been calculated because the radioactive analyte was predicted to have a concentration less than 0.001 pCi/L, which is well below the ability of standard laboratory analytical methods to detect it.

Table D-4. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index per Nonradionuclide Contaminant for Single-Shell Tank 241-C-109 of Potential Concern Using 95% Upper Confidence Level Post-Retrieval Inventory. (5 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[b]	Incremental Lifetime Cancer Risk (Groundwater)[c]	Hazard Quotient (Groundwater)[c]
						WAC 173-340 Method B	
Aluminum	Yes	2.52E+03	0.00E+00	DNA	1.00E+00	NE	NE
Ammonia	Yes	4.03E-02	<1.00E-03	1.05E+04	9.30E-04	NE	NE
Antimony[a]	No	1.01E-01	0.00E+00	DNA	1.00E+00	NE	NE
Arsenic[a]	Yes	1.21E-01	0.00E+00	DNA	3.90E+01	NE	NE
Barium[a]	Yes	1.60E-01	0.00E+00	DNA	6.00E+01	NE	NE
Beryllium[a]	No	1.68E-02	0.00E+00	DNA	7.00E+01	NE	NE
Bismuth	Yes	2.14E+00	8.79E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Boron	No	1.68E-02	0.00E+00	DNA	3.00E+00	NE	NE
Bromide	No	1.03E+00	4.21E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Cadmium[a]	No	1.68E-02	0.00E+00	DNA	1.26E+00	NE	NE
Calcium	Yes	1.94E+01	0.00E+00	DNA	4.00E+00	NE	NE
Cerium	Yes	5.21E+00	2.14E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Chloride	No	1.10E+00	4.50E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Chromium, Total[a]	Yes	2.10E-01	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Cobalt	No	1.68E-02	<1.00E-03	1.20E+04	1.00E-01	NE	NE
Copper	Yes	9.39E-01	0.00E+00	DNA	3.50E+01	NE	NE

Table D-4. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index per Nonradionuclide Contaminant for Single-Shell Tank 241-C-109 of Potential Concern Using 95% Upper Confidence Level Post-Retrieval Inventory. (5 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[b]	Incremental Lifetime Cancer Risk (Groundwater)[c]	Hazard Quotient (Groundwater)[c]
						WAC 173-340 Method B	
Cyanide[a]	Yes	4.88E-01	0.00E+00	DNA	9.90E+00	NE	NE
Europium	No	1.68E-02	0.00E+00	DNA	5.00E+01	NE	NE
Fluoride	Yes	1.02E+02	4.19E-01	1.05E+04	0.00E+00	No CPF	4.36E-04
Formate+A2	No	2.88E+00	1.18E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Iron	Yes	1.20E+02	0.00E+00	DNA	2.50E+01	NE	NE
Lanthanum	Yes	1.52E-01	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Lead[a]	Yes	5.47E+00	0.00E+00	DNA	5.20E+00	NE	NE
Lithium	Yes	2.20E-02	0.00E+00	DNA	3.00E+02	NE	NE
Magnesium	Yes	1.52E+00	0.00E+00	DNA	4.50E+00	NE	NE
Manganese	Yes	7.99E-01	0.00E+00	DNA	1.00E+00	NE	NE
Mercury[a]	Yes	2.61E-02	0.00E+00	DNA	5.20E+00	NE	NE
Molybdenum	Yes	3.30E-02	0.00E+00	DNA	4.00E+00	NE	NE
Neodymium	Yes	1.86E-01	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Nickel[a]	Yes	1.68E+01	0.00E+00	DNA	4.80E+01	NE	NE
Niobium	No	2.69E+00	0.00E+00	DNA	1.00E+02	NE	NE
Nitrate	Yes	4.95E+00	2.03E-02	1.05E+04	0.00E+00	No CPF	7.94E-07
Nitrite	Yes	3.85E+00	1.58E-02	1.05E+04	0.00E+00	No CPF	9.88E-06

Table D-4. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index per Nonradionuclide Contaminant for Single-Shell Tank 241-C-109 of Potential Concern Using 95% Upper Confidence Level Post-Retrieval Inventory. (5 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[b]	Incremental Lifetime Cancer Risk (Groundwater)[c]	Hazard Quotient (Groundwater)[c]
						WAC 173-340 Method B	
Oxalate	No	1.79E+00	7.33E-03	1.05E+04	0.00E+00	No CPF	No Rfd
o-Xylene	No	1.49E-05	<1.00E-03	1.20E+04	7.23E-02	NE	NE
Palladium	No	1.52E-01	0.00E+00	DNA	5.00E+01	NE	NE
Phosphate	Yes	1.27E+03	5.21E+00	1.05E+04	0.00E+00	No CPF	No Rfd
Potassium	No	3.36E-01	1.38E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Praseodymium	No	3.59E+00	1.47E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Rhodium	Yes	1.28E-01	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Rubidium	No	5.05E-01	2.07E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Ruthenium	No	6.70E-02	0.00E+00	DNA	1.00E+00	NE	NE
Samarium	Yes	5.04E-01	0.00E+00	DNA	1.00E+00	NE	NE
Selenium[a]	No	1.01E-01	0.00E+00	DNA	5.00E+00	NE	NE
Silicon	Yes	4.39E+01	0.00E+00	DNA	3.00E+01	NE	NE
Silver[a]	Yes	1.63E-01	0.00E+00	DNA	2.70E+00	NE	NE
Sodium	Yes	1.64E+03	6.73E+00	1.05E+04	0.00E+00	No CPF	No Rfd
Strontium	Yes	6.45E-01	0.00E+00	DNA	1.61E+01	NE	NE
Sulfate	Yes	3.11E+00	1.28E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Tantalum	No	4.47E+00	1.84E-02	1.05E+04	0.00E+00	No CPF	No Rfd

Table D-4. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index per Nonradionuclide Contaminant for Single-Shell Tank 241-C-109 of Potential Concern Using 95% Upper Confidence Level Post-Retrieval Inventory. (5 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[b]	Incremental Lifetime Cancer Risk (Groundwater)[c]	Hazard Quotient (Groundwater)[c]
						WAC 173-340 Method B	
Tellurium	No	8.40E-02	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Thallium[a]	Yes	9.34E-02	0.00E+00	DNA	7.10E+01	NE	NE
Thorium	Yes	1.03E-01	0.00E+00	DNA	1.00E+00	NE	NE
Tin	No	5.05E-02	0.00E+00	DNA	2.50E+02	NE	NE
Titanium	Yes	7.20E-02	0.00E+00	DNA	1.00E+03	NE	NE
Tungsten	No	1.10E-01	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Uranium	Yes	3.64E+01	0.00E+00	DNA	6.00E-01	NE	NE
Vanadium	No	1.68E-02	0.00E+00	DNA	5.00E+01	NE	NE
Yttrium	Yes	3.22E-02	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Zinc	Yes	7.17E-01	0.00E+00	DNA	6.20E+01	NE	NE
1, 1, 2-Trichloroethylene	No	1.95E-05	<1.00E-03	1.20E+04	2.82E-02	NE	NE
2-Butanone (MEK)[a]	No	3.18E-04	<1.00E-03	1.05E+04	1.35E-03	NE	NE
2-Propanone (Acetone)[a]	Yes	1.99E-03	<1.00E-03	1.05E+04	1.73E-04	NE	NE
4-Methyl-2-pentanone (MIBK)	No	2.76E-04	<1.00E-03	1.20E+04	4.02E-02	NE	NE
Acetate $C_2H_3O_2^-$	No	1.92E+00	7.88E-03	1.05E+04	3.00E-04	No CPF	No Rfd
Glycolate $C_2H_3O_3$	No	1.10E+00	4.50E-03	1.05E+04	0.00E+00	No CPF	No Rfd
m-Xylene	No	2.70E-05	<1.00E-03	1.20E+04	5.88E-02	NE	NE

Table D-4. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index per Nonradionuclide Contaminant for Single-Shell Tank 241-C-109 of Potential Concern Using 95% Upper Confidence Level Post-Retrieval Inventory. (5 sheets)

Analyte	Above Detection Limits in Residual Waste	Inventory (kg)	Waste Management Area C Fenceline Concentration (µg/L)	Peak Year	K_d (mL/g)[b]	Incremental Lifetime Cancer Risk (Groundwater)[c]	Hazard Quotient (Groundwater)[c]
						WAC 173-340 Method B	
Polychlorinated Biphenyls (high risk)[a]	No	1.71E-04	0.00E+00	DNA	9.27E+01	NE	NE
Tributyl phosphate	No	1.12E-02	<1.00E-03	1.20E+04	5.67E-01	NE	NE
Xylenes	No	3.29E-05	<1.00E-03	1.20E+04	5.88E-02	NE	NE
Performance Objective[d]						**1.0E-06[e]**	**1.0[f]**

[a] Dangerous waste constituent per *Washington Administrative Code* (WAC) 173-303-9905, "Dangerous Waste Constituents List."

[b] See PNNL-13895, *Hanford Contaminant Distribution Coefficient Database and Users Guide*, Rev. 1, for the basis for the K_d values listed for chromium and nitrate. The K_d values listed for the organic chemical compounds are determined from the chemicals' organic carbon/water partitioning coefficient and an estimate of 0.03% for the Hanford Site sediments fraction of organic content (PNNL-13895, Rev. 1, page 11, paragraph 3).

[c] All exposure scenarios are described in HNF-SD-WM-TI-707, *Exposure Scenarios and Unit Factors for Hanford Tank Waste Performance Assessments.*

[d] Single Analyte Performance objectives apply to entire waste management area, not just a single component of the waste management area.

[e] WAC 173-340-705, "Use of Method B," subpart (2)(c)(ii).

[f] WAC 173-340-705 (2)(c)(i).

DNA = Did not arrive at fenceline within the 10,000-year modeling period.

NE = Incremental cancer risk or hazard quotient calculated under WAC 173-340, "Model Toxics Control Act – Cleanup," Method B not evaluated because hazardous chemical constituent had no estimated initial inventory or did not arrive in concentrations greater than zero at the fenceline within the 10,000-year modeling period. In the Decision Management Tool (DMT) that is used to implement the calculational methodology documented in DOE/ORP-2005-01, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site* for this Retrieval Data Report, calculated concentrations less than 1.00E-21 µg/L are considered to be effectively zero. The risk metric may have also not been calculated because the chemical analyte was predicted to have a concentration less than 0.001 µg/L, which is well below the ability of standard laboratory analytical methods to detect it.

No CPF = No cancer potency factor available.

No Rfd = No reference dose available.

Table D-5. Well Driller Scenario Doses (mrem) for Single-Shell Tank 241-C-109 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

A – Average Inventory										
	Years After Site Closure (January 1, 2032)									
Nuclide	100	200	300	400	500	600	700	800	900	1,000
Antimony-125	4.10E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tin-126	1.33E-04	1.33E-04	1.32E-04	1.32E-04	1.32E-04	1.32E-04	1.32E-04	1.32E-04	1.32E-04	1.32E-04
Iodine-129	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07	2.03E-07
Cesium-137 + Daughters	3.59E-01	3.56E-02	3.53E-03	3.51E-04	3.48E-05	3.45E-06	3.42E-07	3.40E-08	3.37E-09	3.34E-10
Barium-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon-14	5.42E-09	5.35E-09	5.29E-09	5.22E-09	5.16E-09	5.10E-09	5.04E-09	4.98E-09	4.92E-09	4.86E-09
Europium-152	3.39E-04	1.87E-06	1.03E-08	5.70E-11	3.15E-13	2.30E-15	5.74E-16	5.65E-16	5.65E-16	5.65E-16
Europium-154	8.65E-06	2.71E-09	8.51E-13	2.67E-16	8.37E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	1.72E-10	6.37E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-228 + D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-230	3.84E-04	5.37E-04	6.83E-04	8.23E-04	9.57E-04	1.09E-03	1.21E-03	1.33E-03	1.44E-03	1.54E-03
Protactinium-231	9.28E-03	9.37E-03	9.35E-03	9.33E-03	9.31E-03	9.29E-03	9.27E-03	9.25E-03	9.23E-03	9.21E-03
Thorium-232	6.09E-06	6.09E-06	6.09E-06	6.09E-06	6.09E-06	6.09E-06	6.09E-06	6.09E-06	6.09E-06	6.09E-06
Uranium-233	5.92E-04	8.18E-04	1.04E-03	1.26E-03	1.48E-03	1.70E-03	1.92E-03	2.13E-03	2.34E-03	2.55E-03
Uranium-234	7.11E-06	7.24E-06	7.41E-06	7.63E-06	7.89E-06	8.18E-06	8.51E-06	8.88E-06	9.28E-06	9.71E-06
Uranium-235 + D	1.36E-05	1.40E-05	1.44E-05	1.47E-05	1.51E-05	1.55E-05	1.58E-05	1.62E-05	1.66E-05	1.69E-05
Uranium-236	2.13E-07	2.13E-07	2.13E-07	2.13E-07	2.13E-07	2.13E-07	2.13E-07	2.13E-07	2.13E-07	2.13E-07
Neptunium-237 + D	4.83E-04	4.83E-04	4.83E-04	4.83E-04	4.83E-04	4.83E-04	4.83E-04	4.83E-04	4.83E-04	4.83E-04

Table D-5. Well Driller Scenario Doses (mrem) for Single-Shell Tank 241-C-109 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

