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14-TF-0086

AUG 0 6 2014

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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-110

Reference: ORP letter from K.W. Smith 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-104," 14-TF-0007, dated January 29, 2014.

The U.S. Department of Energy, Office of River Protection (ORP) is transmitting RPP-RPT-56769, Revision 0, *Retrieval Data Report for Single-Shell Tank 241-C-110*, 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-56769, Revision 0, documents completion of waste retrieval and post-retrieval sampling at Tank 241-C-110 using modified sluicing as a first retrieval technology and mechanical waste conditioning with an in-tank vehicle as a second retrieval technology.

ORP provided a retrieval completion certification on Tank 241-C-110 on January 29, 2014 (Reference).

If you have any questions, please contact Christopher J. Kemp, Acting Federal Project Director, Retrieval and Closure, at (509) 373-0649.

K.W. Smith

Kevin W. Smith
Manger

Attachment

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1223020 M-045-86

cc w/attach:
TPA Administrative Record
Environmental Portal, LMSI
WRPS Correspondence

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14-TF-0086

RPP-RPT-56796
RETRIEVAL DATA REPORT FOR SINGLE-SHELL TANK 241-C-110

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Retrieval Data Report for Single-Shell Tank 241-C-110

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Abstract: This Retrieval Data Report presents information showing that waste retrieval operations in single-shell tank 241-C-110 used three retrieval technologies, each to its limits of technology. The first waste retrieval technology deployed was modified sluicing, which removed ~90% of the initial waste inventory. Additional waste retrieval was performed using two technologies, an in-tank vehicle (FoldTrack® Mobile Retrieval Tool), combined with high-pressure water. The residual waste volume contained within tank 241-C-110 is estimated to be 281 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 performance during the waste removal campaigns, and describes measures taken to prevent and detect leaks during waste retrieval operations.

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APPROVED
By Julia Raymer at 3:39 pm, Jun 25, 2014

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Retrieval Data Report for Single-Shell Tank 241-C-110

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Office of River Protection under Contract DE-AC27-08RV14800

Approved for public release; distribution unlimited

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 State of Washington Department of Ecology (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 0 of its certification of retrieval, RPP-56214, *Retrieval Completion Certification Report for Tank 241-C-110*, to Ecology on January 29, 2014.

This Retrieval Data Report presents information showing that single-shell tank 241-C-110 (C-110) has undergone waste retrieval using three retrieval technologies, each to its limits of technology. The first waste retrieval technology deployed was modified sluicing, which removed ~90% of the initial waste inventory. Additional waste retrieval was performed using two technologies, an in-tank vehicle (FoldTrack® Mobile Retrieval Tool[1] [MRT]), combined with high-pressure water. The residual waste volume contained within tank C-110 is estimated to be 281 ft^3 (RPP-CALC-56399, *Post-Hard Heel Retrieval Camera/CAD Modeling System Waste Volume Estimate for Tank 241-C-110*). The DOE has determined that the Consent Decree waste residue goal of less than 360 ft^3 of waste has been met. 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.

RPP-56214 documents that the three retrieval technologies deployed in tank C-110 retrieved the waste in tank C-110 to the limits of the technologies, resulting in a residual waste volume less than the Consent Decree waste residue goal of 360 ft^3. The tank C-110 modified sluicing waste retrieval campaign began September 22, 2008 and was completed on April 27, 2009. The MRT (mechanical and high-pressure water) retrieval operations began on August 14, 2013 and reached the limits of technology on October 16, 2013. The tank C-110 waste which was removed was transferred to double-shell tank 241-AN-106.

The tank C-110 leak detection, monitoring, and mitigation program used 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-110 retrieval operations.

Prior to retrieval, the best estimate of waste volume was ~178,000 gal (23,800 ft^3). After modified sluicing, the estimated volume of waste remaining in the tank was ~17,200 gal (~2,300 ft^3). After MRT/sluicing the final estimated volume of waste remaining in the tank was ~2,100 gal (~281 ft^3) (RPP-CALC-56399).

[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-110 was determined by laboratory analysis of waste samples taken once it was determined that the Consent Decree waste residue goal had been met and that deployment of a third retrieval technology would not be necessary. The risk assessment for the residual waste in tank C-110 based on sampling analysis shows that for the groundwater pathway, the estimated risk impacts for tank C-110 are 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-110 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 Abstracts Service
CCMS	Camera/CAD Modeling System
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	*Code of Federal Regulations*
CPF	cancer potency factor
DFR	dose factor
DOE	U.S. Department of Energy
DQO	Data Quality Objectives
DST	double-shell tank
Ecology	State of Washington Department of Ecology
EPA	U.S. Environmental Protection Agency
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
HRR	high-resolution resistivity
HTWOS	Hanford Tank Waste Operations Simulator
HWMA	Hazardous Waste Management Act
ILCR	incremental lifetime cancer risk
LDM	leak detection and monitoring
LDMM	leak detection, monitoring, and mitigation
MRT	Mobile Retrieval Tool
MTCA	*Model Toxics Control Act*
ORP	U.S. Department of Energy Office of River Protection
ORSS	Off-Riser Sampling System

PA	performance assessment
PCB	polychlorinated biphenyl
RCRA	*Resource Conservation and Recovery Act of 1976*
RCW	*Revised Code of Washington*
RDR	Retrieval Data Report
Rfd	reference dose
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
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-110 (C-110) waste occurred in two campaigns. The first campaign on September 22, 2008 consisted of modified sluicing technology to remove the bulk of the waste. The sluicing campaign was suspended on April 27, 2009. This first campaign of retrieval reached the limit of its technology with an estimated 17,200 gal (~2,300 ft^3) of waste remaining in tank C-110 (RPP-RPT-49876, *Derivation of Best-Basis Inventory for Tank 241-C-110 as of January 1, 2014*). The second campaign started on August 14, 2013, using a FoldTrack® Mobile Retrieval Tool[2] (MRT) that provided both mechanical and high-pressure water technologies combined with sluicing retrieval operation. This campaign reached the limit of technology for the combined technologies on October 16, 2013. After concluding the second waste retrieval campaign, the quantity of waste remaining in tank C-110 was estimated to be 2,100 gal or 281 ft^3 (RPP-CALC-56399, *Post-Hard Heel Retrieval Camera/CAD Modeling System Waste Volume Estimate for Tank 241-C-110*). The modified sluicing campaign is described (and approved by the State of Washington Department of Ecology [Ecology]) in Revision 1 of RPP-33116, *241-C-110 Tank Waste Retrieval Work Plan.* An MRT providing mechanical waste conditioning (second technology) and high-pressure water (third technology) was described (and approved by Ecology) in Revision 3 of RPP-33116, *241-C-110 Tank Waste Retrieval Work Plan.*

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* [HWMA]) and its implementing regulations, but is provided for information purposes only.

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-110 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

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

- 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-110 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 Tank Waste Retrieval Work Plan (RPP-33116) establishes the three 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 three technologies established by the Tank Waste Retrieval Work Plan for tank C-110 were deployed to their limits of technology, resulting in a waste residual volume of ~281 ft^3, less than the Consent Decree goal of 360 ft^3.

1.3 DOCUMENT STRUCTURE

This tank C-110 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-110 waste retrieval, presents requirements applicable to this report, and outlines the report structure.

- **Section 2,** *Single-Shell Tank 241-C-110 Residual Waste Volume Measurement* describes the method for determining the volume of residual waste in tank C-110 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-110 Risk Assessment* describes the potential risk to human health from tank C-110 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-110 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-110 and actions being taken 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-110 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-110 RESIDUAL WASTE VOLUME MEASUREMENT

This section presents the residual waste volume measurement process and the results for tank C-110. The post-retrieval residual waste volume estimate was performed using a method described in RPP-CALC-56399. The total measured volume of residual waste in tank C-110 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. The residual waste volume used for all calculations in this RDR is the volume reported as the 95% upper confidence level (UCL) in RPP-CALC-55938, *Estimated Waste Volume Remaining in Single-Shell Tank 241-C-110 After Hard Heel Retrieval* (see Table 2-1).

Table 2-1. Tank 241-C-110 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)	6.343	1,676	223.97	267.91
Waste in tank equipment[b]	0	0	0	0
On the stiffener ring and tank walls[c, d]	0.379	100	13.38	13.38
Total	6.722	1,776	237.35	281.29

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% UCL = 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.

2.1 RESIDUAL WASTE VOLUME MEASUREMENT PROCESS

RPP-CALC-56399 documents the video camera/computer-aided design (CAD) computer modeling system (CCMS) estimate for the post-hard heel retrieval waste volume in tank C-110. Although all solids were covered for Enraf®[3] volume displacement estimates (RPP-CALC-55938), the CCMS volume was obtained for comparison with liquid displacement values and to better estimate the volume of waste remaining on the tank walls and stiffener rings.

After the CCMS video was completed, the video was reviewed to develop an AutoCAD® Civil 3D®[4] drawing of tank C-110 and the tank waste residuals and to complete tank bottom

[3] Honeywell Enraf® is a registered trademark of Honeywell International Inc., Corporation Delaware, 101 Columbia Road Morristown, New Jersey.

[4] AutoCAD® and Civil 3D® are trademarks of Autodesk, Inc., 111 McInnis Parkway, San Rafael, California.

volume estimates per TFC-ENG-FACSUP-CD-22, "Post-Retrieval Tank Waste Volume Determination." 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 (Figure 2-1 shows a mosaic of tank C-110 post-retrieval operations). 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. These processes are described in more detail below.

2.1.1 Video Camera/Computer-aided Design Modeling System

The post-hard heel retrieval waste consists of solids piles and a liquid pool (mostly liquid, may be some submerged solids). The volume of this waste was estimated using the CCMS method per TFC-ENG-FACSUP-CD-22, calculated using AutoCAD® Civil 3D® to be ~268 ft^3 (Table 2-1).

The shape of the pool, not round and off-centered (see Section 3.2), 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 was conservatively assumed that the waste on the tank bottom remains saturated, and the waste volume was 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 13.38 ft^3 (~100 gal). The volume of waste on the stiffener rings 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. The volume of waste on the tank walls was estimated based on the surface area between the stiffener rings and the average depth of waste on the tank wall. After reviewing the CCMS video, it was determined that preliminary estimates for the volume of waste on the stiffener rings and walls were adequate. The estimated thickness of the waste on the tank stiffener rings and tank walls and associated waste volume calculations are presented in RPP-CALC-55938.

2.1.3 Estimation of Waste in Equipment

Waste remaining in equipment was negligible compared to other volumes.

Figure 2-1. Tank 241-C-110 Photo Mosaic Looking to the North from Riser 3.

2.2 RESIDUAL WASTE VOLUME RESULTS

The total CCMS volume of post-retrieval residual waste in tank C-110 and the waste volumes associated with the various waste components are given in Table 2-1. The best estimate for the total post-retrieval waste volume in tank C-110 is 281 ft^3.

3.0 RESIDUAL TANK WASTE CHARACTERIZATION

This section describes the results of residual tank waste characterization for tank C-110. 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

A tank sampling and analysis plan (TSAP) (RPP-PLAN-55750, *Sampling and Analysis Plan for Residual Waste Solids in Tank 241-C-110*) identified sample collection, laboratory analysis, quality assurance/quality control, and reporting requirements for the characterization of waste solids remaining in tank C-110 after completion of retrieval to support tank closure. The samples were analyzed according to the requirements in RPP-23403, *Single-Shell Tank Component Closure Data Quality Objectives* and RPP-PLAN-23827, *Sampling and Analysis Plan for Single-Shell Tanks Component Closure*.

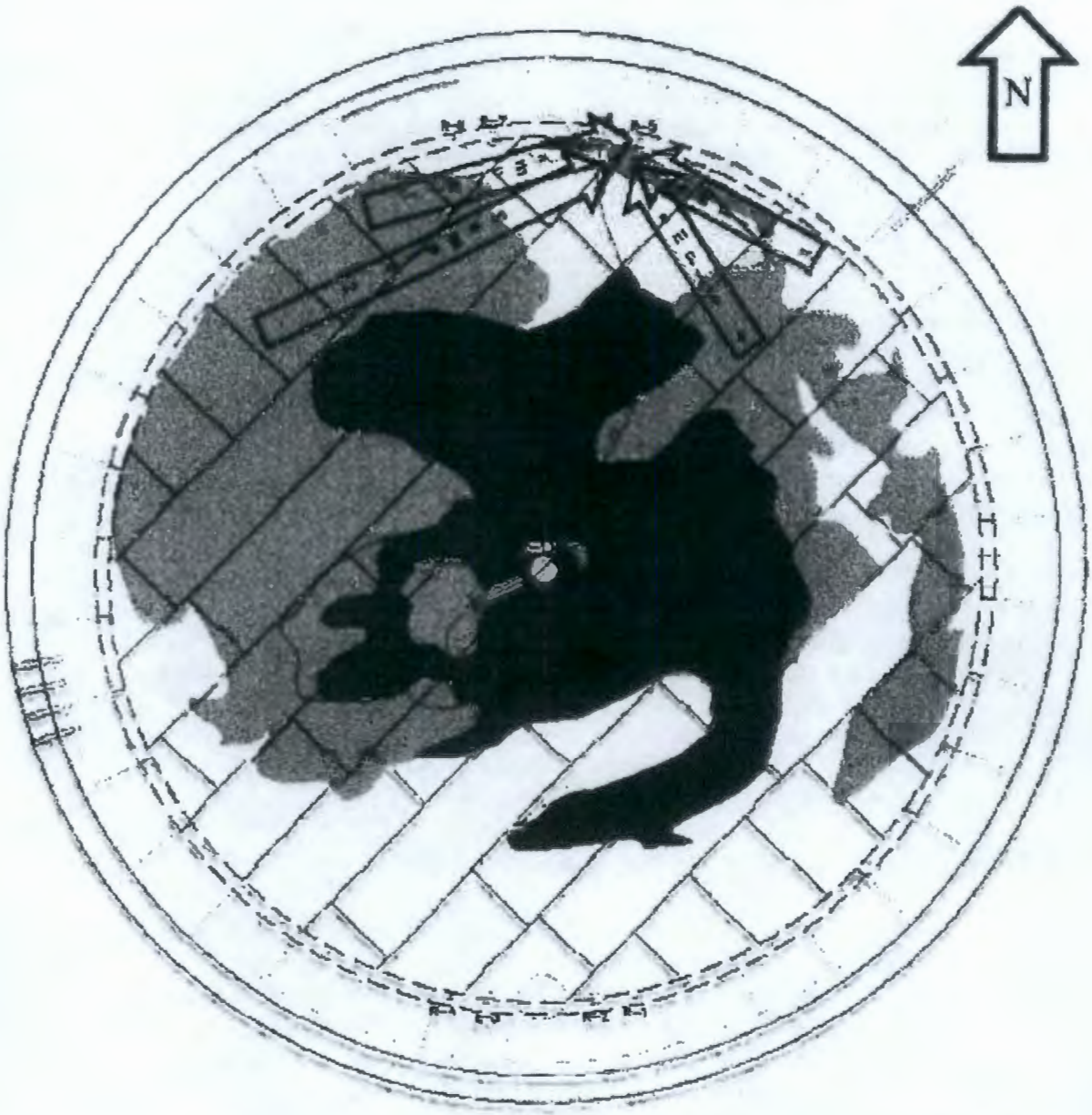
RPP-PLAN-23827 calls for nine samples to be collected. The sampling design for tank C-110 was modified, due to the location and small volume of solids that was expected to remain following retrieval. In the new sampling design, four samples were planned to be taken from the remaining solids, and analysis performed on the individual samples instead of composites as specified in RPP-PLAN-23827. The modified sampling design was documented in RPP-PLAN-55750, and representatives from both the DOE Office of River Protection (ORP) and Ecology concurred with the modified plan, as shown in the document Signature Page.

3.2 SAMPLING AT SINGLE-SHELL TANK 241-C-110

The tank-specific sampling design for the tank C-110 post-heel retrieval sample allowed the use of either an Off-Riser Sampling System (ORSS) or a Foldtrack® with a clamshell sampler to retrieve solid samples. The planned approach involved the use of the Foldtrack® to push waste solids into one long pile from which four cross-cut samples would be taken. This sampling approach minimizes sampling bias, but requires a substantial amount of work with the Foldtrack® to stage the solids. Upon starting the Foldtrack® to initiate sampling, it became clear that the Foldtrack® had severe hydraulic fluid leakage. The plan was modified to reduce the necessary Foldtrack® operation by pushing samples toward the sampling location, then sampling in place. Concurrence with this revised plan was obtained from ORP and Ecology prior to proceeding.

The arrows in Figure 3-1 show the approximate paths used by the Foldtrack® to push the solids to the sampling locations (RPP-RPT-56778, *Final Report for Tank 241-C-110 Residual Solid Samples in Support of Tank Closure*). After each push, a sample was collected using the clamshell sampler, and the solids were cleared for the next sample. The bulk of the residual waste was located in the north side of the tank, from which the samples were taken. All four samples were used for waste constituent analysis as described in Section 3.4.1.

Figure 3-1. Approximate Locations of Post-Heel Removal Samples (not to scale).



The volume of waste solids collected in the four samples was sufficient to characterize the bulk of the residual solids in the tank. Therefore, the sampling objectives were judged to have been achieved with the collected samples. The tank C-110 solid samples, retrieved October 30, 2013, in accordance with RPP-PLAN-55750 (modified as described above) were shipped to the 222-S Laboratory for analysis.

Descriptions of the solids samples C110-13-1, C110-13-2, C110-13-3, and C110-13-4 are provided in Table 3-1 as reported in RPP-RPT-56778.

3.3 SAMPLE ANALYSES

The samples listed in Table 3-1 were analyzed for the constituents identified in RPP-23403 and RPP-PLAN-23827 as defined by RPP-PLAN-55750. Analytical methods performed on the 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-56778. Electronic data were also loaded into the Tank Waste Information Network System.

Table 3-1. Description of Tank 241-C-110 Post-Heel Retrieval Samples.

Sample Identification	Date Sampled	Date Received	Solid Weight (g)	Liquid Volume (mL)	Sample Description
C110-13-1	10/30/2013 10:47	10/30/2013 15:00	140.1	None	Partially full 240-mL Teflon jar; brown, yellow, white and grey dry solids; no organic layer visible
C110-13-2	10/30/2013 13:30	10/30/2013 15:00	181.4	None	Partially full 240-mL Teflon jar; brown, yellow, white and grey dry solids; no organic layer visible
C110-13-3	10/30/2013 13:45	10/30/2013 15:00	139.9	None	Partially full 240-mL Teflon jar; brown, yellow, white and grey dry solids; no organic layer visible
C110-13-4	10/30/2013 10:47	10/30/2013 15:00	135.3	None	Partially full 240-mL Teflon jar; brown, yellow, white and grey dry solids; no organic layer visible

Source: RPP-RPT-56778, *Final Report for Tank 241 C 110 Residual Solid Samples in Support of Tank Closure.*

3.4 CALCULATION OF RESIDUAL INVENTORY

The residual waste inventories were computed by following the Best-Basis Inventory (BBI) process as described in RPP-7625, *Guidelines for Updating Best-Basis Inventory.*
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. In both cases the 95% UCL for volume was used. 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. Table 3-3 identifies the residual solids compounds in tank C-110.

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

Analysis Technique	SW-846 Reference Method
Inorganic Analyses	
Bulk Density – Gravimetric	Not applicable
pH	9045D
Weight percent water – Thermogravimetric Analysis	Not applicable
Cyanide – Spectrophotometric	9010C4
Mercury – Cold Vapor Atomic Absorption	7471B
Ammonium – Ion Chromatography	EPA 300.7*
Anions & Organic Acids – Ion Chromatography	9056A
Metals – Inductively Coupled Plasma/Atomic Emission Spectrometry	6010C
^{99}Tc – Inductively Coupled Plasma/Mass Spectrometry	3050B
Actinides – Inductively Coupled Plasma/Mass Spectrometry	3050B
Radiochemical Analyses	
Gamma Energy Analysis	Not applicable
^{90}Sr – Separation/Beta counting	Not applicable
^{14}C – Liquid Scintillation	Not applicable
^{129}I – Separation/Gamma Energy Analysis	Not applicable
^{79}Se – Liquid Scintillation	Not applicable
^{3}H – Liquid Scintillation	Not applicable
^{63}Ni – Liquid Scintillation	Not applicable
^{99}Tc – Liquid Scintillation	Not applicable
^{241}Am – Separation/Alpha Energy Analysis	Not applicable
$^{239/240}$Pu, ^{238}Pu – Separation/Alpha Energy Analysis	Not applicable
^{241}Pu – Separation/Liquid Scintillation	Not applicable
^{228}Th – Separation/Alpha Energy Analysis	Not applicable
Organic Analyses	
Volatile Organic Compound – Gas Chromatography-Mass Spectrometry	8260C
Semivolatile Organic Compound – Gas Chromatography-Mass Spectrometry	8270D
Polychlorinated Biphenyls – Gas Chromatography-Electron Capture Detection	8082A

EPA = U.S. Environmental Protection Agency

* EPA Method 300.7, *Dissolved Sodium, Ammonium, Potassium, Magnesium, and Calcium in Wet Deposition by Chemically Suppressed Ion Chromatography.*

Reference: SW-846, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, Third Edition as amended.

Table 3-3. Tentatively Identified Compounds in Tank 241-C-110 Residual Solids Samples. (2 sheets)

Laboratory Sample Number	Result Type	Tentatively Identified Compound	Result (µg/kg)	Retention Time (minutes)	CAS[a] Number	Organic: SVOA or VOA
S13T011130	Dup	1,3-Diaminonaphtho[2,3]	3.0E+03	21.22	52306-18-0	VOA
S13T011130	Dup	Cholesta-3,5-diene	5.1E+03	21.74	747-90-0	VOA
S13T011130	Dup	Benzenamine, 4-octyl-N	7.3E+03	22.02	101-67-7	VOA
S13T011149	Primary	Hexamethyldisiloxane	7.00E+01	10.20	107-46-0	SVOA
S13T011149	Primary	2-Ethylacrolein	2.30E+02	11.53	922-63-4	SVOA
S13T011149	Primary	Octadecane, 2-methyl-	3.70E+01	15.29	1560-88-9	SVOA
S13T011149	Primary	Benzene, 1,2,3-trimeth	1.10E+02	15.57	526-73-8	SVOA
S13T011149	Primary	Undecane	1.90E+02	16.35	1120-21-4	SVOA
S13T011149	Primary	Dodecane	3.10E+02	17.35	112-40-3	SVOA
S13T011149	Primary	Nonanal	9.20E+01	17.48	124-19-6	SVOA
S13T011153	Primary	Amylene Hydrate	5.9E+03	3.03	75-85-4	SVOA
S13T011153	Primary	2,5-Cyclohexadiene-1,4	1.1E+04	11.87	719-22-2	SVOA
S13T011153	Primary	3,5-di-tert-Butyl-4-hydride	3.4E+03	14.26	1620-98-0	SVOA
S13T011153	Primary	9,12-Octadecadienoic acid	3.8E+03	16.42	2566-97-4	SVOA
S13T011153	Primary	9-Octadecenoic acid	2.3E+04	16.46	2462-84-2	SVOA
S13T011153	Primary	11-Hexadecenoic acid	5.2E+03	16.49	55044-54-7	SVOA
S13T011153	Primary	9-Octadecenoic acid(Z)	6.5E+03	18.00	112-62-9	SVOA
S13T011153	Primary	9-Octadecenoic acid (Z)	1.7E+05	19.55	111-03-5	SVOA
S13T011153	Primary	Benzenamine, 4-octyl-N	1.8E+04	22.03	101-67-7	SVOA
S13T011174	Primary	Hexamethyldisiloxane	9.30E+01	10.20	107-46-0	SVOA
S13T011178	Primary	Amylene Hydrate	6.6E+03	3.03	75-85-4	SVOA
S13T011178	Primary	Butane, 1-chloro-	2.7E+03	3.12	109-69-3	SVOA
S13T011178	Primary	2,5-Cyclohexadiene-1,4	1.8E+03	11.87	719-22-2	VOA
S13T011178	Primary	1,2-Benzenedicarboxylic	4.9E+03	14.90	84-69-5	VOA
S13T011178	Primary	1,2Benzenedicarboxylic	1.5E+03	15.56	17851-53-5	VOA
S13T011178	Primary	1-Hexadecene	1.9E+03	16.36	629-73-2	VOA
S13T011178	Primary	9-Octadecenoic acid	5.0E+03	16.45	2462-84-2	VOA
S13T011178	Primary	1-Nonadecene	5.3E+03	18.75	18435-45-5	VOA
S13T011178	Primary	Benzenamine, 4-octyl-N	2.4E+03	22.03	101-67-7	VOA