A – Average Inventory (continued)										
	Years After Site Closure (January 1, 2032)									
Nuclide	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1,000**
Plutonium-238	2.89E-04	1.31E-04	5.94E-05	2.70E-05	1.22E-05	5.56E-06	2.53E-06	1.16E-06	5.36E-07	2.54E-07
Uranium-238 + D	6.50E-05	6.50E-05	6.50E-05	6.50E-05	6.50E-05	6.50E-05	6.51E-05	6.51E-05	6.51E-05	6.51E-05
Plutonium-239	1.99E-02	1.98E-02	1.98E-02	1.97E-02	1.96E-02	1.96E-02	1.95E-02	1.95E-02	1.94E-02	1.94E-02
Plutonium-240	2.14E-03	2.12E-03	2.10E-03	2.07E-03	2.05E-03	2.03E-03	2.01E-03	1.99E-03	1.97E-03	1.95E-03
Americium-241	1.66E-02	1.41E-02	1.20E-02	1.02E-02	8.73E-03	7.44E-03	6.34E-03	5.40E-03	4.60E-03	3.92E-03
Plutonium-241 + D	1.36E-03	1.16E-03	9.92E-04	8.45E-04	7.20E-04	6.14E-04	5.23E-04	4.46E-04	3.80E-04	3.24E-04
Curium-242	3.69E-08	1.68E-08	7.60E-09	3.45E-09	1.57E-09	7.12E-10	3.24E-10	1.48E-10	6.81E-11	3.19E-11
Plutonium-242	6.55E-06	6.55E-06	6.55E-06	6.55E-06	6.55E-06	6.55E-06	6.54E-06	6.54E-06	6.54E-06	6.54E-06
Curium-243	9.42E-08	1.00E-08	2.64E-09	1.99E-09	1.92E-09	1.91E-09	1.91E-09	1.90E-09	1.89E-09	1.89E-09
Curium-244	2.59E-07	9.67E-08	9.23E-08	9.12E-08	9.03E-08	8.93E-08	8.84E-08	8.74E-08	8.65E-08	8.56E-08
Tritium	1.28E-12	4.64E-15	1.68E-17	6.08E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cobalt-60	1.48E-08	2.87E-14	5.60E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel-63	1.55E-06	7.76E-07	3.88E-07	1.94E-07	9.72E-08	4.86E-08	2.43E-08	1.22E-08	6.09E-09	3.05E-09
Selenium-79	1.29E-07	1.29E-07	1.29E-07	1.29E-07	1.29E-07	1.29E-07	1.29E-07	1.29E-07	1.29E-07	1.29E-07
Strontium-90 + D	2.79E-01	2.38E-02	2.03E-03	1.73E-04	1.47E-05	1.25E-06	1.07E-07	9.11E-09	7.76E-10	6.62E-11
Yttrium-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Technetium-99	1.43E-07	1.43E-07	1.43E-07	1.43E-07	1.43E-07	1.42E-07	1.42E-07	1.42E-07	1.42E-07	1.42E-07
Total Dose	**6.90E-01**	**1.08E-01**	**5.23E-02**	**4.56E-02**	**4.37E-02**	**4.25E-02**	**4.15E-02**	**4.07E-02**	**4.01E-02**	**3.96E-02**

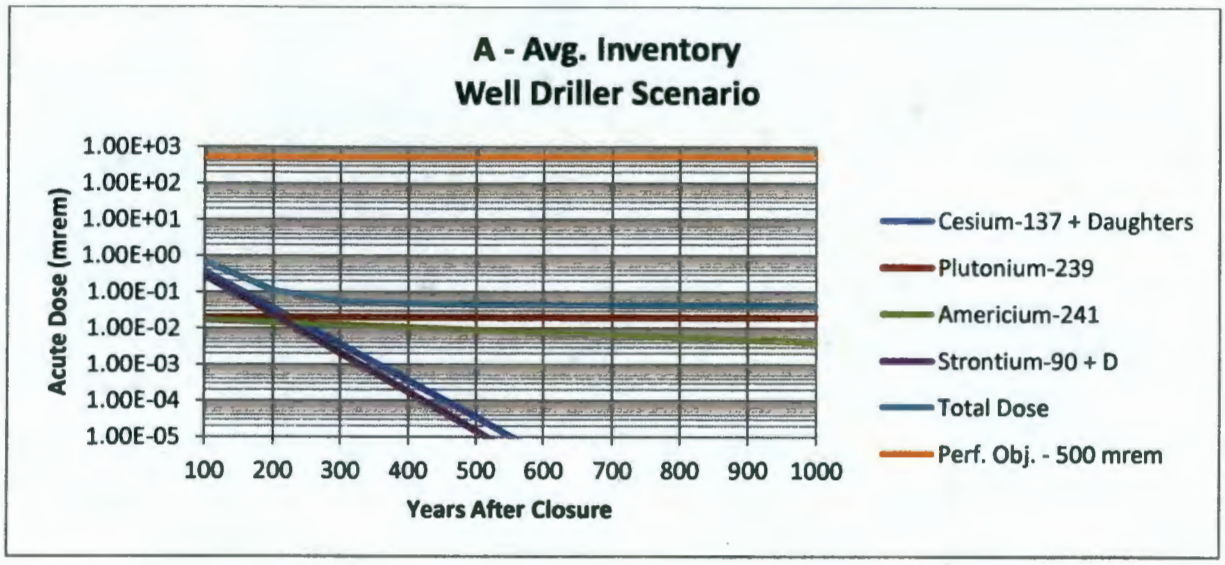
Table D-5. Well Driller Scenario Doses (mrem) for Single-Shell Tank 241-C-109 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

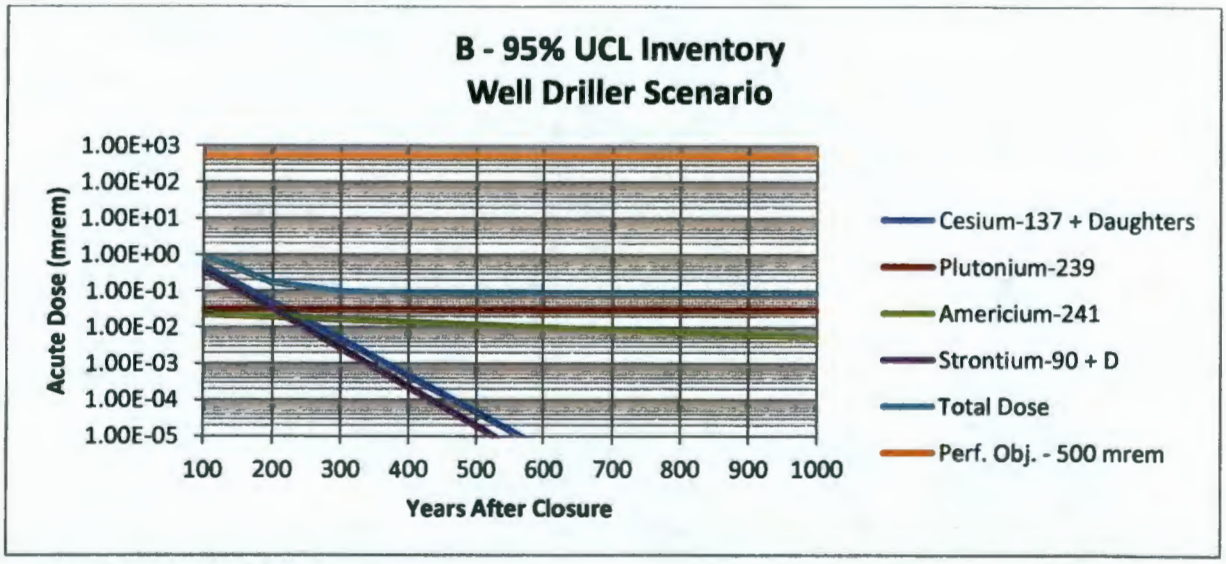
B – 95% Upper Confidence Level Inventory										
	Years After Site Closure (January 1, 2032)									
Nuclide	100	200	300	400	500	600	700	800	900	1,000
Antimony-125	1.23E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tin-126	3.98E-04	3.98E-04	3.97E-04	3.97E-04	3.97E-04	3.97E-04	3.97E-04	3.97E-04	3.97E-04	3.97E-04
Iodine-129	6.08E-07	6.08E-07	6.08E-07	6.08E-07	6.08E-07	6.08E-07	6.08E-07	6.08E-07	6.08E-07	6.08E-07
Cesium-137 + Daughters	4.63E-01	4.60E-02	4.56E-03	4.52E-04	4.49E-05	4.45E-06	4.42E-07	4.38E-08	4.35E-09	4.31E-10
Barium-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon-14	1.63E-08	1.61E-08	1.59E-08	1.57E-08	1.55E-08	1.53E-08	1.51E-08	1.49E-08	1.48E-08	1.46E-08
Europium-152	1.02E-03	5.62E-06	3.10E-08	1.71E-10	9.45E-13	6.90E-15	1.72E-15	1.69E-15	1.69E-15	1.69E-15
Europium-154	2.60E-05	8.14E-09	2.55E-12	8.01E-16	2.51E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	5.17E-10	1.91E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-228 + D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-230	1.15E-03	1.61E-03	2.05E-03	2.47E-03	2.87E-03	3.26E-03	3.62E-03	3.98E-03	4.31E-03	4.63E-03
Protactinium-231	2.78E-02	2.81E-02	2.80E-02	2.80E-02	2.79E-02	2.79E-02	2.78E-02	2.78E-02	2.77E-02	2.76E-02
Thorium-232	8.10E-06	8.10E-06	8.10E-06	8.10E-06	8.10E-06	8.10E-06	8.10E-06	8.10E-06	8.10E-06	8.10E-06
Uranium-233	1.78E-03	2.45E-03	3.13E-03	3.79E-03	4.45E-03	5.11E-03	5.75E-03	6.39E-03	7.03E-03	7.66E-03
Uranium-234	2.13E-05	2.17E-05	2.23E-05	2.29E-05	2.37E-05	2.46E-05	2.56E-05	2.67E-05	2.79E-05	2.92E-05
Uranium-235 + D	2.02E-05	2.07E-05	2.13E-05	2.18E-05	2.24E-05	2.29E-05	2.35E-05	2.40E-05	2.45E-05	2.51E-05
Uranium-236	3.87E-07	3.87E-07	3.87E-07	3.87E-07	3.87E-07	3.87E-07	3.87E-07	3.87E-07	3.87E-07	3.87E-07
Neptunium-237 + D	1.45E-03	1.45E-03	1.45E-03	1.45E-03	1.45E-03	1.45E-03	1.45E-03	1.45E-03	1.45E-03	1.45E-03

Table D-5. Well Driller Scenario Doses (mrem) for Single-Shell Tank 241-C-109 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

B – 95% Upper Confidence Level Inventory (continued)										
	Years After Site Closure (January 1, 2032)									
Nuclide	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1,000**
Plutonium-238	3.93E-04	1.78E-04	8.08E-05	3.67E-05	1.66E-05	7.57E-06	3.44E-06	1.58E-06	7.29E-07	3.45E-07
Uranium-238 + D	9.63E-05	9.63E-05	9.63E-05	9.63E-05	9.63E-05	9.63E-05	9.63E-05	9.64E-05	9.64E-05	9.64E-05
Plutonium-239	2.99E-02	2.98E-02	2.97E-02	2.96E-02	2.95E-02	2.94E-02	2.94E-02	2.93E-02	2.92E-02	2.91E-02
Plutonium-240	3.22E-03	3.18E-03	3.15E-03	3.12E-03	3.08E-03	3.05E-03	3.02E-03	2.99E-03	2.96E-03	2.92E-03
Americium-241	2.16E-02	1.84E-02	1.57E-02	1.34E-02	1.14E-02	9.72E-03	8.28E-03	7.06E-03	6.01E-03	5.12E-03
Plutonium-241 + D	1.62E-03	1.38E-03	1.18E-03	1.00E-03	8.55E-04	7.29E-04	6.21E-04	5.29E-04	4.51E-04	3.84E-04
Curium-242	1.11E-07	5.03E-08	2.28E-08	1.04E-08	4.70E-09	2.14E-09	9.72E-10	4.44E-10	2.04E-10	9.57E-11
Plutonium-242	1.97E-05	1.97E-05	1.96E-05	1.96E-05	1.96E-05	1.96E-05	1.96E-05	1.96E-05	1.96E-05	1.96E-05
Curium-243	2.82E-07	3.01E-08	7.91E-09	5.95E-09	5.76E-09	5.73E-09	5.71E-09	5.69E-09	5.67E-09	5.66E-09
Curium-244	7.76E-07	2.90E-07	2.77E-07	2.74E-07	2.71E-07	2.68E-07	2.65E-07	2.62E-07	2.60E-07	2.57E-07
Tritium	3.84E-12	1.39E-14	5.03E-17	1.82E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cobalt-60	4.43E-08	8.62E-14	1.68E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel-63	1.90E-06	9.51E-07	4.76E-07	2.38E-07	1.19E-07	5.96E-08	2.98E-08	1.49E-08	7.46E-09	3.73E-09
Selenium-79	3.87E-07	3.86E-07	3.86E-07	3.86E-07	3.86E-07	3.86E-07	3.86E-07	3.86E-07	3.86E-07	3.86E-07
Strontium-90 + D	3.59E-01	3.06E-02	2.60E-03	2.22E-04	1.89E-05	1.61E-06	1.37E-07	1.17E-08	9.98E-10	8.51E-11
Yttrium-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Technetium-99	1.79E-07	1.79E-07	1.79E-07	1.79E-07	1.79E-07	1.79E-07	1.79E-07	1.79E-07	1.79E-07	1.79E-07
Total Dose	**9.12E-01**	**1.64E-01**	**9.23E-02**	**8.41E-02**	**8.22E-02**	**8.12E-02**	**8.05E-02**	**8.00E-02**	**7.97E-02**	**7.95E-02**

Figure D-1. Comparison of Well Driller Scenario Doses (mrem) with Performance Objective for Acute Exposure for Key Analytes – A) Average Inventory and B) 95% Upper Confidence Level Inventory in Residual Wastes within Single-Shell Tank 241-C-109.