Table 3-3. Tentatively Identified Compounds in Tank 241-C-110 Residual Solids Samples. (2 sheets)

Laboratory Sample Number	Result Type	Tentatively Identified Compound	Result (µg/kg)	Retention Time (minutes)	CAS[a] Number	Organic: SVOA or VOA
S13T011198	Primary	Hexamethyldisiloxane	5.90E+01	10.20	107-46-0	SVOA
S13T011198	Primary	2-Ethylacrolein	3.90E+01	11.53	922-63-4	SVOA
S13T011198	Primary	Undecane	1.60E+02	16.36	1120-21-4	SVOA
S13T011198	Primary	Dodecane	3.00E+02	17.34	112-40-3	SVOA
S13T011202	Primary	Oxirane, trimethyl-	2.0E+03	2.88	5076-19-7	SVOA
S13T011202	Primary	Amylene Hydrate	4.2E+03	3.03	75-85-4	SVOA
S13T011202	Primary	2,5-Cyclohexadiene-1,4	4.3E+03	11.87	719-22-2	SVOA
S13T011202	Primary	1,2-Benzenedicarboxylic	3.4E+03	14.90	84-69-5	SVOA
S13T011202	Primary	Hexadecanoic acid, met	1.9E+03	15.27	112-39-0	VOA
S13T011202	Primary	Cyclotetradecane	1.7E+03	16.37	295-17-0	VOA
S13T011202	Primary	9-Octadecenoic acid	1.0E+04	16.45	2462-84-2	VOA
S13T011202	Primary	9-Octadecenoic acid(Z)	2.0E+03	18.00	112-62-9	SVOA
S13T011202	Primary	1-Nonadecene	3.9E+03	18.75	18435-45-5	SVOA
S13T011202	Primary	9-Octadecenoic acid (Z)	1.8E+04	19.53	111-03-5	SVOA
S13T011202	Primary	Benzenamine, 4-octyl-N	6.4E+03	22.03	101-67-7	SVOA
S13T011202	Primary	9-Octadecenoic acid(Z)	9.6E+03	22.16	3443-84-3	SVOA

µg/kg = microgram per kilogram
CAS = Chemical Abstracts Service
SVOA = semivolatile organics analysis
VOA = volatile organic analysis

As described earlier, tank C-110 solids were sampled in tank C-110 after the heel retrieval which removed more than half of the amount of waste after bulk retrieval. The mean concentrations 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 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 (RSDs) 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. The concentration means used by the BBIM tool to calculate the average inventories are provided in Appendix B.

As shown in Table 2-1, ~268 ft^3 of waste was left on the bottom of the tank floor (RPP-CALC-56399). The estimated volume of solids on the rings and side walls was ~13 ft^3. The total residual volume used for inventory estimates is 281 ft^3 (268 + 13 = 281 ft^3). There are 7.481 gal per ft^3 and 3.785 L per gal, therefore the solid volume is ~8 kL [(281 ft^3 × 7.481 gal/ft^3 × 3.785 L/gal) × 1 kL/1,000 L = 7.96 kL] used for inventory.

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-56399 provides estimates of post-retrieval residual waste volumes on the tank bottom, on the tank wall, and on the tank stiffener rings (see Table 2-1). The total waste volume was estimated at 281 ft^3 (95% UCL). For purposes of these calculations, the RSD of the volume was assumed to be zero.

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 with the ORSS after heel removal using an accepted sampling method described in the Data Quality Objectives (DQO) document (RPP-23403). The solids RSDs in Appendix B, 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-56778).

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. 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 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 144 ft^3 pool of mostly liquids (RPP-CALC-56399). The volume of the submerged solids in the liquids is

not estimated; therefore, the volume of the pool is included in the total residual solids volume in the tank. The liquid is assumed to be water remaining in tank C-110 after final sluicing.

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

- Uranium concentration was estimated from concentrations of uranium isotopes detected by inductively coupled plasma/mass spectrometry (^{234}U, ^{235}U, ^{236}U, and ^{238}U).

- Plutonium and curium (except for ^{242}Cm) isotopes were calculated from the $^{239/240}$Pu and $^{243/244}$Cm analytical results, using process knowledge of the isotopic distributions ratios of tank C-110.

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

- As the name implies, 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-56703, *Tank 241-C-110 Residual Waste Inventory Estimates for Component Closure Risk Assessment* are in Table 3-3. The samples contained numerous alkanes and their alterations to ketones.

- The laboratory was not able to measure xylene (m) and xylene (p) separately; therefore, these compounds were reported as xylene (m&p).

- Bulk density sample results had a range from 1.16 g/mL to 1.34g/mL (RPP-RPT-56778) and a sample mean density of 1.24 g/mL.

The samples were analyzed for the 61 compounds that the laboratory currently reports. In addition to the primary analytes listed in the TSAP, the following secondary analytes displayed in Table 3-4 had results above the minimum detection limit (RPP-RPT-56778).

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 were decay-corrected to January 1, 2008.

Table 3-4. Inventory Estimates for Selected Constituents in Tank 241-C-110 Residual Solids. (4 Sheets)

Constituent	Chemical Abstracts Service Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units[1]
^{125}Sb	14234-35-6	<	4.20E+00	1.26E+01	Ci
^{126}Sn	15832-50-5		2.38E-02	3.37E-02	Ci
^{129}I	15046-84-1	<	2.30E-04	6.90E-04	Ci
^{137}Cs	10045-97-3		2.66E+01	4.04E+01	Ci
^{137m}Ba	N/A		2.51E+01	3.81E+01	Ci
^{14}C	14762-75-5	<	1.51E-03	4.53E-03	Ci
^{152}Eu	14683-23-9	<	1.11E+00	3.33E+00	Ci
^{154}Eu	15585-10-1	<	1.22E+00	3.66E+00	Ci
^{155}Eu	14391-16-3	<	2.86E+00	8.58E+00	Ci
^{228}Th	14274-82-9	<	2.13E-04	6.39E-04	Ci
^{230}Th	14269-63-7	<	2.88E-03	8.64E-03	Ci
^{231}Pa	14331-85-2	<	6.59E-03	1.98E-02	Ci
^{232}Th	N/A	<	1.16E-06	3.48E-06	Ci
^{233}U	13968-55-3	<	9.62E-03	2.89E-02	Ci
^{234}U	13966-29-5		2.64E-03	3.61E-03	Ci
^{235}U	15117-96-1		1.14E-04	1.41E-04	Ci
^{236}U	13982-70-2		2.93E-05	3.32E-05	Ci
^{237}Np	13994-20-2		1.09E-03	1.31E-03	Ci
^{238}Pu	13981-16-3		1.72E-02	2.28E-02	Ci
^{238}U	N/A		2.59E-03	3.21E-03	Ci
^{239}Pu	15117-48-3		1.17E+00	1.61E+00	Ci
^{240}Pu	14119-33-6		1.27E-01	1.75E-01	Ci
^{241}Am	14596-10-2		5.04E-02	6.32E-02	Ci
^{241}Pu	14119-32-5		6.38E-01	7.45E-01	Ci
^{242}Cm	15510-73-3	<	6.94E-04	2.08E-03	Ci
^{242}Pu	13982-10-0		1.77E-06	2.44E-06	Ci
^{243}Cm	15757-87-6	<	1.06E-04	3.18E-04	Ci
^{244}Cm	13981-15-2	<	2.24E-03	6.72E-03	Ci
2-Butanone	78-93-3	<	1.53E-04	4.59E-04	kg

Table 3-4. Inventory Estimates for Selected Constituents in Tank 241-C-110 Residual Solids. (4 Sheets)

Constituent	Chemical Abstracts Service Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units[1]
^{3}H	15086-10-9		3.53E-03	4.52E-03	Ci
^{60}Co	10198-40-0	<	6.14E-01	1.84E+00	Ci
^{63}Ni	13981-37-8		4.43E-01	5.37E-01	Ci
^{79}Se	15758-45-9	<	5.03E-03	1.51E-02	Ci
^{90}Sr	10098-97-2		3.50E+03	4.63E+03	Ci
^{90}Y	10098-91-6		3.50E+03	4.63E+03	Ci
^{99}Tc	14133-76-7		4.46E-02	6.81E-02	Ci
1,2,4-Trichlorobenzene	120-82-1		2.98E-05	4.51E-05	kg
1,2-Dichlorobenzene	95-50-1		1.27E-05	2.04E-05	kg
1,4-Dichlorobenzene	106-46-7	<	6.99E-06	2.10E-05	kg
Acetate	71-50-1	<	1.10E+00	3.30E+00	kg
Acetone	67-64-1	<	1.98E-04	5.94E-04	kg
Ag	7440-22-4		2.49E-01	4.04E-01	kg
Al	7429-90-5		1.29E+03	1.61E+03	kg
Aroclors (Total PCB)	1336-36-3		1.59E-04	2.83E-04	kg
As	7440-38-2		5.93E-02	6.82E-02	kg
B	7440-42-8		2.33E-02	4.44E-02	kg
Ba	7440-39-3		5.00E-01	7.43E-01	kg
Be	7440-41-7	<	9.98E-03	2.99E-02	kg
Bi	7440-69-9		3.63E+01	4.29E+01	kg
Br	24959-67-9	<	5.87E-01	1.76E+00	kg
Ca	7440-70-2		5.84E+00	6.74E+00	kg
Cd	7440-43-9	<	9.98E-03	2.99E-02	kg
Ce	7440-45-1	<	1.30E+01	3.90E+01	kg
Cl	16887-00-6	<	6.26E-01	1.88E+00	kg
CN	57-12-5		8.12E-03	9.41E-03	kg
Co	7440-48-4		2.35E-02	2.80E-02	kg
Cr	7440-47-3		1.12E+00	1.54E+00	kg
Cu	7440-50-8		3.15E+00	5.76E+00	kg

Table 3-4. Inventory Estimates for Selected Constituents in Tank 241-C-110 Residual Solids. (4 Sheets)

Constituent	Chemical Abstracts Service Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units[1]
Ethylbenzene	100-41-4	<	1.21E-05	3.63E-05	kg
Eu	7440-53-1	<	9.98E-03	2.99E-02	kg
F	16984-48-8		1.38E+02	1.69E+02	kg
Fe	7439-89-6		1.90E+02	2.53E+02	kg
Formate	12311-97-6	<	1.64E+00	4.92E+00	kg
Free OH	N/A		1.27E+00	1.58E+00	kg
Glycolate	666-14-8	<	6.26E-01	1.88E+00	kg
Hexone	108-10-1	<	1.33E-04	3.99E-04	kg
Hg	7439-97-6		1.07E-01	1.58E-01	kg
K	7440-09-7		4.46E-01	6.44E-01	kg
La	7439-91-0	<	9.98E-03	2.99E-02	kg
Li	7439-93-2		1.35E-01	1.64E-01	kg
Mg	7439-95-4		2.81E+00	3.06E+00	kg
Mn	7439-96-5		7.61E-01	9.74E-01	kg
Mo	7439-98-7		2.16E-02	3.04E-02	kg
Na	7440-23-5		1.20E+03	1.44E+03	kg
Nb	7440-03-1	<	5.99E-02	1.80E-01	kg
Nd	7440-00-8	<	1.50E-01	4.50E-01	kg
NH_3	7664-41-7		1.65E-02	2.15E-02	kg
Ni	7440-02-0		4.13E-01	4.91E-01	kg
NO_2	14797-65-0	<	2.74E+00	8.22E+00	kg
NO_3	14797-55-8		6.73E+00	1.30E+01	kg
Oxalate	338-70-5	<	1.02E+00	3.06E+00	kg
Pb	7439-92-1		5.62E+00	6.66E+00	kg
Pd	7440-05-3	<	1.20E-01	3.60E-01	kg
Phenol	108-95-2		8.33E-03	1.58E-02	kg
PO_4	14265-44-2		1.40E+03	1.67E+03	kg
Pr	7440-10-0	<	2.59E-01	7.77E-01	kg
Rb	7440-17-7	<	5.69E-01	1.71E+00	kg

Table 3-4. Inventory Estimates for Selected Constituents in Tank 241-C-110 Residual Solids. (4 Sheets)

Constituent	Chemical Abstracts Service Number	< Detection Limit	Average Inventory	Upper-Bounding Inventory	Inventory Units[1]
Rh	7440-16-6	<	8.98E-02	2.69E-01	kg
Ru	7440-18-8	<	3.99E-02	1.20E-01	kg
Sb	7440-36-0	<	5.99E-02	1.80E-01	kg
Se	7782-49-2	<	3.99E-02	1.20E-01	kg
Si	7440-21-3		2.05E+01	2.58E+01	kg
Sm	7440-19-9	<	1.70E-01	5.10E-01	kg
Sn	7440-31-5		8.42E-01	1.01E+00	kg
SO_4	14808-79-8		7.46E+00	8.07E+00	kg
Sr	7440-24-6		5.63E+01	8.64E+01	kg
Ta	7440-25-7	<	4.99E-02	1.50E-01	kg
Te	13494-80-9	<	7.98E-02	2.39E-01	kg
Th	7440-29-1	<	1.05E-02	1.39E-02	kg
Ti	7440-32-6		4.27E-02	5.05E-02	kg
Tl	7440-28-0	<	4.29E-02	1.29E-01	kg
Tributyl phosphate	126-73-8		1.01E-01	2.11E-01	kg
Trichloroethene	79-01-6	<	9.43E-06	2.83E-05	kg
U	7440-61-1		5.49E+00	7.02E+00	kg
V	7440-62-2	<	1.23E-02	3.69E-02	kg
W	7440-33-7	<	1.60E-01	4.80E-01	kg
Xylene (m & p)	108-28-3M		3.36E-05	6.21E-05	kg
Xylene (o)	95-47-6		1.67E-05	3.03E-05	kg
Xylenes (total)	1330-20-7		4.94E-05	9.28E-05	kg
Y	7440-65-5	<	1.06E-02	3.18E-02	kg
Zn	7440-66-6		2.13E+00	2.56E+00	kg
Zr	7440-67-7		3.62E-01	4.16E-01	kg

N/A = not available PCB = polychlorinated biphenyl

Note: Radionuclide concentrations are decay corrected to January 1, 2008.

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4.0 RETRIEVAL SYSTEM PERFORMANCE

This section discusses the tank C-110 waste retrieval system 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-ORP has deployed three technologies at tank C-110: (1) modified sluicing and the FoldTrack® MRT, including (2) mechanical waste conditioning and (3) high-pressure water technologies. Modified sluicing operations started on September 22, 2008 with an initial waste volume of ~178,000 gal (~23,800 ft^3), and reached the limits of technology on April 27, 2009. A total of ~160,800 gal (~21,500 ft^3) of waste were removed by the first retrieval technology, leaving ~17,200 gal (~2,300 ft^3). The second and third retrieval technologies (FoldTrack® MRT mechanical waste conditioning and high-pressure water technologies, respectively) started on August 14, 2013 and reached the limits of technology on October 16, 2013. The residual waste solids volume remaining in the tank was estimated at 2,100 gal (281 ft^3) (RPP-CALC-56399), which is less than the Consent Decree retrieval goal of 360 ft^3.

4.1 WASTE RETRIEVAL PROCESS DESCRIPTION

The WRSs deployed at tank C-110 were designed to mobilize, size reduce, and dissolve portions of the sludge waste so it could be transferred to double-shell tank (DST) 241-AN-106 (AN-106). Descriptions of WRSs may be found in RPP-33116. 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-110 was monitored and balanced by the volume pumped out of tank C-110. 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-110 waste using sluicers, eroding and moving the waste toward the center transfer pump so pumpable material could be transferred to the DST.

The second waste retrieval campaign at tank C-110 deployed a combination of mechanical waste conditioning using an in-tank vehicle (FoldTrack® MRT) with plow-blade, high-pressure water (MRT water cannon and scarifiers) and modified sluicing. Mechanical waste conditioning and sluicing were performed initially to remove as much of the waste as possible; high-pressure water and sluicing were then applied as needed. The solids were first pushed closer to the slurry pump and sluicers using the MRT plow-blade. During this process, water was added through the MRT scarifier nozzles to prevent the nozzles from plugging. As solids were moved toward the pump, the solids were sluiced using supernate from tank AN-106. As needed, the flow rates and pressures of the scarifiers were increased to break up solids using high-pressure water and to work with the plow-blade to move solids to the pump. A backstop to hold and suspend sluiced solids was created by mounding waste on the opposite side of the slurry pump from the sluice stream. High-pressure water from the MRT nozzles also provided an effective backstop for sluicing by providing a physical block to stop the particles from being pushed past the pump and, using the scarifier nozzles, creating turbulence to hold the waste particles in suspension to be drawn into the pump.

4.2 RETRIEVAL SYSTEM PERFORMANCE

The sluicing retrieval system effectively removed most of the sludge from tank C-110. Most of the waste in tank C-110 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. Grainier, light-colored solids became more prevalent as the softer, dark-colored sludge was washed out of the tank. A few larger chunks of material and some hard material on the tank bottom were observed, but the bulk of the light-colored waste appeared sandy and mobile. Although mobilized by the sluicers, this waste settled rapidly and was not easily retrieved with the existing installed equipment.

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-110 to tank AN-106. The occasional decreases in the volume retrieved in Figure 4-1 reflect fluctuations in the ending tank C-110 liquid pool volume. It was not always possible to pump the tank C-110 liquid pool to the same minimum heel at the end of each operating period.

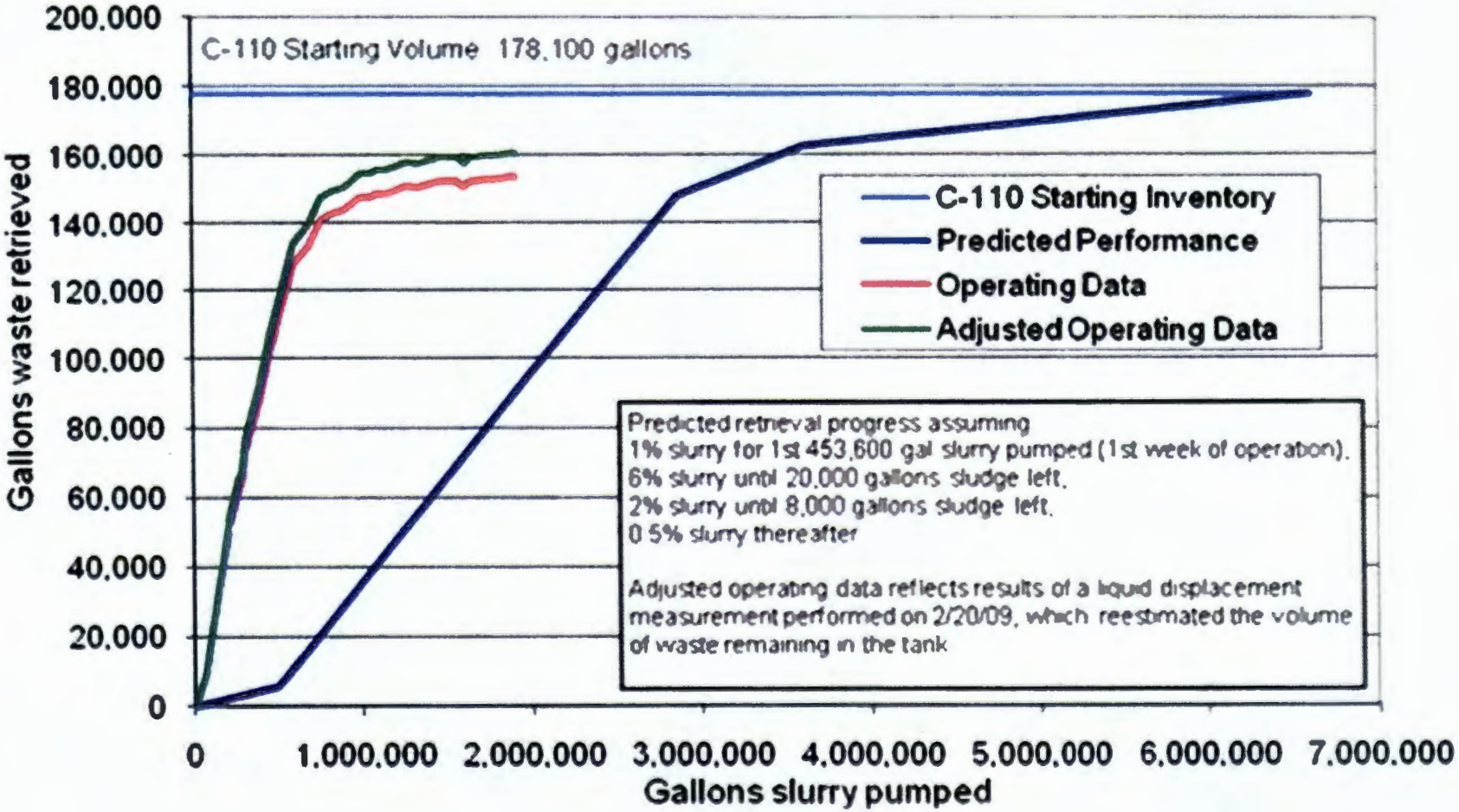
Retrieval system performance was tracked by trending the net waste volume increase in the receiver tank AN-106 after accounting for water additions. This running volume balance did not distinguish between liquids and solids and did not account for solids dissolution or liquid evaporation. As the volume retrieved approached the starting waste volume, the estimate of the volume remaining in tank C-110 by difference became increasingly sensitive to uncertainties in the starting waste volume estimate because of pore space in the waste and cumulative measurement uncertainties. Near the end of retrieval, the operating data was adjusted to account for evaporation and pore space, as shown in the "Adjusted Operating Data" line in Figure 4-1.

Based on the volume displacement and video evaluation established in previous waste volume determinations and by using subsequent material balances, the total volume of waste left in tank C-110 was ~17,200 gal (2,300 ft^3) (RPP-CALC-55938). At the end of sluicing operations, an estimated 160,900 gal (21,500 ft^3) or ~90% of the waste had been retrieved.

Based on the performance metrics evaluated with the implementation of this technology and consideration of these other factors, DOE-ORP concluded that the modified sluicing retrieval technology was deployed to the limit of technology in its use at tank C-110 (RPP-56214, *Retrieval Completion Certification Report for Tank 241-C-110*).