UCL = upper confidence level

Table D-6. Rural Pasture Doses (mrem/y) for Single-Shell Tank 241-C-109 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

A – Average Inventory										
	Years After Site Closure (January 1, 2032)									
Nuclide	100	200	300	400	500	600	700	800	900	1,000
Antimony-125	4.29E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tin-126	1.50E-05	1.50E-05	1.50E-05	1.50E-05	1.50E-05	1.50E-05	1.50E-05	1.50E-05	1.50E-05	1.50E-05
Iodine-129	2.06E-06	2.06E-06	2.06E-06	2.06E-06	2.06E-06	2.06E-06	2.06E-06	2.06E-06	2.06E-06	2.06E-06
Cesium-137 + Daughters	9.66E-02	9.58E-03	9.50E-04	9.43E-05	9.35E-06	9.28E-07	9.21E-08	9.13E-09	9.06E-10	8.99E-11
Barium-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon-14	5.97E-07	5.90E-07	5.83E-07	5.76E-07	5.69E-07	5.62E-07	5.55E-07	5.49E-07	5.42E-07	5.36E-07
Europium-152	3.84E-05	2.12E-07	1.17E-09	6.45E-12	3.57E-14	3.55E-16	1.60E-16	1.59E-16	1.59E-16	1.59E-16
Europium-154	9.78E-07	3.07E-10	9.62E-14	3.02E-17	9.46E-21	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	1.48E-11	5.46E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-228 + D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-230	9.30E-05	1.26E-04	1.57E-04	1.87E-04	2.16E-04	2.43E-04	2.69E-04	2.94E-04	3.18E-04	3.41E-04
Protactinium-231	2.37E-03	2.39E-03	2.39E-03	2.38E-03	2.38E-03	2.37E-03	2.36E-03	2.36E-03	2.35E-03	2.35E-03
Thorium-232	1.10E-06	1.10E-06	1.10E-06	1.10E-06	1.10E-06	1.10E-06	1.10E-06	1.10E-06	1.10E-06	1.10E-06
Uranium-233	2.41E-04	2.92E-04	3.44E-04	3.95E-04	4.45E-04	4.95E-04	5.44E-04	5.93E-04	6.41E-04	6.89E-04
Uranium-234	4.08E-06	4.11E-06	4.15E-06	4.20E-06	4.26E-06	4.33E-06	4.40E-06	4.48E-06	4.57E-06	4.66E-06
Uranium-235 + D	1.85E-06	1.94E-06	2.04E-06	2.13E-06	2.22E-06	2.32E-06	2.41E-06	2.50E-06	2.59E-06	2.69E-06
Uranium-236	1.24E-07	1.24E-07	1.24E-07	1.24E-07	1.24E-07	1.24E-07	1.24E-07	1.24E-07	1.24E-07	1.24E-07
Neptunium-237 + D	1.03E-04	1.03E-04	1.03E-04	1.03E-04	1.03E-04	1.03E-04	1.03E-04	1.03E-04	1.03E-04	1.03E-04

Table D-6. Rural Pasture Doses (mrem/y) for Single-Shell Tank 241-C-109 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

A – Average Inventory (continued)										
	Years After Site Closure (January 1, 2032)									
Nuclide	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1,000**
Plutonium-238	8.19E-05	3.72E-05	1.69E-05	7.65E-06	3.48E-06	1.58E-06	7.23E-07	3.33E-07	1.56E-07	7.60E-08
Uranium-238 + D	1.68E-05	1.68E-05	1.68E-05	1.68E-05	1.68E-05	1.68E-05	1.68E-05	1.68E-05	1.68E-05	1.68E-05
Plutonium-239	5.66E-03	5.64E-03	5.63E-03	5.61E-03	5.59E-03	5.58E-03	5.56E-03	5.55E-03	5.53E-03	5.51E-03
Plutonium-240	6.09E-04	6.03E-04	5.96E-04	5.90E-04	5.84E-04	5.78E-04	5.72E-04	5.66E-04	5.60E-04	5.54E-04
Americium-241	4.56E-03	3.89E-03	3.31E-03	2.82E-03	2.40E-03	2.05E-03	1.75E-03	1.49E-03	1.27E-03	1.08E-03
Plutonium-241 + D	3.76E-04	3.21E-04	2.73E-04	2.33E-04	1.98E-04	1.69E-04	1.44E-04	1.23E-04	1.05E-04	8.91E-05
Curium-242	1.05E-08	4.76E-09	2.16E-09	9.80E-10	4.45E-10	2.02E-10	9.24E-11	4.25E-11	1.99E-11	9.59E-12
Plutonium-242	1.87E-06	1.87E-06	1.86E-06	1.86E-06	1.86E-06	1.86E-06	1.86E-06	1.86E-06	1.86E-06	1.86E-06
Curium-243	2.03E-08	2.28E-09	6.99E-10	5.59E-10	5.45E-10	5.42E-10	5.41E-10	5.39E-10	5.38E-10	5.36E-10
Curium-244	7.42E-08	2.76E-08	2.63E-08	2.60E-08	2.57E-08	2.54E-08	2.52E-08	2.49E-08	2.46E-08	2.44E-08
Tritium	4.76E-11	1.72E-13	6.24E-16	2.26E-18	8.17E-21	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cobalt-60	1.69E-09	3.28E-15	6.39E-21	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel-63	4.13E-05	2.06E-05	1.03E-05	5.17E-06	2.59E-06	1.29E-06	6.48E-07	3.24E-07	1.62E-07	8.11E-08
Selenium-79	6.16E-07	6.16E-07	6.16E-07	6.16E-07	6.16E-07	6.16E-07	6.16E-07	6.16E-07	6.16E-07	6.16E-07
Strontium-90 + D	1.61E+01	1.37E+00	1.17E-01	9.97E-03	8.50E-04	7.24E-05	6.17E-06	5.26E-07	4.48E-08	3.82E-09
Yttrium-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Technetium-99	2.60E-05	2.60E-05	2.60E-05	2.60E-05	2.60E-05	2.60E-05	2.60E-05	2.60E-05	2.60E-05	2.60E-05
Total Dose	**1.62E+01**	**1.40E+00**	**1.31E-01**	**2.25E-02**	**1.29E-02**	**1.17E-02**	**1.14E-02**	**1.11E-02**	**1.10E-02**	**1.08E-02**

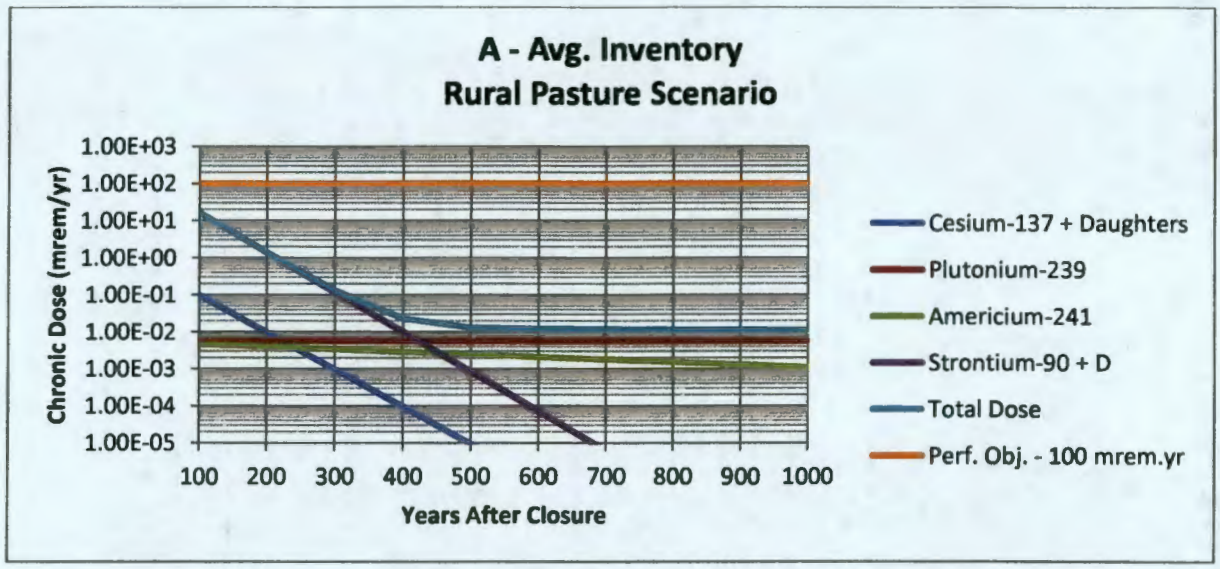
Table D-6. Rural Pasture Doses (mrem/y) for Single-Shell Tank 241-C-109 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

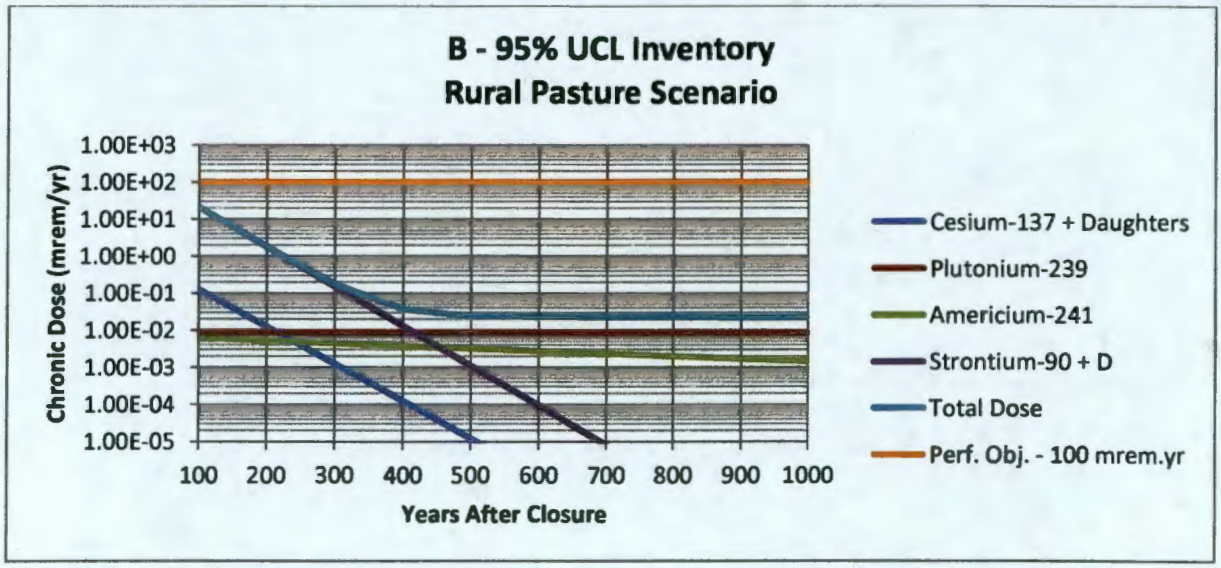
B – 95% Upper Confidence Level Inventory										
	Years After Site Closure (January 1, 2032)									
Nuclide	100	200	300	400	500	600	700	800	900	1,000
Antimony-125	1.29E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tin-126	4.51E-05	4.51E-05	4.51E-05	4.51E-05	4.51E-05	4.50E-05	4.50E-05	4.50E-05	4.50E-05	4.50E-05
Iodine-129	6.18E-06	6.18E-06	6.18E-06	6.18E-06	6.18E-06	6.18E-06	6.18E-06	6.18E-06	6.18E-06	6.18E-06
Cesium-137 + Daughters	1.25E-01	1.24E-02	1.23E-03	1.22E-04	1.21E-05	1.20E-06	1.19E-07	1.18E-08	1.17E-09	1.16E-10
Barium-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon-14	1.79E-06	1.77E-06	1.75E-06	1.73E-06	1.71E-06	1.69E-06	1.67E-06	1.65E-06	1.63E-06	1.61E-06
Europium-152	1.15E-04	6.35E-07	3.51E-09	1.93E-11	1.07E-13	1.07E-15	4.81E-16	4.78E-16	4.78E-16	4.78E-16
Europium-154	2.93E-06	9.20E-10	2.88E-13	9.05E-17	2.84E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	4.44E-11	1.64E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-228 + D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-230	2.79E-04	3.77E-04	4.71E-04	5.61E-04	6.47E-04	7.29E-04	8.08E-04	8.83E-04	9.55E-04	1.02E-03
Protactinium-231	7.10E-03	7.17E-03	7.16E-03	7.14E-03	7.13E-03	7.11E-03	7.09E-03	7.08E-03	7.06E-03	7.05E-03
Thorium-232	1.47E-06	1.47E-06	1.47E-06	1.47E-06	1.47E-06	1.47E-06	1.47E-06	1.47E-06	1.47E-06	1.47E-06
Uranium-233	7.22E-04	8.77E-04	1.03E-03	1.18E-03	1.33E-03	1.48E-03	1.63E-03	1.78E-03	1.92E-03	2.07E-03
Uranium-234	1.23E-05	1.23E-05	1.25E-05	1.26E-05	1.28E-05	1.30E-05	1.32E-05	1.34E-05	1.37E-05	1.40E-05
Uranium-235 + D	2.74E-06	2.88E-06	3.01E-06	3.15E-06	3.29E-06	3.43E-06	3.57E-06	3.70E-06	3.84E-06	3.98E-06
Uranium-236	2.25E-07	2.25E-07	2.25E-07	2.25E-07	2.25E-07	2.25E-07	2.25E-07	2.25E-07	2.25E-07	2.25E-07
Neptunium-237 + D	3.08E-04	3.08E-04	3.08E-04	3.08E-04	3.08E-04	3.08E-04	3.08E-04	3.08E-04	3.08E-04	3.08E-04

Table D-6. Rural Pasture Doses (mrem/y) for Single-Shell Tank 241-C-109 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

B – 95% Upper Confidence Level Inventory (continued)										
	Years After Site Closure (January 1, 2032)									
Nuclide	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1,000**
Plutonium-238	1.11E-04	5.06E-05	2.29E-05	1.04E-05	4.73E-06	2.15E-06	9.83E-07	4.53E-07	2.12E-07	1.03E-07
Uranium-238 + D	2.49E-05	2.49E-05	2.49E-05	2.49E-05	2.49E-05	2.49E-05	2.49E-05	2.49E-05	2.49E-05	2.49E-05
Plutonium-239	8.50E-03	8.48E-03	8.45E-03	8.43E-03	8.41E-03	8.38E-03	8.36E-03	8.33E-03	8.31E-03	8.29E-03
Plutonium-240	9.15E-04	9.06E-04	8.96E-04	8.87E-04	8.78E-04	8.68E-04	8.59E-04	8.50E-04	8.41E-04	8.32E-04
Americium-241	5.96E-03	5.08E-03	4.33E-03	3.69E-03	3.14E-03	2.68E-03	2.28E-03	1.94E-03	1.66E-03	1.41E-03
Plutonium-241 + D	4.46E-04	3.81E-04	3.24E-04	2.76E-04	2.36E-04	2.01E-04	1.71E-04	1.46E-04	1.24E-04	1.06E-04
Curium-242	3.15E-08	1.43E-08	6.48E-09	2.94E-09	1.34E-09	6.08E-10	2.78E-10	1.28E-10	5.96E-11	2.88E-11
Plutonium-242	5.60E-06	5.60E-06	5.59E-06	5.59E-06	5.59E-06	5.59E-06	5.59E-06	5.59E-06	5.59E-06	5.59E-06
Curium-243	6.08E-08	6.84E-09	2.09E-09	1.67E-09	1.63E-09	1.62E-09	1.62E-09	1.61E-09	1.61E-09	1.60E-09
Curium-244	2.23E-07	8.27E-08	7.88E-08	7.79E-08	7.71E-08	7.63E-08	7.55E-08	7.47E-08	7.39E-08	7.31E-08
Tritium	1.43E-10	5.16E-13	1.87E-15	6.76E-18	2.45E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cobalt-60	5.06E-09	9.84E-15	1.92E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel-63	5.06E-05	2.53E-05	1.27E-05	6.34E-06	3.17E-06	1.59E-06	7.94E-07	3.97E-07	1.99E-07	9.94E-08
Selenium-79	1.84E-06	1.84E-06	1.84E-06	1.84E-06	1.84E-06	1.84E-06	1.84E-06	1.84E-06	1.84E-06	1.84E-06
Strontium-90 + D	2.07E+01	1.76E+00	1.50E-01	1.28E-02	1.09E-03	9.31E-05	7.94E-06	6.76E-07	5.76E-08	4.91E-09
Yttrium-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Technetium-99	3.27E-05	3.27E-05	3.27E-05	3.27E-05	3.27E-05	3.27E-05	3.26E-05	3.26E-05	3.26E-05	3.26E-05
Total Dose	**2.09E+01**	**1.80E+00**	**1.75E-01**	**3.56E-02**	**2.33E-02**	**2.20E-02**	**2.17E-02**	**2.15E-02**	**2.13E-02**	**2.12E-02**

Figure D-2. Comparison of Rural Pasture Scenario Doses with Performance Objective for Chronic Exposure for Key Analytes within A) Average Inventory and B) 95% Upper Confidence Level Inventory Estimated for Residual Wastes in Single-Shell Tank 241-C-109.