The chemical and radionuclide composition and inventory of the waste remaining after bulk retrieval was documented in the BBI estimate, and is based on the results of grab samples obtained in 2010 and process knowledge of the types of waste that were received at tank C-110 (RPP-RPT-49876). The BBI identifies the waste as saltcake remaining after the completion of bulk retrieval. The BBI saltcake volume was based on an evaluation of the completion of bulk retrieval.

Figure 4-1. Tank 241-C-110 Modified Sluicing System Performance.



The following is a discussion of the performance of the enhanced modified sluicing using the in-tank vehicle (FoldTrack® MRT) System process steps as specified in the tank C-110 process control plan (RPP-PLAN-53943, *Process Control Plan for Tank 241-C-110 Waste Heel Retrieval*) that demonstrates that the limits of technology were met in tank C-110.

The solids in tank C-110 consist primarily of sodium fluoride phosphate [$Na_7F(PO_4)2 \cdot 19\ H_2O$, also known as natrophosphate]. A combination of mechanical waste conditioning, high-pressure water and sluicing was selected to retrieve the remaining solids (RPP-PLAN-48868, *Single-Shell Tank 241-C-110 Hard Heel Retrieval Method Selection*). Mechanical waste conditioning and sluicing was performed to remove the waste.

The in-tank vehicle (MRT) with plow-blade and high-pressure water systems (water cannon and scarifiers) provided mechanical waste conditioning to enable the sluicing system to remove the waste, and high-pressure water and sluicing were then applied as needed. In the final days of operation, hydraulic fluid leaks were observed and the MRT was used only as a backstop during sluicing.

Hot water was then sluiced into the tank to size-reduce solids and to move solids toward the pump. High-pressure hot water was also applied through the MRT nozzles to wash sluiced solids into the pump and to suspend the solids. The slurry was then pumped from the tank. Plow-blade and high-pressure water operations were conducted as specified in the process control plan (RPP-53943) and the tank waste retrieval work plan (RPP-33116).

Following the transfer of the dissolution liquors to tank AN-106, ~15,000 gal of hot water were used to knock down piles as much as possible in preparation for final liquid displacement and flush. It was then determined that solids were almost completely covered by the water addition. The waste was pumped down while adding high-pressure water through the MRT nozzles in an attempt to enhance solids removal. There was a noticeable reduction in the solids volume after the final liquid displacement.

On October 16, 2013, final sluicing and hard heel removal operations were shut down on tank C-110. RPP-CALC-55938 developed an initial estimate of ~280 ft^3 (2,100 gal) of tank waste residuals, based on liquid displacement and video information. This residual waste estimate was confirmed based on the subsequent CCMS evaluation. At the conclusion of final sluicing retrieval operations, tank C-110 was estimated to contain about 281 ft^3 (~2,100 gal) of remaining waste (see RPP-RPT-56399), meeting the volume requirement provided in the Consent Decree (*Washington v. DOE* [E.D.Wa. October 25, 2010]).

Based on the performance metrics examined with the implementation of these technologies and consideration of the factors specified in the Consent Decree, DOE-ORP concluded that the MRT mechanical and high-pressure water retrieval technologies had been deployed to the limits of technology at tank C-110.

4.3 WASTE RETRIEVAL EFFICIENCY

The preliminary estimate for the tank C-110 modified sluicing rate campaign indicated that it would require ~6,700,000 gal of slurry to transfer the estimated 178,000 gal of tank C-110 waste to tank AN-106. In the first 700,000 gal of the slurry pumped from tank C-110, over 140,000 gal of waste was transferred from tank C-110 to tank AN-106, at over three times the expected rate. However, when the campaign had transferred ~87% (operating day 17) of the forecasted waste volume (~154,000 gal) to tank AN-106, the tank C-110 waste retrieval rate dropped off.

As can be seen from Figure 4-2, the rate of waste retrieval by MRT and high-pressure water progressed nearly linearly.

4.4 RETRIEVAL DURATION

The pre-retrieval modified sluicing duration estimate was ~60 days based on a progression of waste per gallon of slurry and the expected slurry per shift. Retrieval operations were performed during 31 operating days (61 shifts) starting on September 22, 2008 and ending on April 27, 2009. Early in the modified sluicing retrieval operation, progress was better than expected. After 33 shifts of sluicing, sluicing efficiency began to fall off.

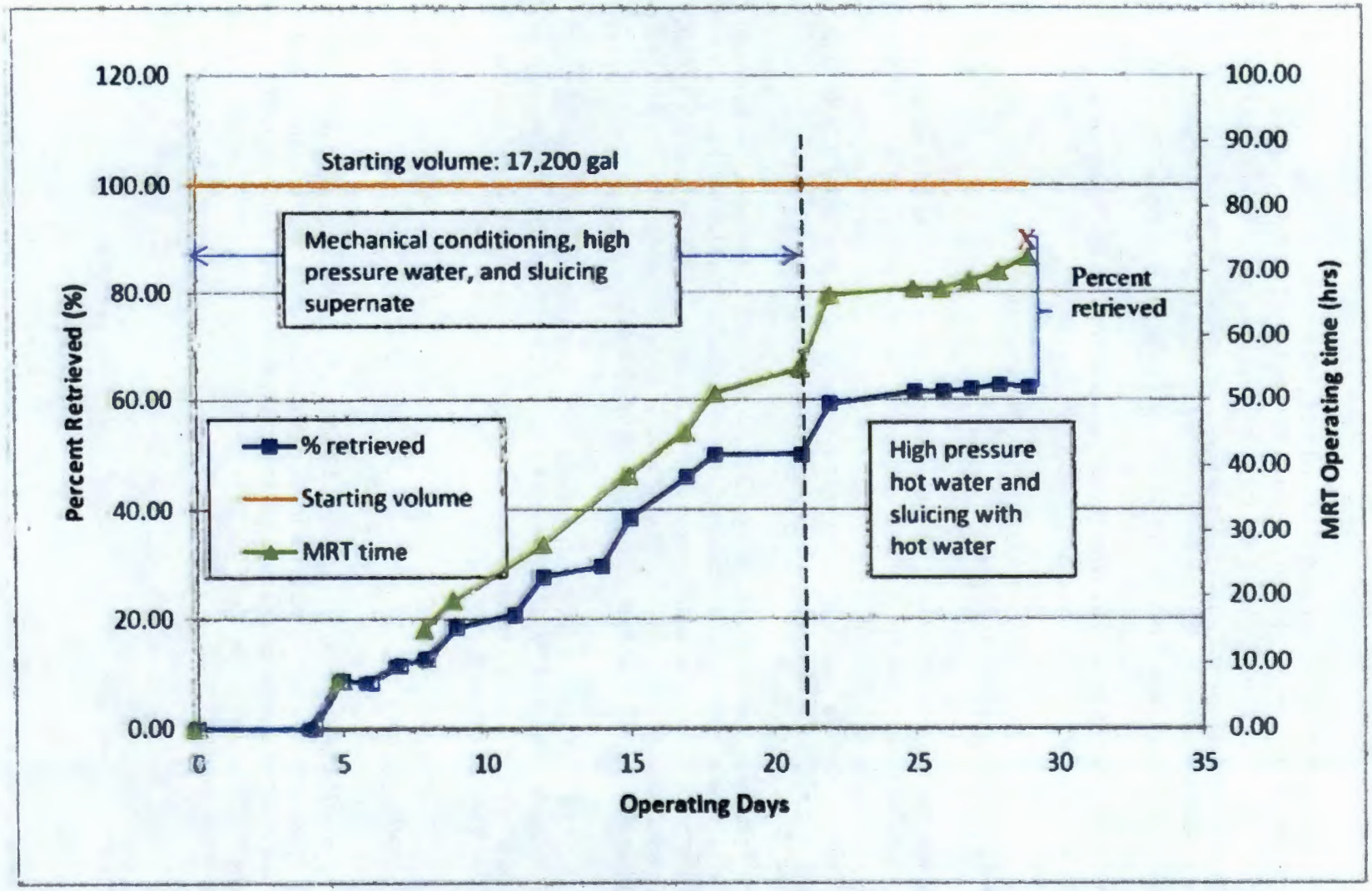
Retrieval operations restarted on August 14, 2013 using the MRT, high-pressure water, and modified sluicing to remove the remaining solids; they ended on October 16, 2013. A total of 1.7 million gal of slurry were pumped over 29 operating days. During the retrieval, ~ 79,000 gal of water were added to tank C-110. Of this amount, 57,000 gal of water was added after sluicing with supernate to constitute a triple rinse of the remaining solids.

The tank C-110 WRS campaigns consisted of a sluicing operation over a 217-calendar-day period starting on September 22, 2008 and ending on April 27, 2009. The MRT/high-pressure water and sluicing waste retrieval campaign extended over a 63-calendar-day period from August 14, 2013 to October 16, 2013.

4.5 CONCLUSION

Based on the information contained in Section 4.2 above, DOE-ORP concluded that waste retrieval operations were performed to the limits of the modified sluicing technology, the MRT mechanical retrieval technology and the high-pressure water retrieval technology (RPP-56214). The waste residual volume estimate of 281 ft^3 at the 95% UCL reached the goal of 360 ft^3 using the three technologies.

Figure 4-2. Volume Balance Results for Tank 241-C-110 Retrieval.



X = 87.8%, 15,100 gal retrieved based on liquid displacement measurement and video

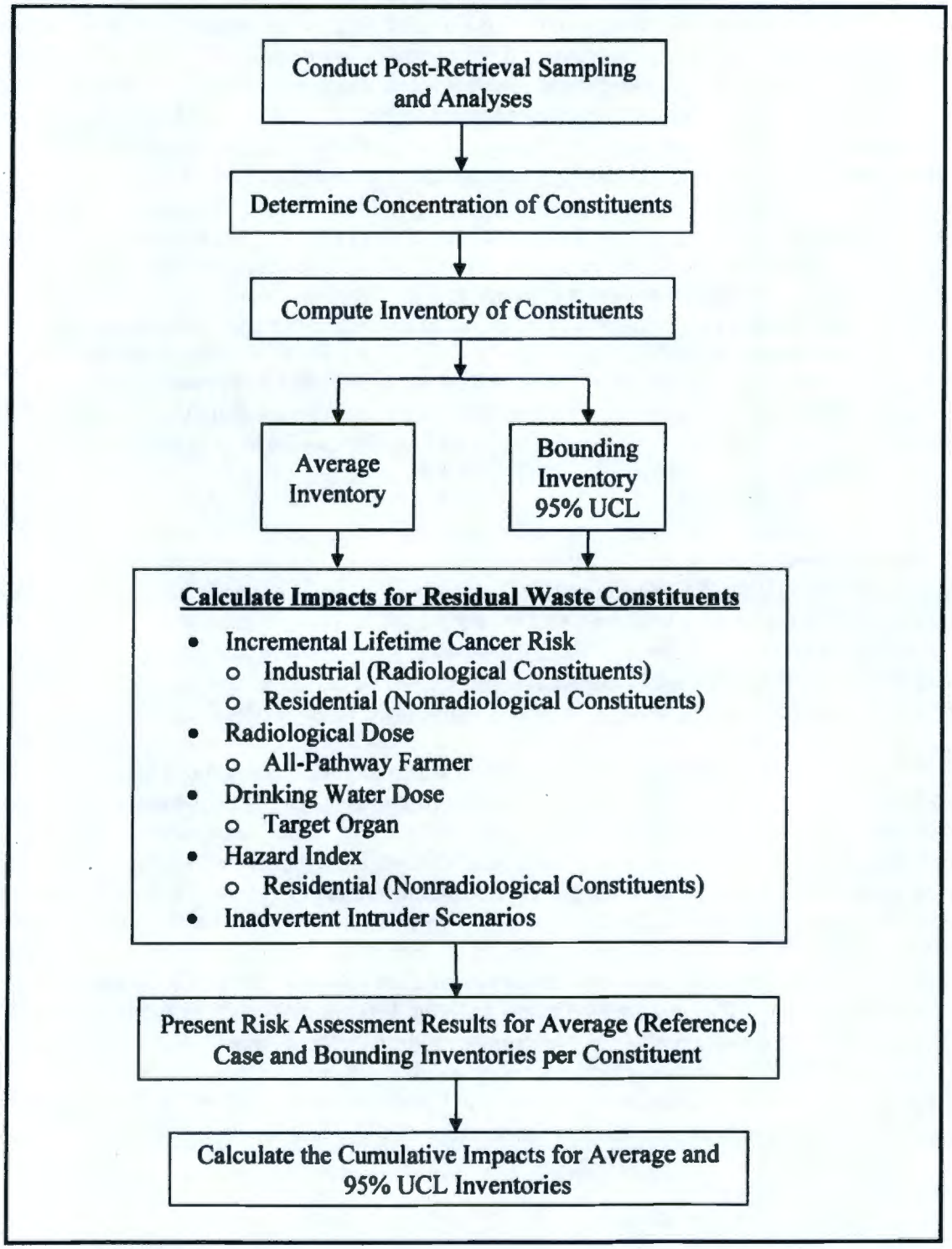
5.0 POST-RETRIEVAL SINGLE-SHELL TANK 241-C-110 RISK ASSESSMENT