UCL = upper confidence level

Table D-7. Suburban Garden Doses (mrem/y) for Single-Shell Tank 241-C-109 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2007) and Pathways. (4 sheets)

A – Average Inventory										
	Years After Site Closure (January 1, 2032)									
Nuclide	100	200	300	400	500	600	700	800	900	1,000
Antimony-125	4.17E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tin-126	1.45E-04	1.45E-04	1.45E-04	1.45E-04	1.45E-04	1.45E-04	1.44E-04	1.44E-04	1.44E-04	1.44E-04
Iodine-129	1.02E-05	1.02E-05	1.02E-05	1.02E-05	1.02E-05	1.02E-05	1.02E-05	1.02E-05	1.02E-05	1.02E-05
Cesium-137 + Daughters	9.36E-01	9.29E-02	9.21E-03	9.14E-04	9.07E-05	8.99E-06	8.92E-07	8.85E-08	8.78E-09	8.71E-10
Barium-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon-14	1.05E-05	1.04E-05	1.02E-05	1.01E-05	9.98E-06	9.86E-06	9.74E-06	9.63E-06	9.51E-06	9.40E-06
Europium-152	3.69E-04	2.04E-06	1.12E-08	6.20E-11	3.44E-13	4.14E-15	2.27E-15	2.26E-15	2.26E-15	2.26E-15
Europium-154	9.41E-06	2.95E-09	9.25E-13	2.90E-16	9.10E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	1.45E-10	5.37E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-228 + D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-230	1.59E-03	2.34E-03	3.07E-03	3.77E-03	4.43E-03	5.07E-03	5.67E-03	6.26E-03	6.81E-03	7.34E-03
Protactinium-231	5.02E-02	5.06E-02	5.05E-02	5.04E-02	5.03E-02	5.02E-02	5.01E-02	5.00E-02	4.99E-02	4.98E-02
Thorium-232	1.28E-05	1.28E-05	1.28E-05	1.28E-05	1.28E-05	1.28E-05	1.28E-05	1.28E-05	1.28E-05	1.28E-05
Uranium-233	9.24E-03	9.96E-03	1.07E-02	1.14E-02	1.21E-02	1.28E-02	1.35E-02	1.42E-02	1.49E-02	1.55E-02
Uranium-234	1.94E-04	1.94E-04	1.95E-04	1.96E-04	1.97E-04	1.98E-04	2.00E-04	2.01E-04	2.03E-04	2.05E-04
Uranium-235 + D	3.84E-05	4.03E-05	4.23E-05	4.43E-05	4.63E-05	4.82E-05	5.02E-05	5.22E-05	5.41E-05	5.61E-05
Uranium-236	5.89E-06	5.89E-06	5.89E-06	5.89E-06	5.89E-06	5.89E-06	5.89E-06	5.89E-06	5.89E-06	5.89E-06
Neptunium-237 + D	7.09E-03	7.09E-03	7.09E-03	7.09E-03	7.09E-03	7.09E-03	7.09E-03	7.09E-03	7.09E-03	7.09E-03

Table D-7. Suburban Garden Doses (mrem/y) for Single-Shell Tank 241-C-109 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2007) and Pathways. (4 sheets)

A – Average Inventory (continued)										
	Years After Site Closure (January 1, 2032)									
Nuclide	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1,000**
Plutonium-238	1.81E-03	8.22E-04	3.73E-04	1.70E-04	7.71E-05	3.52E-05	1.62E-05	7.57E-06	3.66E-06	1.89E-06
Uranium-238 + D	6.27E-04	6.27E-04	6.27E-04	6.27E-04	6.27E-04	6.28E-04	6.28E-04	6.28E-04	6.28E-04	6.28E-04
Plutonium-239	1.26E-01	1.25E-01	1.25E-01	1.24E-01	1.24E-01	1.24E-01	1.23E-01	1.23E-01	1.23E-01	1.22E-01
Plutonium-240	1.35E-02	1.34E-02	1.32E-02	1.31E-02	1.30E-02	1.28E-02	1.27E-02	1.26E-02	1.24E-02	1.23E-02
Americium-241	9.99E-02	8.51E-02	7.25E-02	6.18E-02	5.27E-02	4.49E-02	3.83E-02	3.26E-02	2.78E-02	2.37E-02
Plutonium-241 + D	8.23E-03	7.02E-03	5.98E-03	5.10E-03	4.35E-03	3.70E-03	3.16E-03	2.69E-03	2.29E-03	1.96E-03
Curium-242	2.32E-07	1.05E-07	4.78E-08	2.17E-08	9.87E-09	4.51E-09	2.07E-09	9.67E-10	4.66E-10	2.39E-10
Plutonium-242	4.13E-05	4.13E-05	4.13E-05	4.12E-05	4.12E-05	4.12E-05	4.12E-05	4.12E-05	4.12E-05	4.12E-05
Curium-243	3.89E-07	4.52E-08	1.50E-08	1.23E-08	1.21E-08	1.20E-08	1.20E-08	1.19E-08	1.19E-08	1.19E-08
Curium-244	1.60E-06	6.10E-07	5.83E-07	5.76E-07	5.70E-07	5.64E-07	5.58E-07	5.52E-07	5.46E-07	5.41E-07
Tritium	4.16E-10	1.51E-12	5.45E-15	1.97E-17	7.14E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cobalt-60	1.69E-08	3.28E-14	6.39E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel-63	2.80E-04	1.40E-04	7.01E-05	3.51E-05	1.75E-05	8.78E-06	4.39E-06	2.20E-06	1.10E-06	5.50E-07
Selenium-79	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05
Strontium-90 + D	2.28E+02	1.95E+01	1.66E+00	1.41E-01	1.21E-02	1.03E-03	8.75E-05	7.46E-06	6.36E-07	5.42E-08
Yttrium-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Technetium-99	1.98E-03	1.98E-03	1.98E-03	1.98E-03	1.98E-03	1.98E-03	1.98E-03	1.98E-03	1.98E-03	1.98E-03
Total Dose	**2.30E+02**	**1.99E+01**	**1.96E+00**	**4.23E-01**	**2.83E-01**	**2.64E-01**	**2.57E-01**	**2.52E-01**	**2.47E-01**	**2.43E-01**

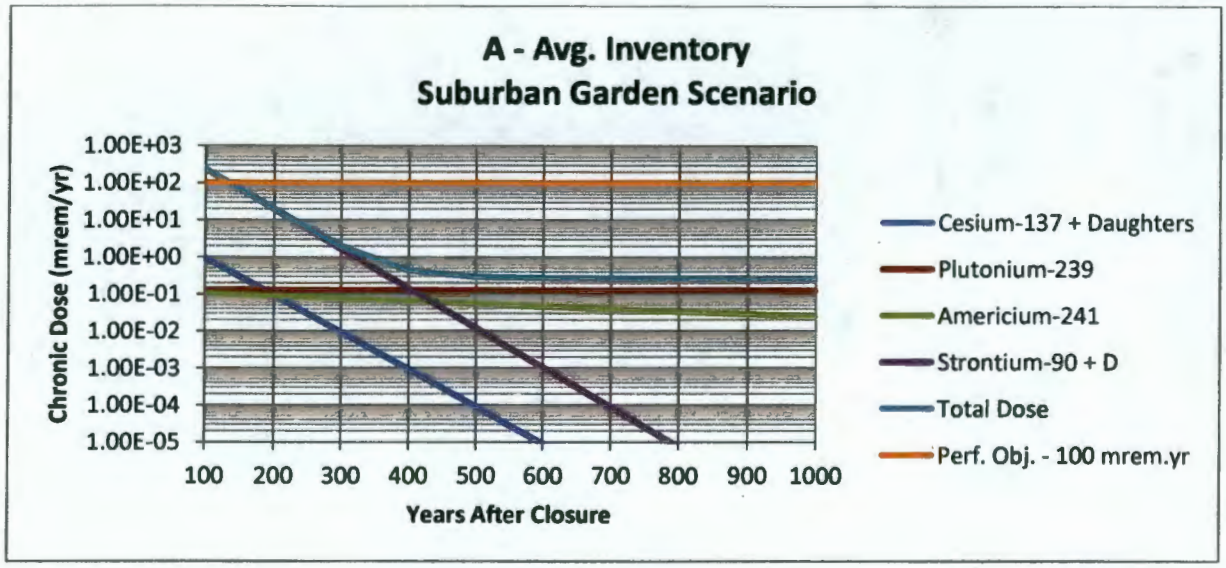
Table D-7. Suburban Garden Doses (mrem/y) for Single-Shell Tank 241-C-109 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2007) and Pathways. (4 sheets)

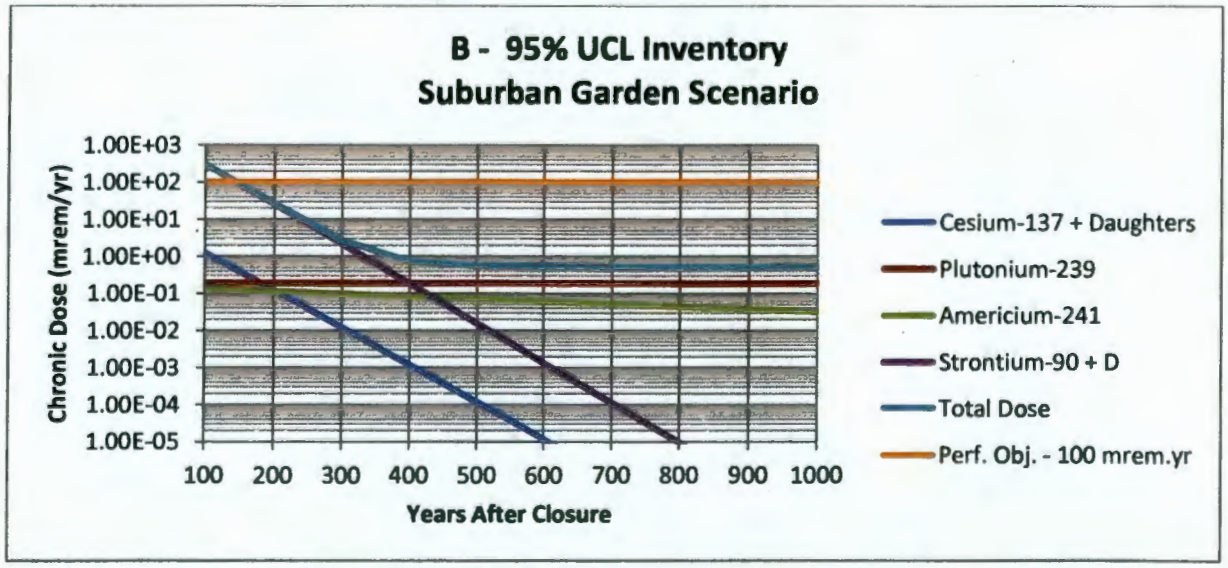
B – 95% Upper Confidence Level Inventory										
	Years After Site Closure (January 1, 2032)									
Nuclide	100	200	300	400	500	600	700	800	900	1,000
Antimony-125	1.26E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tin-126	4.34E-04	4.34E-04	4.34E-04	4.34E-04	4.34E-04	4.34E-04	4.33E-04	4.33E-04	4.33E-04	4.33E-04
Iodine-129	3.07E-05	3.07E-05	3.07E-05	3.07E-05	3.07E-05	3.07E-05	3.07E-05	3.07E-05	3.07E-05	3.07E-05
Cesium-137 + Daughters	1.21E+00	1.20E-01	1.19E-02	1.18E-03	1.17E-04	1.16E-05	1.15E-06	1.14E-07	1.13E-08	1.12E-09
Barium-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon-14	3.15E-05	3.11E-05	3.07E-05	3.03E-05	3.00E-05	2.96E-05	2.93E-05	2.89E-05	2.86E-05	2.82E-05
Europium-152	1.11E-03	6.11E-06	3.37E-08	1.86E-10	1.03E-12	1.24E-14	6.80E-15	6.77E-15	6.77E-15	6.77E-15
Europium-154	2.82E-05	8.85E-09	2.78E-12	8.70E-16	2.73E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	4.35E-10	1.61E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-228 + D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-230	4.77E-03	7.03E-03	9.21E-03	1.13E-02	1.33E-02	1.52E-02	1.70E-02	1.88E-02	2.04E-02	2.20E-02
Protactinium-231	1.51E-01	1.52E-01	1.52E-01	1.51E-01	1.51E-01	1.51E-01	1.50E-01	1.50E-01	1.50E-01	1.49E-01
Thorium-232	1.70E-05	1.70E-05	1.70E-05	1.70E-05	1.70E-05	1.70E-05	1.70E-05	1.70E-05	1.70E-05	1.70E-05
Uranium-233	2.77E-02	2.99E-02	3.20E-02	3.42E-02	3.63E-02	3.84E-02	4.05E-02	4.25E-02	4.46E-02	4.66E-02
Uranium-234	5.81E-04	5.83E-04	5.85E-04	5.88E-04	5.91E-04	5.95E-04	6.00E-04	6.05E-04	6.10E-04	6.16E-04
Uranium-235 + D	5.68E-05	5.97E-05	6.27E-05	6.56E-05	6.85E-05	7.15E-05	7.44E-05	7.73E-05	8.02E-05	8.31E-05
Uranium-236	1.07E-05	1.07E-05	1.07E-05	1.07E-05	1.07E-05	1.07E-05	1.07E-05	1.07E-05	1.07E-05	1.07E-05
Neptunium-237 + D	2.13E-02	2.13E-02	2.13E-02	2.13E-02	2.13E-02	2.13E-02	2.13E-02	2.13E-02	2.13E-02	2.13E-02