The potential impacts to human health posed by the residual waste in SST C-110 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-110 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-110, 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* (RCRA), 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-110 risk assessment was derived from post-retrieval residual inventory samples (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-110 are one 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 nine orders of magnitude below the ILCR performance objectives (1.0E-05) for non-radioactive analytes. The hazard indices for the tank C-110 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-110 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 about three 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-110 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-110 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-110 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-110 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-110 were collected and analyzed as defined by the closure DQOs. The post-retrieval samples were analyzed for 110 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
^{125}Sb	Antimony-125	U	DFR/CPF	7440-48-4	Cobalt		RfD/CPF
^{126}Sn	Tin-126		DFR/CPF	7440-50-8	Copper		RfD
^{129}I	Iodine-129	U	DFR/CPF	57-12-5	Cyanide*		RfD
^{137}Cs	Cesium-137 + Daughters		DFR/CPF	100-41-4	Ethylbenzene	U	RfD/CPF
^{137m}Ba	Barium-137m		--	7440-53-1	Europium	U	--
^{14}C	Carbon-14	U	DFR/CPF	16984-48-8	Fluoride		RfD
^{152}Eu	Europium-152	U	DFR/CPF	12311-97-6	Formate+A_2	U	--
^{154}Eu	Europium-154	U	DFR/CPF	666-14-8	Glycolate $C_2H_3O_3$	U	--
^{155}Eu	Europium-155	U	DFR/CPF	7439-89-6	Iron		RfD
^{228}Th	Thorium-228 + D	U	DFR/CPF	7439-91-0	Lanthanum	U	--
^{230}Th	Thorium-230	U	DFR/CPF	^{205}Pb	Lead*		--
^{231}Pa	Protactinium-231	U	DFR/CPF	7439-93-2	Lithium		RfD
^{232}Th	Thorium-232	U	DFR/CPF	7439-95-4	Magnesium		--
^{233}U	Uranium-233	U	DFR/CPF	7439-96-5	Manganese		RfD
^{234}U	Uranium-234		DFR/CPF	7439-97-6	Mercury*		RfD
^{235}U	Uranium-235 + D		DFR/CPF	7439-98-7	Molybdenum		RfD
^{236}U	Uranium-236		DFR/CPF	108-38-3	m-Xylene		RfD
^{237}Np	Neptunium-237 + D		DFR/CPF	7440-00-8	Neodymium	U	--
^{238}Pu	Plutonium-238		DFR/CPF	^{59}Ni	Nickel*		RfD
^{238}U	Uranium-238 + D		DFR/CPF	7440-03-1	Niobium	U	--
^{239}Pu	Plutonium-239		DFR/CPF	14797-55-8	Nitrate		RfD
^{240}Pu	Plutonium-240		DFR/CPF	14797-65-0	Nitrite	U	RfD

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	95-50-1	o-Dichlorobenzene*		RfD
^{241}Pu	Plutonium-241 + D		DFR/CPF	338-70-5	Oxalate	U	--
^{242}Cm	Curium-242	U	DFR/CPF	95-47-6	o-Xylene		RfD
^{242}Pu	Plutonium-242		DFR/CPF	7440-05-3	Palladium	U	--
^{243}Cm	Curium-243	U	DFR/CPF	108-95-2	Phenol*		RfD
^{244}Cm	Curium-244	U	DFR/CPF	14265-44-2	Phosphate		--
^{3}H	Tritium		DFR/CPF	1336-36-3	Polychlorinated Biphenyls*		CPF
^{60}Co	Cobalt-60	U	DFR/CPF	7440-09-7	Potassium		--
^{63}Ni	Nickel-63		DFR/CPF	7440-10-0	Praseodymium	U	--
^{79}Se	Selenium-79	U	DFR/CPF	7440-16-6	Rhodium	U	--
^{90}Sr	Strontium-90 + D		DFR/CPF	7440-17-7	Rubidium	U	--
^{90}Y	Yttrium-90		--	7440-18-8	Ruthenium	U	--
^{99}Tc	Technetium-99		DFR/CPF	7440-19-9	Samarium	U	--
79-01-6	1, 1, 2-Trichloroethylene	U	RfD/CPF	^{79}Se	Selenium*	U	RfD
120-82-1	1, 2, 4-Trichlorobenzene*		RfD	7440-21-3	Silicon		--
106-46-7	1, 4-Dichlorobenzene	U	RfD/CPF	^{108m}Ag	Silver*		RfD
78-93-3	2-Butanone(MEK)	U	RfD	7440-23-5	Sodium		--
67-64-1	2-Propanone (Acetone)	U	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	--
7429-90-5	Aluminum		RfD	13494-80-9	Tellurium	U	--
^{125}Sb	Antimony*	U	RfD	6533-73-9	Thallium*	U	RfD

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
7440-38-2	Arsenic*		RfD/CPF	7440-29-1	Thorium	U	--
^{133}Ba	Barium*		RfD	7440-31-5	Tin		RfD
^{10}Be	Beryllium*	U	RfD/CPF	7440-32-6	Titanium		--
7440-69-9	Bismuth		--	126-73-8	Tributyl phosphate		RfD/CPF
7440-42-8	Boron		RfD	7440-33-7	Tungsten	U	--
24959-67-9	Bromide	U	--	7440-61-1	Uranium		--
^{109}Cd	Cadmium*	U	RfD/CPF	7440-62-2	Vanadium	U	RfD
7440-70-2	Calcium		--	1330-20-7	Xylenes		RfD
7440-45-1	Cerium	U	RfD	7440-65-5	Yttrium	U	--
16887-00-6	Chloride	U	--	7440-66-6	Zinc		RfD
7440-47-3	Chromium, Total*		--	7440-67-7	Zirconium		--

[a] RPP-RPT-56703, *Tank 241-C-110 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)
DFR = 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-110

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-110. 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-110. 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) is 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-110 AND WASTE MANAGEMENT AREA C

The cumulative analysis (i.e., sum of the risk metrics) for tank C-110 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-110.

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	7.55E-04	1.16E-03	9.78E+03	0.00E+00	5.73E+03	9.03E-12	6.53E-11	5.63E-06	2.33E-06
^{99}Tc	Yes	4.46E-02	1.78E-01	1.05E+04	0.00E+00	2.11E+05	2.45E-09	5.98E-08	3.12E-04	7.91E-04
^{129}I	No	1.15E-04	<1.00E-03[c]	1.20E+04	2.00E-01	1.57E+07	NE	NE	NE	NE
^{234}U	Yes	2.64E-03	0.00E+00	DNA	6.00E-01	2.46E+05	NE	NE	NE	NE
^{235}U	Yes	1.14E-04	0.00E+00	DNA	6.00E-01	7.04E+08	NE	NE	NE	NE
^{236}U	Yes	2.93E-05	0.00E+00	DNA	6.00E-01	2.34E+07	NE	NE	NE	NE
^{238}U	Yes	2.59E-03	0.00E+00	DNA	6.00E-01	4.47E+09	NE	NE	NE	NE
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 fence line, 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
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 indicates non-detects 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-110.

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	1.12E+00	4.60E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Fluoride	Yes	1.38E+02	5.67E-01	1.05E+04	0.00E+00	No CPF	5.90E-04
Nitrate	Yes	6.73E+00	2.76E-02	1.05E+04	0.00E+00	No CPF	1.08E-06
Nitrite	No	1.37E+00	5.62E-03	1.05E+04	0.00E+00	No CPF	3.52E-06
Uranium	Yes	5.49E+00	0.00E+00	DNA	6.00E-01	NE	NE
Performance Objective[c]						**1.0E-06[d]**	**1.0[e]**

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

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

[e] 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
No Rfd = no reference dose 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, Radionuclide Dose, 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-110. (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]	2.45E-09	3.75E-09	5.98E-08	9.13E-08	1.0E-06 to 1.0E-4[e]
Total with non-detects[d]	2.46E-09	3.77E-09	5.98E-08	9.15E-08	
Incremental Lifetime Cancer Risk from Non-Radioactive Analytes (unitless)					
Total without non-detects[c]	6.54E-15	7.80E-15	2.11E-14	2.52E-14	1.0E-5[f]
Total with non-detects[d]	2.06E-13	6.07E-13	4.16E-13	1.21E-12	
Hazard Index (unitless)					
Total without non-detects[c]	9.41E-05	1.15E-04	6.60E-04	8.09E-04	1.0[f]
Total with non-detects[d]	9.64E-05	1.22E-04	6.65E-04	8.25E-04	
	All-Pathways		Drinking Water		
Radiological Dose (mrem/yr)	Average Inventory	95% Upper Confidence Level Inventory	Average Inventory	95% Upper Confidence Level Inventory	Performance Objective[b]
Total without non-detects[c]	3.12E-04	4.76E-04	7.91E-04	1.21E-03	25[g] and 4[h] mrem
Total with non-detects[d]	3.17E-04	4.93E-04	7.94E-04	1.22E-03	

Table 5-4. Comparison of Cumulative Incremental Lifetime Cancer Risk, Hazard Index, Radionuclide Dose, 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-110. (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	1.78E-01 pCi/L	2.72E-01 pCi/L	900 pCi/L
Iodine-129	No	<1.00E-03[d] pCi/L	<1.00E-03[d] pCi/L	1 pCi/L
Carbon-14	No	1.16E-03 pCi/L	3.49E-03 pCi/L	2,000 pCi/L
Chromium, Total*	Yes	<1.00E-03[c] µg/L	<1.00E-03[c] 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 a comparison done on Table 5-4 are summarized in Table 5-5.

Table 5-5. Comparison Summary of Cumulative Incremental Lifetime Cancer Risk, Hazard Index, Radionuclide Dose, 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-110.

Performance Metric	Comparison(s) with Performance Objective
Incremental Lifetime Cancer Risk (ILCR) for Radioactive Analytes (1.0E-06 to 1.0E-04 ILCR)	• Estimated ILCRs for all radionuclides are between one 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 nine 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 Five orders of magnitude below the performance objective for the all-pathways dose of 25 mrem/yr o Four 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 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-110 at 100 years and 500 years after closure for tank C-110 are provided in Table 5-6. 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-110 are provided in Table 5-7. 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 5-6. Comparison of Intruder Doses at 100 and 500 Years After Closure from Residual Waste for Single-Shell Tank 241-C-110.