Table D-7. Suburban Garden Doses (mrem/y) for Single-Shell Tank 241-C-109 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2007) and Pathways. (4 sheets)

B – 95% Upper Confidence Level Inventory (continued)										
	Years After Site Closure (January 1, 2032)									
Nuclide	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1,000**
Plutonium-238	2.46E-03	1.12E-03	5.08E-04	2.31E-04	1.05E-04	4.79E-05	2.20E-05	1.03E-05	4.98E-06	2.57E-06
Uranium-238 + D	9.28E-04	9.28E-04	9.29E-04	9.29E-04	9.29E-04	9.29E-04	9.30E-04	9.30E-04	9.30E-04	9.31E-04
Plutonium-239	1.89E-01	1.88E-01	1.88E-01	1.87E-01	1.86E-01	1.86E-01	1.85E-01	1.85E-01	1.84E-01	1.84E-01
Plutonium-240	2.03E-02	2.01E-02	1.99E-02	1.97E-02	1.95E-02	1.93E-02	1.91E-02	1.89E-02	1.87E-02	1.85E-02
Americium-241	1.30E-01	1.11E-01	9.48E-02	8.08E-02	6.88E-02	5.87E-02	5.00E-02	4.26E-02	3.63E-02	3.10E-02
Plutonium-241 + D	9.78E-03	8.34E-03	7.11E-03	6.06E-03	5.16E-03	4.40E-03	3.75E-03	3.20E-03	2.73E-03	2.32E-03
Curium-242	6.96E-07	3.16E-07	1.43E-07	6.52E-08	2.96E-08	1.35E-08	6.22E-09	2.90E-09	1.40E-09	7.17E-10
Plutonium-242	1.24E-04	1.24E-04	1.24E-04	1.24E-04	1.24E-04	1.24E-04	1.24E-04	1.24E-04	1.24E-04	1.24E-04
Curium-243	1.16E-06	1.35E-07	4.50E-08	3.70E-08	3.62E-08	3.60E-08	3.59E-08	3.58E-08	3.57E-08	3.56E-08
Curium-244	4.80E-06	1.83E-06	1.75E-06	1.73E-06	1.71E-06	1.69E-06	1.67E-06	1.66E-06	1.64E-06	1.62E-06
Tritium	1.25E-09	4.51E-12	1.63E-14	5.91E-17	2.14E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cobalt-60	5.06E-08	9.85E-14	1.92E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel-63	3.43E-04	1.72E-04	8.59E-05	4.30E-05	2.15E-05	1.08E-05	5.38E-06	2.69E-06	1.35E-06	6.74E-07
Selenium-79	3.00E-05	3.00E-05	3.00E-05	3.00E-05	3.00E-05	3.00E-05	3.00E-05	3.00E-05	3.00E-05	3.00E-05
Strontium-90 + D	2.94E+02	2.50E+01	2.13E+00	1.82E-01	1.55E-02	1.32E-03	1.13E-04	9.59E-06	8.18E-07	6.97E-08
Yttrium-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Technetium-99	2.49E-03	2.49E-03	2.49E-03	2.49E-03	2.49E-03	2.49E-03	2.49E-03	2.49E-03	2.49E-03	2.48E-03
Total Dose	**2.95E+02**	**2.57E+01**	**2.67E+00**	**7.00E-01**	**5.22E-01**	**5.00E-01**	**4.92E-01**	**4.87E-01**	**4.83E-01**	**4.80E-01**

Figure D-3. Comparison of Doses from Suburban Gardener Scenario with Performance Objective for Chronic Exposure for Key Analytes within A) Average Inventory and B) 95% Upper Confidence Level Inventory Estimated for Residual Wastes in Single-Shell Tank 241-C-109.





UCL = upper confidence level

Table D-8. Commercial Farm Doses (mrem/y) for Single-Shell Tank 241-C-109 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

A – Average Inventory										
	Years After Site Closure (January 1, 2032)									
Nuclide	100	200	300	400	500	600	700	800	900	1,000
Antimony-125	1.64E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tin-126	5.71E-07	5.71E-07	5.71E-07	5.71E-07	5.71E-07	5.71E-07	5.70E-07	5.70E-07	5.70E-07	5.70E-07
Iodine-129	9.49E-10	9.49E-10	9.49E-10	9.49E-10	9.49E-10	9.49E-10	9.49E-10	9.49E-10	9.49E-10	9.49E-10
Cesium-137 + Daughters	1.55E-03	1.53E-04	1.52E-05	1.51E-06	1.50E-07	1.48E-08	1.47E-09	1.46E-10	1.45E-11	1.44E-12
Barium-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon-14	2.89E-11	2.86E-11	2.82E-11	2.79E-11	2.76E-11	2.72E-11	2.69E-11	2.66E-11	2.63E-11	2.59E-11
Europium-152	1.46E-06	8.08E-09	4.46E-11	2.46E-13	1.36E-15	1.31E-17	5.61E-18	5.57E-18	5.57E-18	5.57E-18
Europium-154	3.73E-08	1.17E-11	3.67E-15	1.15E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	5.63E-13	2.08E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-228 + D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-230	2.65E-06	3.35E-06	4.03E-06	4.67E-06	5.29E-06	5.88E-06	6.44E-06	6.98E-06	7.50E-06	7.99E-06
Protactinium-231	6.73E-05	6.79E-05	6.78E-05	6.76E-05	6.75E-05	6.73E-05	6.72E-05	6.71E-05	6.69E-05	6.68E-05
Thorium-232	3.28E-08	3.28E-08	3.28E-08	3.28E-08	3.28E-08	3.28E-08	3.28E-08	3.28E-08	3.28E-08	3.28E-08
Uranium-233	4.13E-06	5.87E-06	7.60E-06	9.30E-06	1.10E-05	1.27E-05	1.43E-05	1.60E-05	1.76E-05	1.92E-05
Uranium-234	4.53E-08	4.62E-08	4.72E-08	4.85E-08	4.99E-08	5.15E-08	5.33E-08	5.53E-08	5.74E-08	5.96E-08
Uranium-235 + D	5.56E-08	5.83E-08	6.10E-08	6.36E-08	6.63E-08	6.89E-08	7.16E-08	7.42E-08	7.68E-08	7.94E-08
Uranium-236	1.35E-09	1.35E-09	1.35E-09	1.35E-09	1.35E-09	1.35E-09	1.35E-09	1.35E-09	1.35E-09	1.35E-09
Neptunium-237 + D	3.07E-06	3.07E-06	3.07E-06	3.07E-06	3.07E-06	3.07E-06	3.07E-06	3.07E-06	3.07E-06	3.07E-06
Plutonium-238	2.31E-06	1.05E-06	4.76E-07	2.16E-07	9.80E-08	4.45E-08	2.02E-08	9.25E-09	4.26E-09	2.00E-09

Table D-8. Commercial Farm Doses (mrem/y) for Single-Shell Tank 241-C-109 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

A – Average Inventory (continued)										
	Years After Site Closure (January 1, 2032)									
Nuclide	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1,000**
Uranium-238 + D	3.08E-07	3.08E-07	3.08E-07	3.08E-07	3.08E-07	3.08E-07	3.08E-07	3.08E-07	3.08E-07	3.08E-07
Plutonium-239	1.59E-04	1.59E-04	1.59E-04	1.58E-04	1.58E-04	1.57E-04	1.57E-04	1.56E-04	1.56E-04	1.55E-04
Plutonium-240	1.72E-05	1.70E-05	1.68E-05	1.66E-05	1.65E-05	1.63E-05	1.61E-05	1.59E-05	1.58E-05	1.56E-05
Americium-241	1.29E-04	1.10E-04	9.37E-05	7.99E-05	6.80E-05	5.80E-05	4.94E-05	4.21E-05	3.59E-05	3.06E-05
Plutonium-241 + D	1.06E-05	9.08E-06	7.73E-06	6.59E-06	5.61E-06	4.78E-06	4.08E-06	3.47E-06	2.96E-06	2.52E-06
Curium-242	2.96E-10	1.34E-10	6.09E-11	2.76E-11	1.25E-11	5.69E-12	2.59E-12	1.18E-12	5.42E-13	2.52E-13
Plutonium-242	5.26E-08	5.26E-08	5.26E-08	5.26E-08	5.26E-08	5.26E-08	5.26E-08	5.26E-08	5.26E-08	5.25E-08
Curium-243	5.98E-10	6.66E-11	1.99E-11	1.58E-11	1.54E-11	1.53E-11	1.52E-11	1.52E-11	1.52E-11	1.51E-11
Curium-244	2.06E-09	7.76E-10	7.40E-10	7.32E-10	7.24E-10	7.16E-10	7.09E-10	7.01E-10	6.94E-10	6.87E-10
Tritium	1.67E-12	6.03E-15	2.18E-17	7.90E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cobalt-60	6.41E-11	1.25E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel-63	8.80E-09	4.40E-09	2.20E-09	1.10E-09	5.52E-10	2.76E-10	1.38E-10	6.91E-11	3.46E-11	1.73E-11
Selenium-79	6.74E-10	6.74E-10	6.74E-10	6.74E-10	6.74E-10	6.74E-10	6.74E-10	6.74E-10	6.74E-10	6.74E-10
Strontium-90 + D	1.33E-03	1.13E-04	9.65E-06	8.22E-07	7.01E-08	5.97E-09	5.09E-10	4.34E-11	3.70E-12	3.15E-13
Yttrium-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Technetium-99	6.46E-10	6.45E-10	6.45E-10	6.45E-10	6.45E-10	6.45E-10	6.44E-10	6.44E-10	6.44E-10	6.44E-10
Total Dose	**3.27E-03**	**6.44E-04**	**3.86E-04**	**3.49E-04**	**3.36E-04**	**3.26E-04**	**3.18E-04**	**3.12E-04**	**3.07E-04**	**3.02E-04**

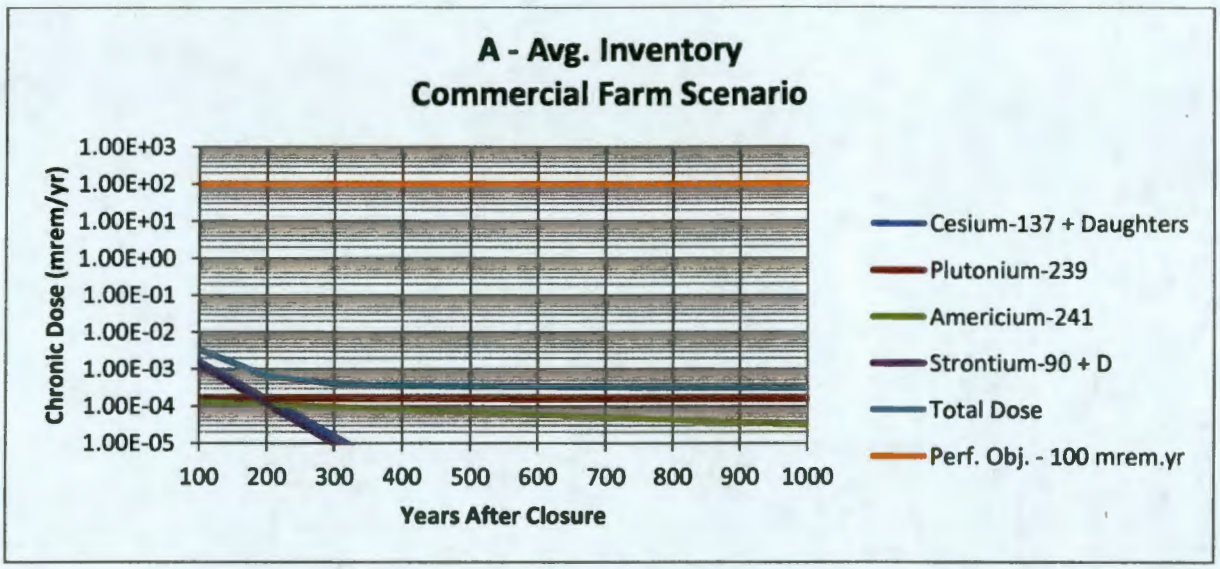
Table D-8. Commercial Farm Doses (mrem/y) for Single-Shell Tank 241-C-109 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

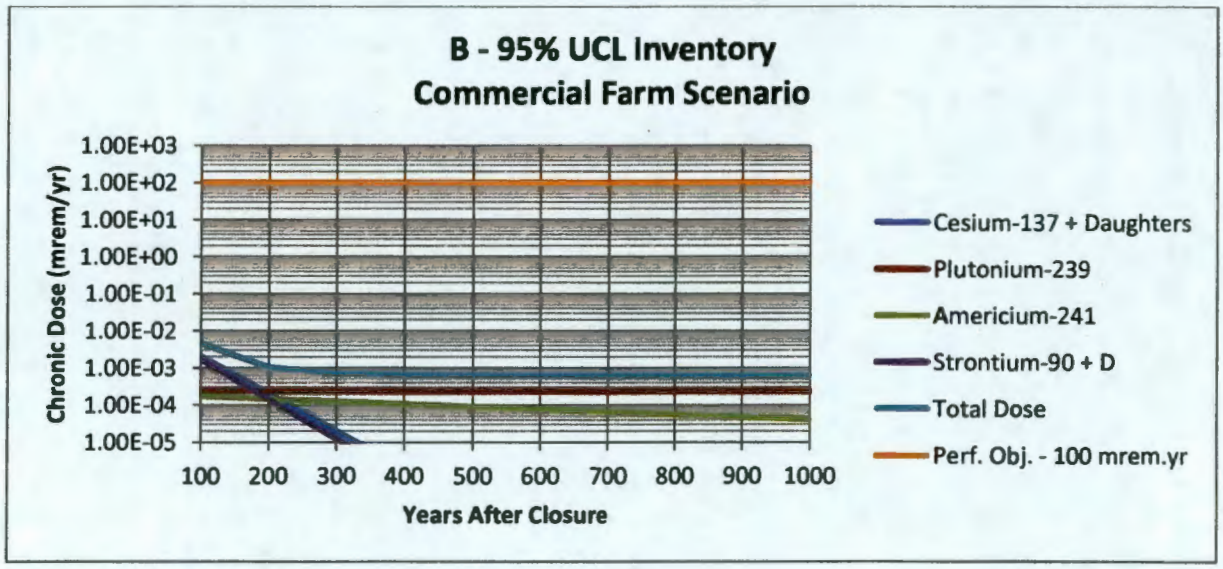
B – 95% Upper Confidence Level Inventory										
	Years After Site Closure (January 1, 2032)									
Nuclide	100	200	300	400	500	600	700	800	900	1,000
Antimony-125	4.93E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Tin-126	1.71E-06	1.71E-06	1.71E-06	1.71E-06	1.71E-06	1.71E-06	1.71E-06	1.71E-06	1.71E-06	1.71E-06
Iodine-129	2.85E-09	2.85E-09	2.85E-09	2.85E-09	2.85E-09	2.85E-09	2.85E-09	2.85E-09	2.85E-09	2.85E-09
Cesium-137 + Daughters	1.99E-03	1.98E-04	1.96E-05	1.95E-06	1.93E-07	1.92E-08	1.90E-09	1.89E-10	1.87E-11	1.86E-12
Barium-137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon-14	8.69E-11	8.58E-11	8.48E-11	8.38E-11	8.28E-11	8.18E-11	8.08E-11	7.98E-11	7.89E-11	7.79E-11
Europium-152	4.39E-06	2.42E-08	1.34E-10	7.38E-13	4.09E-15	3.92E-17	1.68E-17	1.67E-17	1.67E-17	1.67E-17
Europium-154	1.12E-07	3.51E-11	1.10E-14	3.45E-18	1.08E-21	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	1.69E-12	6.24E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-228 + D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Thorium-230	7.95E-06	1.01E-05	1.21E-05	1.40E-05	1.59E-05	1.76E-05	1.93E-05	2.09E-05	2.25E-05	2.40E-05
Protactinium-231	2.02E-04	2.04E-04	2.03E-04	2.03E-04	2.02E-04	2.02E-04	2.02E-04	2.01E-04	2.01E-04	2.00E-04
Thorium-232	4.37E-08	4.37E-08	4.37E-08	4.37E-08	4.37E-08	4.37E-08	4.37E-08	4.37E-08	4.37E-08	4.37E-08
Uranium-233	1.24E-05	1.76E-05	2.28E-05	2.79E-05	3.30E-05	3.80E-05	4.29E-05	4.79E-05	5.27E-05	5.75E-05
Uranium-234	1.36E-07	1.39E-07	1.42E-07	1.46E-07	1.50E-07	1.55E-07	1.60E-07	1.66E-07	1.72E-07	1.79E-07
Uranium-235 + D	8.24E-08	8.64E-08	9.03E-08	9.42E-08	9.82E-08	1.02E-07	1.06E-07	1.10E-07	1.14E-07	1.18E-07
Uranium-236	2.47E-09	2.47E-09	2.47E-09	2.47E-09	2.47E-09	2.47E-09	2.47E-09	2.47E-09	2.47E-09	2.47E-09
Neptunium-237 + D	9.22E-06	9.22E-06	9.22E-06	9.22E-06	9.22E-06	9.22E-06	9.22E-06	9.22E-06	9.22E-06	9.22E-06
Plutonium-238	3.14E-06	1.43E-06	6.47E-07	2.94E-07	1.33E-07	6.05E-08	2.75E-08	1.26E-08	5.79E-09	2.72E-09

Table D-8. Commercial Farm Doses (mrem/y) for Single-Shell Tank 241-C-109 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

B – 95% Upper Confidence Level Inventory (continued)										
	Years After Site Closure (January 1, 2032)									
Nuclide	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1,000**
Uranium-238 + D	4.56E-07	4.56E-07	4.56E-07	4.56E-07	4.56E-07	4.57E-07	4.57E-07	4.57E-07	4.57E-07	4.57E-07
Plutonium-239	2.40E-04	2.39E-04	2.38E-04	2.38E-04	2.37E-04	2.36E-04	2.35E-04	2.35E-04	2.34E-04	2.33E-04
Plutonium-240	2.58E-05	2.55E-05	2.53E-05	2.50E-05	2.47E-05	2.45E-05	2.42E-05	2.40E-05	2.37E-05	2.35E-05
Americium-241	1.69E-04	1.44E-04	1.22E-04	1.04E-04	8.89E-05	7.58E-05	6.46E-05	5.50E-05	4.69E-05	3.99E-05
Plutonium-241 + D	1.26E-05	1.08E-05	9.19E-06	7.83E-06	6.67E-06	5.68E-06	4.84E-06	4.13E-06	3.52E-06	3.00E-06
Curium-242	8.88E-10	4.03E-10	1.83E-10	8.29E-11	3.76E-11	1.71E-11	7.78E-12	3.55E-12	1.63E-12	7.58E-13
Plutonium-242	1.58E-07	1.58E-07	1.58E-07	1.58E-07	1.58E-07	1.58E-07	1.58E-07	1.58E-07	1.58E-07	1.58E-07
Curium-243	1.79E-09	2.00E-10	5.96E-11	4.72E-11	4.60E-11	4.58E-11	4.57E-11	4.55E-11	4.54E-11	4.53E-11
Curium-244	6.17E-09	2.33E-09	2.22E-09	2.20E-09	2.17E-09	2.15E-09	2.13E-09	2.10E-09	2.08E-09	2.06E-09
Tritium	4.99E-12	1.81E-14	6.54E-17	2.37E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cobalt-60	1.92E-10	3.74E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel-63	1.08E-08	5.40E-09	2.70E-09	1.35E-09	6.76E-10	3.38E-10	1.69E-10	8.47E-11	4.24E-11	2.12E-11
Selenium-79	2.02E-09	2.02E-09	2.02E-09	2.02E-09	2.02E-09	2.02E-09	2.02E-09	2.02E-09	2.02E-09	2.02E-09
Strontium-90 + D	1.71E-03	1.46E-04	1.24E-05	1.06E-06	9.01E-08	7.68E-09	6.55E-10	5.58E-11	4.75E-12	4.05E-13
Yttrium-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Technetium-99	8.11E-10	8.11E-10	8.11E-10	8.11E-10	8.10E-10	8.10E-10	8.10E-10	8.09E-10	8.09E-10	8.09E-10
Total Dose	**4.39E-03**	**1.01E-03**	**6.78E-04**	**6.35E-04**	**6.21E-04**	**6.12E-04**	**6.05E-04**	**6.00E-04**	**5.96E-04**	**5.94E-04**

Figure D-4. Comparison of Doses from Commercial Farm Scenario with Performance Objective for Chronic Exposure for Key Analytes within A) Average Inventory and B) 95% Upper Confidence Level Inventory Estimated for Residual wastes in Single-Shell Tank 241-C-109.





UCL = upper confidence level

Table D-9. Average and 95% Upper Confidence Levels for Waste Residuals within Tank 241-C-109, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (6 sheets)

Analyte Name	Average Concentration (mg/kg)[a]	95% Upper Confidence Level Concentration (mg/kg)[b]	Soil Cleanup Level (mg/kg) – Direct Contact Method B	Soil Cleanup Level (mg/kg) – Direct Contact Method C	Soil Concentrations (mg/kg) – Protective of Groundwater	Above Detection Limits
2-Propanone (Acetone)	1.01E-01	1.71E-01	7.20E+04	3.15E+06	2.89E+01	Yes
Aluminum	1.62E+05	2.14E+05	8.00E+04	3.50E+06	4.80E+05	Yes
Americium-241	2.86E-02	3.57E-02	--	--	--	Yes
Ammonia	2.81E+00	3.37E+00	--	--	--	Yes
Arsenic*	7.72E+00	1.03E+01	6.67E-01	8.75E+01	3.41E-02	Yes
Barium*	9.85E+00	1.37E+01	1.60E+04	7.00E+05	1.65E+03	Yes
Barium-137m*	4.05E+00	4.92E+00	--	--	--	Yes
Bismuth	1.49E+02	1.78E+02	--	--	--	Yes
Calcium	1.18E+03	1.66E+03	--	--	--	Yes
Cerium	3.71E+02	4.31E+02	--	--	--	Yes
Cesium-137 + Daughters	4.29E+00	5.27E+00	--	--	--	Yes
Chromium, Total*	1.33E+01	1.79E+01	1.20E+05	5.25E+06	2.00E+03	Yes
Copper	5.50E+01	8.08E+01	3.20E+03	1.40E+05	2.84E+02	Yes
Cyanide*	2.97E+01	4.17E+01	4.80E+01	2.10E+03	9.70E-01	Yes
Fluoride	7.32E+03	8.47E+03	4.80E+03	2.10E+05	2.88E+03	Yes
Iron	7.02E+03	1.03E+04	5.60E+04	2.45E+06	5.64E+03	Yes
Lanthanum	9.10E+00	1.31E+01	--	--	--	Yes
Lead*	4.08E+02	4.34E+02	--	1.00E+03	3.00E+03	Yes
Lithium	1.50E+00	1.85E+00	1.60E+02	7.00E+03	1.92E+02	Yes

Table D-9. Average and 95% Upper Confidence Levels for Waste Residuals within Tank 241-C-109, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (6 sheets)

Analyte Name	Average Concentration (mg/kg)[a]	95% Upper Confidence Level Concentration (mg/kg)[b]	Soil Cleanup Level (mg/kg) – Direct Contact Method B	Soil Cleanup Level (mg/kg) – Direct Contact Method C	Soil Concentrations (mg/kg) – Protective of Groundwater	Above Detection Limits
Magnesium	9.74E+01	1.30E+02	--	--	--	Yes
Manganese	4.26E+01	6.91E+01	1.12E+04	4.90E+05	5.01E+02	Yes
Mercury*	1.39E+00	2.24E+00	2.40E+01	1.05E+03	2.09E+00	Yes
Molybdenum	1.88E+00	2.84E+00	4.00E+02	1.75E+04	3.23E+01	Yes
Neodymium	1.15E+01	1.59E+01	--	--	--	Yes
Nickel*	1.01E+03	1.45E+03	1.60E+03	7.00E+04	1.30E+02	Yes
Nickel-63*	7.20E-02	8.25E-02	--	--	--	Yes
Nitrate[c]	3.42E+02	4.16E+02	5.68E+05	2.49E+07	1.80E+02	Yes
Nitrite[d]	2.89E+02	2.95E+02	2.40E+04	1.05E+06	1.32E+01	Yes
Phosphate	7.43E+04	1.09E+05	--	--	--	Yes
Plutonium-238	1.30E-03	1.70E-03	--	--	--	Yes
Plutonium-239	3.03E-02	4.44E-02	--	--	--	Yes
Plutonium-240	3.30E-03	4.83E-03	--	--	--	Yes
Plutonium-241 + D	6.86E-02	7.35E-02	--	--	--	Yes
Rhodium	9.06E+00	1.06E+01	--	--	--	Yes
Samarium	3.52E+01	4.22E+01	--	--	--	Yes
Silicon	2.11E+03	3.80E+03	--	--	--	Yes
Silver*	6.31E+00	1.42E+01	4.00E+02	1.75E+04	1.36E+01	Yes
Sodium	9.85E+04	1.40E+05	--	--	--	Yes

Table D-9. Average and 95% Upper Confidence Levels for Waste Residuals within Tank 241-C-109, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (6 sheets)

Analyte Name	Average Concentration (mg/kg)[a]	95% Upper Confidence Level Concentration (mg/kg)[b]	Soil Cleanup Level (mg/kg) – Direct Contact Method B	Soil Cleanup Level (mg/kg) – Direct Contact Method C	Soil Concentrations (mg/kg) – Protective of Groundwater	Above Detection Limits
Strontium	3.71E+01	5.54E+01	4.80E+04	2.10E+06	6.76E+03	Yes
Strontium-90 + D	2.35E+02	2.87E+02	--	--	--	Yes
Sulfate	2.16E+02	2.60E+02	--	--	1.00E+03	Yes
Technetium-99	6.63E-04	7.85E-04	--	--	--	Yes
Thallium*	6.68E+00	7.72E+00	--	--	2.28E-01	Yes
Thorium	6.81E+00	8.71E+00	--	--	--	Yes
Thorium-228 + D	2.65E-05	3.27E-05	--	--	--	Yes
Thorium-232	7.50E-07	9.59E-07	--	--	--	Yes
Titanium	4.49E+00	6.14E+00	--	--	--	Yes
Uranium	2.16E+03	3.12E+03	2.40E+02	1.05E+04	2.70E+02	Yes
Uranium-235 + D	3.03E-05	4.36E-05	--	--	--	Yes
Uranium-236	7.26E-06	1.30E-05	--	--	--	Yes
Uranium-238 + D	7.21E-04	1.04E-03	--	--	--	Yes
Yttrium	2.30E+00	2.67E+00	--	--	--	Yes
Yttrium-90	2.35E+02	2.87E+02	--	--	--	Yes
Zinc	5.31E+01	5.75E+01	2.40E+04	1.05E+06	5.97E+03	Yes
1, 1, 2-Trichloroethylene	1.15E-03	3.40E-03	2.17E+01	1.75E+03	6.29E-03	No
2-Butanone(MEK)	1.87E-02	5.54E-02	4.80E+04	2.10E+06	1.97E+01	No
4-Methyl-2-pentanone (MIBK)	1.62E-02	4.80E-02	6.40E+03	2.80E+05	2.73E+00	No