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	0.66	21	302	3.29E-03
	95% UCL	0.91	28	399	4.57E-03
500	Average	0.09	0.025	0.53	6.70E-04
	95% UCL	0.13	0.035	0.75	9.43E-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 observations about key analytes for inadvertent intruder impacts as given in Table 5-8.

At 100 years after closure (see Table 5-6 and 5-7), doses for the well driller scenario were estimated to be ~0.13% 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 ~21% and 28% 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 ~302% and 399% of the 100 mrem/yr chronic exposure performance objective for the average and 95% UCL inventories, respectively (see Table 5-6). Doses resulting from the commercial farmer were well below (e.g., 0.003% and 0.004%) the 100 mrem/yr chronic exposure performance objective for the average and 95% UCL inventories, respectively (see Table 5-6).

By 500 years after closure (see Tables 5-6 and 5-7), the estimated doses for the well driller scenario for the average and 95% UCL inventories was ~0.018% and 0.025% 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 ~0.75% of the 100 mrem/yr performance objective (see Table 5-5).

Table 5-7. 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	0.66	0.14	0.095	0.090	0.089	0.088	0.088	0.087	0.087	0.087
95% Upper Confidence Level Inventory	0.91	0.20	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12
Inadvertent Intrusion Chronic Dose[3] (mrem/yr) – Rural Pasture Scenario										
Average Inventory	21	1.8	0.18	0.037	0.025	0.023	0.023	0.023	0.023	0.023
95% Upper Confidence Level Inventory	28	2.4	0.24	0.051	0.035	0.033	0.033	0.033	0.032	0.032
Inadvertent Intrusion Chronic Dose[3] (mrem/yr) – Suburban Gardener Scenario										
Average Inventory	302	26	2.7	0.70	0.53	0.51	0.51	0.51	0.50	0.50
95% Upper Confidence Level Inventory	399	35	3.6	0.98	0.75	0.72	0.72	0.71	0.71	0.71
Inadvertent Intrusion Chronic Dose[3] (mrem/yr) – Commercial Farm Scenario										
Average Inventory	3.3E-03	9.2E-04	7.0E-04	6.8E-04	6.7E-04	6.7E-04	6.6E-04	6.6E-04	6.5E-04	6.5E-04
95% Upper Confidence Level Inventory	4.6E-03	1.3E-03	9.8E-04	9.5E-04	9.4E-04	9.4E-04	9.3E-04	9.3E-04	9.2E-04	9.2E-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.

Table 5-8. Impact Results of Key Analytes for an Inadvertent Intruder.

Inadvertent Intrusion Scenario	Key Radionuclides			
	^{137}Cs	^{90}Sr	^{239}Pu	^{241}Am
Well Driller	Secondary contributor to dose up to ~150 yrs after closure	Primary contributor to dose up to ~160 yrs after closure	Primary contributor to dose after ~160 yrs after closure	Secondary contributor to dose ~310 yrs after closure
Rural Pasture	Secondary contributor to dose up to ~140 yrs after closure	Primary contributor to dose up to ~380 yrs after closure	Secondary contributor to dose between ~150 and ~380 yrs after closure; primary contributor to dose after ~380 yrs post-closure	Secondary contributor to dose after ~550 yrs
Suburban Gardener	Secondary contributor to dose up to ~100 yrs after closure	Primary contributor to dose up to ~360 yrs after closure	Secondary contributor to dose between ~100 and ~360 yrs after closure; primary contributor to dose after ~360 yrs post-closure	Secondary contributor to dose after ~540 yrs
Commercial Farm	Secondary contributor to dose up to ~120 yrs after closure	Primary contributors to dose up to ~150 yrs after closure	Primary contributor to dose after ~150 years post-closure	Secondary contributor to dose after ~300 yrs

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-110 compared against the *Model Toxics Control Act* (MTCA) (RCW 70.105D, "Hazardous Waste Cleanup — Model Toxics Control Act") WAC 173-340 cleanup standards. In this section, specific comparisons are made between the concentrations of constituents remaining in tank C-110 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-110 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-110 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 5-9 contains the average and 95% UCL concentrations of detected constituents estimated in residual waste for tank C-110 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 5-9 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 5-10 and 5-11, 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-110 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 5-10 and 5-11 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-10 and D-11 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. Arsenic had a concentration more than 9 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, copper, fluoride, iron, mercury, nitrate, silver, tributyl phosphate, and uranium are all above the concentration predicted by the MTCA fixed parameter three-phase model. The estimated average arsenic concentration was 176 times above the concentration protective of groundwater. Arsenic, mercury, and silver are listed as dangerous constituents per WAC 173-303-9905.

Table 5-9. Average and 95% Upper Limit Concentrations of Selected Constituents Estimated for Waste Residuals within Tank 241-C-110, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (4 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)[d,e,f]	Above Detection Limits
1, 2, 4-Trichlorobenzene*	3.01E-03	4.51E-03	3.45E+01	4.53E+03	5.63E-02	--	Yes
Aluminum	1.31E+05	1.62E+05	8.00E+04	3.50E+06	4.80E+05	1.18E+07	Yes
Arsenic*	6.01E+00	6.81E+00	6.67E-01	8.75E+01	3.41E-02	6.47E+03	Yes
Barium*	5.06E+01	7.45E+01	1.60E+04	7.00E+05	1.65E+03	1.32E+05	Yes
Bismuth	3.68E+03	4.29E+03	--	--	--	--	Yes
Boron	2.36E+00	4.45E+00	1.60E+04	7.00E+05	2.05E+02	3.89E+03	Yes
Calcium	5.91E+02	6.72E+02	--	--	--	1.72E+07	Yes
Chromium, Total*	1.13E+02	1.54E+02	1.20E+05	5.25E+06	2.00E+03	--	Yes
Cobalt	2.38E+00	2.80E+00	2.40E+01	1.05E+03	4.34E+00	1.57E+04	Yes
Copper	3.18E+02	5.75E+02	3.20E+03	1.40E+05	2.84E+02	2.20E+04	Yes
Cyanide*	8.22E-01	9.40E-01	4.80E+01	2.10E+03	9.70E-01	--	Yes
Fluoride	1.40E+04	1.70E+04	4.80E+03	2.10E+05	2.88E+03	2.81E+03	Yes
Iron	1.92E+04	2.53E+04	5.60E+04	2.45E+06	5.64E+03	3.26E+07	Yes
Lead*	5.69E+02	6.67E+02	--	1.00E+03	3.00E+03	1.02E+04	Yes
Lithium	1.36E+01	1.63E+01	1.60E+02	7.00E+03	1.92E+02	1.33E+04	Yes
Magnesium	2.85E+02	3.03E+02	--	--	--	7.06E+06	Yes
Manganese	7.70E+01	9.77E+01	1.12E+04	4.90E+05	5.01E+02	5.12E+05	Yes

Table 5-9. Average and 95% Upper Limit Concentrations of Selected Constituents Estimated for Waste Residuals within Tank 241-C-110, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (4 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)[d,e,f]	Above Detection Limits
Mercury*	1.08E+01	1.58E+01	2.40E+01	1.05E+03	2.09E+00	1.30E+01	Yes
Molybdenum	2.19E+00	3.05E+00	4.00E+02	1.75E+04	3.23E+01	4.70E+02	Yes
m-Xylene	3.40E-03	6.22E-03	1.60E+04	7.00E+05	1.35E+01	--	Yes
Nickel*	4.18E+01	4.91E+01	1.60E+03	7.00E+04	1.30E+02	1.91E+04	Yes
Nitrate[c]	6.82E+02	1.30E+03	5.68E+05	2.49E+07	1.80E+02	5.20E+04	Yes
o-Dichlorobenzene*	1.28E-03	2.04E-03	7.20E+03	3.15E+05	7.03E+00	--	Yes
o-Xylene	1.69E-03	3.03E-03	1.60E+04	7.00E+05	1.47E+01	--	Yes
Phenol*	8.43E-01	1.58E+00	2.40E+04	1.05E+06	1.10E+01	--	Yes
Phosphate	1.41E+05	1.67E+05	--	--	--	7.85E+02	Yes
Polychlorinated Biphenyls*	1.61E-02	2.83E-02	5.00E-01	6.56E+01	--	--	Yes
Potassium	4.52E+01	6.47E+01	--	--	--	2.15E+06	Yes
Silicon	2.07E+03	2.58E+03	--	--	--	--	Yes
Silver*	2.52E+01	4.05E+01	4.00E+02	1.75E+04	1.36E+01	1.67E+02	Yes
Sodium	1.21E+05	1.43E+05	--	--	--	6.90E+05	Yes
Strontium	5.70E+03	8.66E+03	4.80E+04	2.10E+06	6.76E+03	--	Yes
Polychlorinated Biphenyls*	1.61E-02	2.83E-02	5.00E-01	6.56E+01	--	--	Yes
Potassium	4.52E+01	6.47E+01	--	--	--	2.15E+06	Yes

Table 5-9. Average and 95% Upper Limit Concentrations of Selected Constituents Estimated for Waste Residuals within Tank 241-C-110, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (4 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)[d,e,f]	Above Detection Limits
Silicon	2.07E+03	2.58E+03	--	--	--	--	Yes
Silver*	2.52E+01	4.05E+01	4.00E+02	1.75E+04	1.36E+01	1.67E+02	Yes
Sodium	1.21E+05	1.43E+05	--	--	--	6.90E+05	Yes
Strontium	5.70E+03	8.66E+03	4.80E+04	2.10E+06	6.76E+03	--	Yes
Sulfate	7.55E+02	7.94E+02	--	--	1.00E+03	2.37E+05	Yes
Tin	8.53E+01	1.01E+02	4.80E+04	2.10E+06	4.80E+04	--	Yes
Titanium	4.33E+00	5.06E+00	--	--	--	2.57E+06	Yes
Tributyl phosphate	1.03E+01	2.13E+01	1.11E+02	1.46E+04	4.96E-01	--	Yes
Polychlorinated Biphenyls*	1.61E-02	2.83E-02	5.00E-01	6.56E+01	--	--	Yes
Potassium	4.52E+01	6.47E+01	--	--	--	2.15E+06	Yes
Silicon	2.07E+03	2.58E+03	--	--	--	--	Yes
Silver*	2.52E+01	4.05E+01	4.00E+02	1.75E+04	1.36E+01	1.67E+02	Yes
Sodium	1.21E+05	1.43E+05	--	--	--	6.90E+05	Yes
Strontium	5.70E+03	8.66E+03	4.80E+04	2.10E+06	6.76E+03	--	Yes
Sulfate	7.55E+02	7.94E+02	--	--	1.00E+03	2.37E+05	Yes
Tin	8.53E+01	1.01E+02	4.80E+04	2.10E+06	4.80E+04	--	Yes
Titanium	4.33E+00	5.06E+00	--	--	--	2.57E+06	Yes

Table 5-9. Average and 95% Upper Limit Concentrations of Selected Constituents Estimated for Waste Residuals within Tank 241-C-110, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (4 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)[d,e,f]	Above Detection Limits
Tributyl phosphate	1.03E+01	2.13E+01	1.11E+02	1.46E+04	4.96E-01	--	Yes
Uranium	5.56E+02	7.04E+02	2.40E+02	1.05E+04	2.70E+02	3.21E+03	Yes
Xylenes	5.00E-03	9.29E-03	1.60E+04	7.00E+05	1.46E+01	--	Yes
Zinc	2.15E+02	2.56E+02	2.40E+04	1.05E+06	5.97E+03	6.78E+04	Yes
Zirconium	3.66E+01	4.15E+01	--	--	--	3.98E+04	Yes

[a] Mean Concentrations taken from Table A-1, Appendix A of RPP-RPT-56703, *Tank 241-C-110 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-56703.