Table D-9. Average and 95% Upper Confidence Levels for Waste Residuals within Tank 241-C-109, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (6 sheets)

Analyte Name	Average Concentration (mg/kg)[a]	95% Upper Confidence Level Concentration (mg/kg)[b]	Soil Cleanup Level (mg/kg) – Direct Contact Method B	Soil Cleanup Level (mg/kg) – Direct Contact Method C	Soil Concentrations (mg/kg) – Protective of Groundwater	Above Detection Limits
Acetate	1.13E+02	3.34E+02	--	--	--	No
Antimony*	5.93E+00	1.76E+01	3.20E+01	1.40E+03	5.42E+00	No
Antimony-125*	4.45E-01	1.32E+00	--	--	--	No
Beryllium*	9.89E-01	2.93E+00	1.60E+02	7.00E+03	6.32E+01	No
Boron	9.89E-01	2.93E+00	1.60E+04	7.00E+05	2.05E+02	No
Bromide	6.04E+01	1.79E+02	--	--	--	No
Cadmium*	9.89E-01	2.93E+00	8.00E+01	3.50E+03	6.90E-01	No
Carbon-14	5.79E-05	1.71E-04	--	--	--	No
Chloride	6.44E+01	1.91E+02	--	--	1.00E+03	No
Cobalt	9.89E-01	2.93E+00	2.40E+01	1.05E+03	4.34E+00	No
Cobalt-60	6.27E-02	1.86E-01	--	--	--	No
Curium-242	6.50E-05	1.92E-04	--	--	--	No
Curium-243	4.95E-06	1.47E-05	--	--	--	No
Curium-244	1.05E-04	3.11E-04	--	--	--	No
Europium	9.89E-01	2.93E+00	--	--	--	No
Europium-152	1.52E-01	4.50E-01	--	--	--	No
Europium-154	1.29E-01	3.82E-01	--	--	--	No
Europium-155	3.27E-01	9.68E-01	--	--	--	No
Formate+A2	1.69E+02	5.00E+02	--	--	--	No

Table D-9. Average and 95% Upper Confidence Levels for Waste Residuals within Tank 241-C-109, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (6 sheets)

Analyte Name	Average Concentration (mg/kg)[a]	95% Upper Confidence Level Concentration (mg/kg)[b]	Soil Cleanup Level (mg/kg) – Direct Contact Method B	Soil Cleanup Level (mg/kg) – Direct Contact Method C	Soil Concentrations (mg/kg) – Protective of Groundwater	Above Detection Limits
Glycolate $C_2H_3O_3$	6.44E+01	1.91E+02	--	--	--	No
Iodine-129	1.20E-05	3.55E-05	--	--	--	No
m-Xylene	1.59E-03	4.71E-03	1.60E+04	7.00E+05	1.35E+01	No
Neptunium-237 + D	6.97E-04	2.06E-03	--	--	--	No
Niobium	1.58E+02	4.68E+02	--	--	--	No
Oxalate	1.05E+02	3.11E+02	--	--	--	No
o-Xylene	8.74E-04	2.59E-03	1.60E+04	7.00E+05	1.47E+01	No
Palladium	8.90E+00	2.63E+01	--	--	--	No
Plutonium-242	2.09E-05	6.19E-05	--	--	--	No
Polychlorinated Biphenyls*	1.39E-02	4.11E-02	5.00E-01	6.56E+01	--	No
Potassium	1.98E+01	5.86E+01	--	--	--	No
Praseodymium	2.11E+02	6.25E+02	--	--	--	No
Protactinium-231	3.27E-03	9.68E-03	--	--	--	No
Rubidium	2.97E+01	8.79E+01	--	--	--	No
Ruthenium	3.95E+00	1.17E+01	--	--	--	No
Selenium*	5.93E+00	1.76E+01	4.00E+02	1.75E+04	5.20E+00	No
Selenium-79*	3.39E-04	1.00E-03	--	--	--	No
Tantalum	2.63E+02	7.78E+02	--	--	--	No
Tellurium	4.94E+00	1.46E+01	--	--	--	No

Table D-9. Average and 95% Upper Confidence Levels for Waste Residuals within Tank 241-C-109, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (6 sheets)

Analyte Name	Average Concentration (mg/kg)[a]	95% Upper Confidence Level Concentration (mg/kg)[b]	Soil Cleanup Level (mg/kg) – Direct Contact Method B	Soil Cleanup Level (mg/kg) – Direct Contact Method C	Soil Concentrations (mg/kg) – Protective of Groundwater	Above Detection Limits
Thorium-230	1.43E-03	4.23E-03	--	--	--	No
Tin	2.97E+00	8.79E+00	4.80E+04	2.10E+06	4.80E+04	No
Tin-126	5.03E-05	1.49E-04	--	--	--	No
Tributyl phosphate	6.55E-01	1.94E+00	1.11E+02	1.46E+04	4.96E-01	No
Tritium	5.21E-04	1.54E-03	--	--	--	No
Tungsten	6.47E+00	1.92E+01	--	--	--	No
Uranium-233	1.91E-02	5.65E-02	--	--	--	No
Uranium-234	4.53E-04	1.34E-03	--	--	--	No
Vanadium	9.89E-01	2.93E+00	4.00E+02	1.75E+04	1.60E+03	No
Xylenes	1.93E-03	5.71E-03	1.60E+04	7.00E+05	1.46E+01	No

[a] Mean Concentrations taken from Table A-1, Appendix A of RPP-RPT-55307, *Tank 241-C-104 Residual Waste Inventory Estimates for Component Closure Risk Assessment.*

[b] 95% Upper Confidence Level Concentration = Average Concentration + (1.96 × Average Concentration × Relative Standard Deviation). Average Concentrations and Relative Standard Deviation taken from Table A-1, Appendix A of RPP-RPT-55307.

[c] As nitrate, not nitrogen in nitrate; to convert to nitrogen in nitrate divide this number by 4.43.

[d] As nitrite, not nitrogen in nitrite; to convert to nitrogen in nitrite divide this number by 3.29.

* Dangerous waste constituent per WAC 173-303-9905, "Dangerous Waste Constituents List." Total Cr is assumed to be Chromium(III), insoluble salts.

-- = Value is not available

Table D-10. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for Average Concentrations of Selected Hazardous Constituents in 241-C-109 Tank Residual Wastes. (4 sheets)

Analyte	Average Concentration (mg/kg)[a]	Ratio of Average Concentrations in Tank 241-C-109 Residual Wastes to Soil Cleanup Standards			
		Soil Direct Contact (Method B)	Soil Direct Contact (Method C)	Soil Concentrations Protective of Groundwater	Above Detection Limits
2-Propanone (Acetone)	1.01E-01	1.40E-06	3.21E-08	3.49E-03	Yes
Aluminum	1.62E+05	2.03E+00	4.63E-02	3.37E-01	Yes
Ammonia	2.81E+00	--	--	--	Yes
Arsenic*	7.72E+00	1.16E+01	8.82E-02	2.27E+02	Yes
Barium*	9.85E+00	6.16E-04	1.41E-05	5.98E-03	Yes
Bismuth	1.49E+02	--	--	--	Yes
Calcium	1.18E+03	--	--	--	Yes
Cerium	3.71E+02	--	--	--	Yes
Chromium, Total*	1.33E+01	1.11E-04	2.53E-06	6.65E-03	Yes
Copper	5.50E+01	1.72E-02	3.93E-04	1.94E-01	Yes
Cyanide*	2.97E+01	6.19E-01	1.41E-02	3.06E+01	Yes
Fluoride	7.32E+03	1.53E+00	3.49E-02	2.54E+00	Yes
Iron	7.02E+03	1.25E-01	2.87E-03	1.24E+00	Yes
Lanthanum	9.10E+00	--	--	--	Yes
Lead*	4.08E+02	--	4.08E-01	1.36E-01	Yes
Lithium	1.50E+00	9.38E-03	2.14E-04	7.81E-03	Yes
Magnesium	9.74E+01	--	--	--	Yes
Manganese	4.26E+01	3.80E-03	8.69E-05	8.51E-02	Yes
Mercury*	1.39E+00	5.79E-02	1.32E-03	6.66E-01	Yes

Table D-10. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for Average Concentrations of Selected Hazardous Constituents in 241-C-109 Tank Residual Wastes. (4 sheets)

Analyte	Average Concentration (mg/kg)[a]	Ratio of Average Concentrations in Tank 241-C-109 Residual Wastes to Soil Cleanup Standards			
		Soil Direct Contact (Method B)	Soil Direct Contact (Method C)	Soil Concentrations Protective of Groundwater	Above Detection Limits
Molybdenum	1.88E+00	4.70E-03	1.07E-04	5.82E-02	Yes
Neodymium	1.15E+01	--	--	--	Yes
Nickel*	1.01E+03	6.31E-01	1.44E-02	7.75E+00	Yes
Nitrate[b]	3.42E+02	6.02E-04	1.38E-05	1.90E+00	Yes
Nitrite[c]	2.89E+02	1.20E-02	2.75E-04	2.19E+01	Yes
Phosphate	7.43E+04	--	--	--	Yes
Rhodium	9.06E+00	--	--	--	Yes
Samarium	3.52E+01	--	--	--	Yes
Silicon	2.11E+03	--	--	--	Yes
Silver*	6.31E+00	1.58E-02	3.61E-04	4.64E-01	Yes
Sodium	9.85E+04	--	--	--	Yes
Strontium	3.71E+01	7.73E-04	1.77E-05	5.49E-03	Yes
Sulfate	2.16E+02	--	--	2.16E-01	Yes
Thallium*	6.68E+00	--	--	2.93E+01	Yes
Thorium	6.81E+00	--	--	--	Yes
Titanium	4.49E+00	--	--	--	Yes
Uranium	2.16E+03	9.00E+00	2.06E-01	8.00E+00	Yes
Yttrium	2.30E+00	--	--	--	Yes
Zinc	5.31E+01	2.21E-03	5.06E-05	8.89E-03	Yes

Table D-10. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for Average Concentrations of Selected Hazardous Constituents in 241-C-109 Tank Residual Wastes. (4 sheets)

Analyte	Average Concentration (mg/kg)[a]	Ratio of Average Concentrations in Tank 241-C-109 Residual Wastes to Soil Cleanup Standards			
		Soil Direct Contact (Method B)	Soil Direct Contact (Method C)	Soil Concentrations Protective of Groundwater	Above Detection Limits
1, 1, 2-Trichloroethylene	1.15E-03	5.29E-05	6.57E-07	1.83E-01	No
2-Butanone(MEK)	1.87E-02	3.90E-07	8.90E-09	9.52E-04	No
4-Methyl-2-pentanone (MIBK)	1.62E-02	2.53E-06	5.79E-08	5.94E-03	No
Acetate	1.13E+02	--	--	--	No
Antimony*	5.93E+00	1.85E-01	4.24E-03	1.09E+00	No
Beryllium*	9.89E-01	6.18E-03	1.41E-04	1.56E-02	No
Boron	9.89E-01	6.18E-05	1.41E-06	4.83E-03	No
Bromide	6.04E+01	--	--	--	No
Cadmium*	9.89E-01	1.24E-02	2.83E-04	1.43E+00	No
Chloride	6.44E+01	--	--	6.44E-02	No
Cobalt	9.89E-01	4.12E-02	9.42E-04	2.28E-01	No
Europium	9.89E-01	--	--	--	No
Formate+A2	1.69E+02	--	--	--	No
Glycolate $C_2H_3O_3$	6.44E+01	--	--	--	No
m-Xylene	1.59E-03	9.94E-08	2.27E-09	1.18E-04	No
Niobium	1.58E+02	--	--	--	No
Oxalate	1.05E+02	--	--	--	No
o-Xylene	8.74E-04	5.46E-08	1.25E-09	5.94E-05	No
Palladium	8.90E+00	--	--	--	No

Table D-10. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for Average Concentrations of Selected Hazardous Constituents in 241-C-109 Tank Residual Wastes. (4 sheets)

Analyte	Average Concentration (mg/kg)[a]	Ratio of Average Concentrations in Tank 241-C-109 Residual Wastes to Soil Cleanup Standards			
		Soil Direct Contact (Method B)	Soil Direct Contact (Method C)	Soil Concentrations Protective of Groundwater	Above Detection Limits
Polychlorinated Biphenyls*	1.39E-02	2.78E-02	2.12E-04	--	No
Potassium	1.98E+01	--	--	--	No
Praseodymium	2.11E+02	--	--	--	No
Rubidium	2.97E+01	--	--	--	No
Ruthenium	3.95E+00	--	--	--	No
Selenium*	5.93E+00	1.48E-02	3.39E-04	1.14E+00	No
Tantalum	2.63E+02	--	--	--	No
Tellurium	4.94E+00	--	--	--	No
Tin	2.97E+00	6.19E-05	1.41E-06	6.18E-05	No
Tributyl phosphate	6.55E-01	5.90E-03	4.49E-05	1.32E+00	No
Tungsten	6.47E+00	--	--	--	No
Vanadium	9.89E-01	2.47E-03	5.65E-05	6.18E-04	No
Xylenes	1.93E-03	1.21E-07	2.76E-09	1.32E-04	No

[a] Mean Concentrations taken from Table A-1, Appendix A of RPP-RPT-55803, *Tank 241-C-109 Residual Waste Inventory Estimates for Component Closure Risk Assessment.*

[b] As nitrate, not nitrogen in nitrate; to convert to nitrogen in nitrate divide this number by 4.43.

[c] As nitrite, not nitrogen in nitrite; to convert to nitrogen in nitrite divide this number by 3.29.

* Dangerous waste constituent per WAC 173-303-9905, "Dangerous Waste Constituents List." Total Cr is assumed to be Chromium(III), insoluble salts.

-- = Value is not available

Table D-11. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for 95% Upper Confidence Level Concentrations of Selected Hazardous Constituents above Detection in 241-C-109 Tank Residual Wastes. (4 sheets)

Analyte	95% Upper Confidence Level Concentration (mg/kg)[a]	Ratio of 95% Upper Confidence Level Concentrations in Tank 241-C-109 Residual Wastes to Soil Cleanup Standards			
		Soil Direct Contact (Method B)	Soil Direct Contact (Method C)	Soil Concentrations Protective of Groundwater	Above Detection Limits
2-Propanone (Acetone)	1.71E-01	2.37E-06	5.42E-08	5.91E-03	Yes
Aluminum	2.14E+05	2.68E+00	6.12E-02	4.46E-01	Yes
Ammonia	3.37E+00	--	--	--	Yes
Arsenic*	1.03E+01	1.55E+01	1.18E-01	3.03E+02	Yes
Barium*	1.37E+01	8.55E-04	1.95E-05	8.30E-03	Yes
Bismuth	1.78E+02	--	--	--	Yes
Calcium	1.66E+03	--	--	--	Yes
Cerium	4.31E+02	--	--	--	Yes
Chromium, Total*	1.79E+01	1.49E-04	3.40E-06	8.93E-03	Yes
Copper	8.08E+01	2.52E-02	5.77E-04	2.84E-01	Yes
Cyanide*	4.17E+01	8.70E-01	1.99E-02	4.31E+01	Yes
Fluoride	8.47E+03	1.76E+00	4.03E-02	2.94E+00	Yes
Iron	1.03E+04	1.85E-01	4.22E-03	1.83E+00	Yes
Lanthanum	1.31E+01	--	--	--	Yes
Lead*	4.34E+02	--	4.34E-01	1.45E-01	Yes
Lithium	1.85E+00	1.16E-02	2.65E-04	9.64E-03	Yes
Magnesium	1.30E+02	--	--	--	Yes
Manganese	6.91E+01	6.17E-03	1.41E-04	1.38E-01	Yes
Mercury*	2.24E+00	9.34E-02	2.14E-03	1.07E+00	Yes
Molybdenum	2.84E+00	7.10E-03	1.62E-04	8.79E-02	Yes

Table D-11. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for 95% Upper Confidence Level Concentrations of Selected Hazardous Constituents above Detection in 241-C-109 Tank Residual Wastes. (4 sheets)

Analyte	95% Upper Confidence Level Concentration (mg/kg)[a]	Ratio of 95% Upper Confidence Level Concentrations in Tank 241-C-109 Residual Wastes to Soil Cleanup Standards			
		Soil Direct Contact (Method B)	Soil Direct Contact (Method C)	Soil Concentrations Protective of Groundwater	Above Detection Limits
Neodymium	1.59E+01	--	--	--	Yes
Nickel*	1.45E+03	9.07E-01	2.07E-02	1.11E+01	Yes
Nitrate[b]	4.16E+02	7.32E-04	1.67E-05	2.31E+00	Yes
Nitrite[c]	2.95E+02	1.23E-02	2.81E-04	2.23E+01	Yes
Phosphate	1.09E+05	--	--	--	Yes
Rhodium	1.06E+01	--	--	--	Yes
Samarium	4.22E+01	--	--	--	Yes
Silicon	3.80E+03	--	--	--	Yes
Silver*	1.42E+01	3.55E-02	8.11E-04	1.04E+00	Yes
Sodium	1.40E+05	--	--	--	Yes
Strontium	5.54E+01	1.15E-03	2.64E-05	8.20E-03	Yes
Sulfate	2.60E+02	--	--	2.60E-01	Yes
Thallium*	7.72E+00	--	--	3.39E+01	Yes
Thorium	8.71E+00	--	--	--	Yes
Titanium	6.14E+00	--	--	--	Yes
Uranium	3.12E+03	1.30E+01	2.97E-01	1.15E+01	Yes
Yttrium	2.67E+00	--	--	--	Yes
Zinc	5.75E+01	2.40E-03	5.48E-05	9.63E-03	Yes
1, 1, 2-Trichloroethylene	3.40E-03	1.57E-04	1.95E-06	5.41E-01	No
2-Butanone(MEK)	5.54E-02	1.15E-06	2.64E-08	2.82E-03	No

Table D-11. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for 95% Upper Confidence Level Concentrations of Selected Hazardous Constituents above Detection in 241-C-109 Tank Residual Wastes. (4 sheets)

Analyte	95% Upper Confidence Level Concentration (mg/kg)[a]	Ratio of 95% Upper Confidence Level Concentrations in Tank 241-C-109 Residual Wastes to Soil Cleanup Standards			
		Soil Direct Contact (Method B)	Soil Direct Contact (Method C)	Soil Concentrations Protective of Groundwater	Above Detection Limits
4-Methyl-2-pentanone (MIBK)	4.80E-02	7.49E-06	1.71E-07	1.76E-02	No
Acetate	3.34E+02	--	--	--	No
Antimony*	1.76E+01	5.49E-01	1.25E-02	3.24E+00	No
Beryllium*	2.93E+00	1.83E-02	4.18E-04	4.63E-02	No
Boron	2.93E+00	1.83E-04	4.18E-06	1.43E-02	No
Bromide	1.79E+02	--	--	--	No
Cadmium*	2.93E+00	3.66E-02	8.36E-04	4.24E+00	No
Chloride	1.91E+02	--	--	1.91E-01	No
Cobalt	2.93E+00	1.22E-01	2.79E-03	6.75E-01	No
Europium	2.93E+00	--	--	--	No
Formate+A2	5.00E+02	--	--	--	No
Glycolate $C_2H_3O_3$	1.91E+02	--	--	--	No
m-Xylene	4.71E-03	2.94E-07	6.72E-09	3.48E-04	No
Niobium	4.68E+02	--	--	--	No
Oxalate	3.11E+02	--	--	--	No
o-Xylene	2.59E-03	1.62E-07	3.70E-09	1.76E-04	No
Palladium	2.63E+01	--	--	--	No
Polychlorinated Biphenyls*	4.11E-02	8.23E-02	6.27E-04	--	No
Potassium	5.86E+01	--	--	--	No
Praseodymium	6.25E+02	--	--	--	No

Table D-11. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for 95% Upper Confidence Level Concentrations of Selected Hazardous Constituents above Detection in 241-C-109 Tank Residual Wastes. (4 sheets)

Analyte	95% Upper Confidence Level Concentration (mg/kg)[a]	Ratio of 95% Upper Confidence Level Concentrations in Tank 241-C-109 Residual Wastes to Soil Cleanup Standards			
		Soil Direct Contact (Method B)	Soil Direct Contact (Method C)	Soil Concentrations Protective of Groundwater	Above Detection Limits
Rubidium	8.79E+01	--	--	--	No
Ruthenium	1.17E+01	--	--	--	No
Selenium*	1.76E+01	4.39E-02	1.00E-03	3.38E+00	No
Tantalum	7.78E+02	--	--	--	No
Tellurium	1.46E+01	--	--	--	No
Tin	8.79E+00	1.83E-04	4.19E-06	1.83E-04	No
Tributyl phosphate	1.94E+00	1.74E-02	1.33E-04	3.91E+00	No
Tungsten	1.92E+01	--	--	--	No
Vanadium	2.93E+00	7.32E-03	1.67E-04	1.83E-03	No
Xylenes	5.71E-03	3.57E-07	8.16E-09	3.90E-04	No

[a] 95% Upper Confidence Level Concentration = Mean Concentration + (1.96 × Mean Concentration × Relative Standard Deviation). Mean Concentrations and Relative Standard Deviation provided in Table A-1, Appendix A of RPP-RPT-55803, *Tank 241-C-109 Residual Waste Inventory Estimates for Component Closure Risk Assessment.*

[b] As nitrate, not nitrogen in nitrate; to convert to nitrogen in nitrate divide this number by 4.43.

[c] As nitrite, not nitrogen in nitrite; to convert to nitrogen in nitrite divide this number by 3.29.

* Dangerous waste constituent per WAC 173-303-9905, "Dangerous Waste Constituents List." Total Cr is assumed to be Chromium(III), insoluble salts.

-- = Value is not available

Table D-12. Background Data for Selected Constituents for the Hanford Site. (3 sheets)

Analyte Name	Analyte Symbol	Analyte Class	Units	Lognormal 90th Percentile Background Value	Maximum Background Value	Source of Background Value
Cesium-137	Cs-137	RAD	pCi/g	1.1	1.6	DOE/RL-96-12, Rev. 0
Cobalt-60	Co-60	RAD	pCi/g	0.0084	0.039	DOE/RL-96-12, Rev. 0
Europium-154	Eu-154	RAD	pCi/g	0.033	0.079	DOE/RL-96-12, Rev. 0
Europium-155	Eu-155	RAD	pCi/g	0.054	0.1	DOE/RL-96-12, Rev. 0
Gross Beta	--	RAD	pCi/g	23	25	DOE/RL-96-12, Rev. 0
Plutonium-238	Pu-238	RAD	pCi/g	0.0038	0.019	DOE/RL-96-12, Rev. 0
Plutonium-239/240	Pu-239/240	RAD	pCi/g	0.025	0.033	DOE/RL-96-12, Rev. 0
Potassium-40	K-40	RAD	pCi/g	17	20	DOE/RL-96-12, Rev. 0
Radium-226	Ra-226	RAD	pCi/g	0.82	1.2	DOE/RL-96-12, Rev. 0
Strontium-90	Sr-90	RAD	pCi/g	0.18	0.37	DOE/RL-96-12, Rev. 0
Thorium-232	Th-232	RAD	pCi/g	1.3	1.6	DOE/RL-96-12, Rev. 0
Total beta radiostrontium	--	RAD	pCi/g	0.18	0.37	DOE/RL-96-12, Rev. 0
Uranium-233/234	U-233/234	RAD	pCi/g	1.1	1.5	DOE/RL-96-12, Rev. 0
Uranium-234	U-234	RAD	pCi/g	1.1	1.5	DOE/RL-96-12, Rev. 0
Uranium-235	U-235	RAD	pCi/g	0.11	0.39	DOE/RL-96-12, Rev. 0
Aluminum	Al	Metal	µg/kg	1.18E+07	28,800,000	DOE/RL-92-24, Vol. 1, Rev. 4
Antimony*	An	Metal	µg/kg	130	385	ECF-HANFORD-11-0038
Arsenic*	Ar	Metal	µg/kg	6,470	27,700	DOE/RL-92-24, Vol. 1, Rev. 4
Barium*	Ba	Metal	µg/kg	132,000	480,000	DOE/RL-92-24, Vol. 1, Rev. 4
Beryllium*	Be	Metal	µg/kg	1,510	10,000	DOE/RL-92-24, Vol. 1, Rev. 4
Boron	Bo	Metal	µg/kg	3,890	5,860	ECF-HANFORD-11-0038

Table D-12. Background Data for Selected Constituents for the Hanford Site. (3 sheets)

Analyte Name	Analyte Symbol	Analyte Class	Units	Lognormal 90th Percentile Background Value	Maximum Background Value	Source of Background Value
Cadmium*	Cd	Metal	µg/kg	563	2,900	ECF-HANFORD-11-0038
Calcium	Ca	Metal	µg/kg	1.72E+07	105,000,000	DOE/RL-92-24, Vol. 1, Rev. 4
Chromium	Cr	Metal	µg/kg	18,500	320,000	DOE/RL-92-24, Vol. 1, Rev. 4
Cobalt	Co	Metal	µg/kg	15,700	110,000	DOE/RL-92-24, Vol. 1, Rev. 4
Copper	Cu	Metal	µg/kg	22,000	61,000	DOE/RL-92-24, Vol. 1, Rev. 4
Iron	Fe	Metal	µg/kg	3.26E+07	68,100,000	DOE/RL-92-24, Vol. 1, Rev. 4
Lead*	Pb	Metal	µg/kg	10,200	74,100	DOE/RL-92-24, Vol. 1, Rev. 4
Lithium	Li	Metal	µg/kg	13,300	19,200	ECF-HANFORD-11-0038
Magnesium	Mg	Metal	µg/kg	7.06E+06	32,300,000	DOE/RL-92-24, Vol. 1, Rev. 4
Manganese	Mn	Metal	µg/kg	512,000	1,110,000	DOE/RL-92-24, Vol. 1, Rev. 4
Mercury*	Hg	Metal	µg/kg	13	29	ECF-HANFORD-11-0038
Molybdenum	Mo	Metal	µg/kg	470	3,170	ECF-HANFORD-11-0038
Nickel*	Ni	Metal	µg/kg	19,100	200,000	ECF-HANFORD-11-0038
Potassium	K	Metal	µg/kg	2.15E+06	7,900,000	ECF-HANFORD-11-0038
Selenium*	Se	Metal	µg/kg	780	840	Ecology Publication #94-115
Silver*	Ag	Metal	µg/kg	167	273	ECF-HANFORD-11-0038
Sodium	Na	Metal	µg/kg	690,000	6,060,000	DOE/RL-92-24, Vol. 1, Rev. 4
Thallium*	Th	Metal	µg/kg	185	523	ECF-HANFORD-11-0038
Uranium	U	Metal	µg/kg	3,210	4,042	Isotopic Activity Conversion based on DOE/RL-96-12 values
Vanadium	V	Metal	µg/kg	85,100	140,000	DOE/RL-92-24, Vol. 1, Rev. 4
Zinc	Zn	Metal	µg/kg	67,800	366,000	DOE/RL-92-24, Vol. 1, Rev. 4

Table D-12. Background Data for Selected Constituents for the Hanford Site. (3 sheets)

Analyte Name	Analyte Symbol	Analyte Class	Units	Lognormal 90th Percentile Background Value	Maximum Background Value	Source of Background Value
Ammonia	NH_3	Anion	µg/kg	9,230	26,400	DOE/RL-92-24, Vol. 1, Rev. 4
Chloride	Cl	Anion	µg/kg	100,000	1,480,000	DOE/RL-92-24, Vol. 1, Rev. 4
Fluoride	Fl	Anion	µg/kg	2,810	73,300	DOE/RL-92-24, Vol. 1, Rev. 4
Nitrate	NO_3	Anion	µg/kg	52,000	906,000	DOE/RL-92-24, Vol. 1, Rev. 4
Phosphate	PO_4	Anion	µg/kg	785	225,000	DOE/RL-92-24, Vol. 1, Rev. 4
Sulfate	SO_4	Anion	µg/kg	237,000	12,600,000	DOE/RL-92-24, Vol. 1, Rev. 4

* Dangerous waste constituent per *Washington Administrative Code* 173-303-9905, "Dangerous Waste Constituents List."

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