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

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

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

[f] 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 5-10. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for Average Concentrations of Selected Constituents above Detection in 241-C-110 Tank Residual Wastes. (2 sheets)

Analyte	Average Concentration (mg/kg)[a]	Ratio of Average Concentrations in Tank 241-C-110 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
1, 2, 4-Trichlorobenzene*	0.0030	8.73E-05	6.65E-07	5.35E-02	Yes	--
Aluminum	131,000	1.64E+00	3.74E-02	2.73E-01	Yes	No
Arsenic*	6.0	9.02E+00	6.87E-02	1.76E+02	Yes	No
Barium*	51	3.16E-03	7.23E-05	3.07E-02	Yes	No
Bismuth	3,680	--	--	--	Yes	--
Boron	2.4	1.48E-04	3.37E-06	1.15E-02	Yes	No
Calcium	591	--	--	--	Yes	No
Chromium, Total*	113	9.42E-04	2.15E-05	5.65E-02	Yes	--
Cobalt	2.4	9.92E-02	2.27E-03	5.48E-01	Yes	No
Copper	318	9.94E-02	2.27E-03	1.12E+00	Yes	No
Cyanide*	0.82	1.71E-02	3.91E-04	8.48E-01	Yes	--
Fluoride	14,000	2.92E+00	6.67E-02	4.85E+00	Yes	Yes
Iron	19,200	3.43E-01	7.84E-03	3.40E+00	Yes	No
Lead*	569	--	5.69E-01	1.90E-01	Yes	No
Lithium	14	8.50E-02	1.94E-03	7.08E-02	Yes	No
Magnesium	285	--	--	--	Yes	No
Manganese	77	6.88E-03	1.57E-04	1.54E-01	Yes	No
Mercury*	11	4.50E-01	1.03E-02	5.17E+00	Yes	Yes
Molybdenum	2.2	5.48E-03	1.25E-04	6.78E-02	Yes	No
m-Xylene	0.0034	2.13E-07	4.86E-09	2.52E-04	Yes	--
Nickel*	42	2.61E-02	5.97E-04	3.21E-01	Yes	No
Nitrate[b]	682	1.20E-03	2.74E-05	3.79E+00	Yes	No
o-Dichlorobenzene*	0.0013	1.78E-07	4.06E-09	1.82E-04	Yes	--

Table 5-10. Ratios of Concentrations to Cleanup Levels or Soil Concentrations Protective of Groundwater for Average Concentrations of Selected Constituents above Detection in 241-C-110 Tank Residual Wastes. (2 sheets)

Analyte	Average Concentration (mg/kg)[a]	Ratio of Average Concentrations in Tank 241-C-110 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
o-Xylene	0.0017	1.06E-07	2.41E-09	1.15E-04	Yes	--
Phenol*	0.84	3.51E-05	8.03E-07	7.68E-02	Yes	--
Phosphate	141,000	--	--	--	Yes	Yes
Polychlorinated Biphenyls*	0.016	3.22E-02	2.45E-04	--	Yes	--
Potassium	45	--	--	--	Yes	No
Silicon	2,070	--	--	--	Yes	--
Silver*	25	6.30E-02	1.44E-03	1.85E+00	Yes	No
Sodium	121,000	--	--	--	Yes	No
Strontium	5,700	1.19E-01	2.71E-03	8.43E-01	Yes	--
Sulfate	755	--	--	7.55E-01	Yes	No
Tin	85	1.78E-03	4.06E-05	1.78E-03	Yes	--
Titanium	4.3	--	--	--	Yes	No
Tributyl phosphate	10	9.27E-02	7.06E-04	2.08E+01	Yes	--
Tritium	3.58E-04	--	--	--	Yes	--
Uranium	556	2.32E+00	5.30E-02	2.06E+00	Yes	No
Xylenes	0.0050	3.13E-07	7.14E-09	3.42E-04	Yes	--
Zinc	215	8.96E-03	2.05E-04	3.60E-02	Yes	No
Zirconium	37	--	--	--	Yes	No

[a] Mean Concentrations taken from Table A-1, Appendix A of RPP-RPT-56703, *Tank 241-C-110 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.

* 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 5-11. 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-110 Tank Residual Wastes. (2 sheets)

Analyte	95% Upper Confidence Level Concentration (mg/kg)[a]	Ratio of 95% Upper Confidence Level Concentrations in Tank 241-C-110 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
1, 2, 4-Trichlorobenzene*	0.0045	1.31E-04	9.97E-07	0.080	Yes	--
Aluminum	161,554	2.0	0.046	0.34	Yes	No
Arsenic*	6.8	10	0.078	200	Yes	No
Barium*	75	0.0047	1.06E-04	0.045	Yes	No
Bismuth	4,294	--	--	--	Yes	--
Boron	4.4	2.78E-04	6.35E-06	0.022	Yes	No
Calcium	672	--	--	--	Yes	No
Chromium, Total*	154	0.0013	2.93E-05	0.077	Yes	--
Cobalt	2.8	0.12	0.0027	0.65	Yes	No
Copper	575	0.18	0.0041	2.0	Yes	No
Cyanide*	0.94	0.020	4.48E-04	0.97	Yes	--
Fluoride	16,964	3.5	0.081	5.9	Yes	Yes
Iron	25,334	0.45	0.010	4.5	Yes	No
Lead*	667	--	0.67	0.22	Yes	No
Lithium	16	0.10	0.0023	0.085	Yes	No
Magnesium	303	--	--	--	Yes	No
Manganese	98	0.0087	1.99E-04	0.20	Yes	No
Mercury*	16	0.66	0.015	7.6	Yes	Yes
Molybdenum	3.1	0.0076	1.74E-04	0.094	Yes	No
m-Xylene	0.0062	3.89E-07	8.88E-09	4.60E-04	Yes	--
Nickel*	49	0.031	7.01E-04	0.38	Yes	No
Nitrate[b]	1,305	0.0023	5.25E-05	7.2	Yes	No

Table 5-11. 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-110 Tank Residual Wastes. (2 sheets)

Analyte	95% Upper Confidence Level Concentration (mg/kg)[a]	Ratio of 95% Upper Confidence Level Concentrations in Tank 241-C-110 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
o-Dichlorobenzene*	0.0020	2.83E-07	6.47E-09	2.90E-04	Yes	--
o-Xylene	0.0030	1.89E-07	4.33E-09	2.06E-04	Yes	--
Phenol*	1.6	6.58E-05	1.50E-06	0.14	Yes	--
Phosphate	166,701	--	--	--	Yes	Yes
Polychlorinated Biphenyls*	0.028	0.057	4.32E-04	--	Yes	--
Potassium	65	--	--	--	Yes	No
Silicon	2,577	--	--	--	Yes	--
Silver*	41	0.10	0.0023	3.0	Yes	No
Sodium	143,056	--	--	--	Yes	No
Strontium	8,661	0.18	0.0041	1.3	Yes	--
Sulfate	794	--	--	0.79	Yes	No
Tin	101	0.0021	4.81E-05	0.0021	Yes	--
Titanium	5.1	--	--	--	Yes	No
Tributyl phosphate	21	0.19	0.0015	43	Yes	--
Uranium	704	2.9	0.067	2.6	Yes	No
Xylenes	0.0093	5.81E-07	1.33E-08	6.35E-04	Yes	--
Zinc	256	0.011	2.44E-04	0.043	Yes	No
Zirconium	41	--	--	--	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-56703, *Tank 241-C-110 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.

* 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, copper, fluoride, iron, mercury, nitrate, silver, strontium, tributyl phosphate, and uranium are all above the concentration predicted by the MTCA fixed parameter three-phase model, with arsenic being greater than 200 times above the concentration protective of groundwater. Arsenic, mercury, and silver 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-110 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-110 are summarized as follows.

- The impacts estimated for residual waste left in SST C-110, 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 one 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 nine 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:
    - Five orders of magnitude below the performance objective for the all-pathways dose of 25 mrem/yr
    - Four 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-110 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:** For both the average and 95% UCL inventory, fluoride, nitrate, and nitrite are the primary contributors to the 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 7.9E-04 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 100 to 400 years. Doses from ^{239}Pu and ^{241}Am contribute the majority of the dose realized after 200 to 400 years. For both average and 95% UCL inventories estimated for SST C-110, none of the inadvertent intruder evaluations produce results that exceed the performance objectives for either acute exposure or chronic exposure after ~140 years following closure.

As additional risk management information, concentrations of constituents remaining in waste residuals within tank C-110 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-110 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-110 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-110 water 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, copper, fluoride, iron, mercury, nitrate, silver, tributyl phosphate, and uranium are greater than the soil cleanup level. For the 95% UCL, mercury and silver are also above the soil cleanup level. Arsenic, mercury, and silver are listed as dangerous constituents per WAC 173-303-9905.

Table 5-12 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 5-12 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 three orders of magnitude less than the HTWOS estimate for ^{99}Tc

    - Post-retrieval inventories for chromium are approximately two orders of magnitude greater than the HTWOS estimate for chromium

    - Post-retrieval inventories for nitrate are approximately two times greater than the HTWOS estimates for nitrate

- Post-retrieval inventories for fluoride are approximately two orders of magnitude greater than the HTWOS estimate for fluoride.

- 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 four and five 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 one order of magnitude less than those in the HTWOS estimate

  - Post-retrieval inventories for ^{241}Am are approximately three orders of magnitude less than those in the HTWOS estimate

  - Post-retrieval inventories for the uranium isotopes range from six orders of magnitude greater to approximately four orders of magnitude less than estimated in the HTWOS inventory.

Table 5-12. 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	1.18E-03	1.53E-04	4.53E-04	No	N/A	N/A
	^{99}Tc	Ci	1.67E-01	4.52E-03	6.85E-03	Yes	2.71E-02	4.10E-02
	Chromium, Total	Kg	7.83E+00	1.13E+02	1.54E+02	Yes	1.44E+01	1.96E+01
	Fluoride	Kg	1.40E+02	1.40E+04	1.70E+04	Yes	1.00E+02	1.21E+02
	Nitrate	Kg	5.62E+02	6.82E+02	1.30E+03	Yes	1.21E+00	2.32E+00
	Nitrite	Kg	3.39E+01	2.77E+02	8.20E+02	No	N/A	N/A
Analytes Important for Inadvertent Intruder	^{90}Sr	Ci	9.08E+01	3.55E+02	4.66E+02	Yes	3.91E+00	5.13E+00
	^{137}Cs	Ci	2.07E+02	2.70E+00	4.06E+00	Yes	1.31E-02	1.96E-02
	^{232}Th	Ci	4.91E-12	1.17E-07	3.46E-07	No	N/A	N/A
	^{233}U	Ci	2.09E-08	9.73E-04	2.88E-03	No	N/A	N/A
	^{234}U	Ci	1.99E-02	2.67E-04	3.62E-04	Yes	1.34E-02	1.82E-02
	^{235}U	Ci	8.90E-04	1.16E-05	1.42E-05	Yes	1.30E-02	1.60E-02
	^{236}U	Ci	2.22E-04	2.96E-06	3.30E-06	Yes	1.33E-02	1.48E-02
	^{238}U	Ci	2.03E-02	2.62E-04	3.21E-04	Yes	1.29E-02	1.58E-02
	^{237}Np	Ci	5.00E-05	1.10E-04	1.31E-04	Yes	2.20E+00	2.62E+00
	^{238}Pu	Ci	1.40E-02	1.74E-03	2.29E-03	Yes	1.24E-01	1.64E-01
	^{239}Pu	Ci	1.99E+00	1.18E-01	1.61E-01	Yes	5.93E-02	8.11E-02
	^{240}Pu	Ci	2.17E-01	1.29E-02	1.77E-02	Yes	5.96E-02	8.15E-02
	^{241}Pu	Ci	3.64E-01	6.46E-02	7.44E-02	Yes	1.78E-01	2.05E-01
	^{241}Am	Ci	1.20E+00	5.10E-03	6.33E-03	Yes	4.24E-03	5.27E-03
	^{242}Cm	Ci	2.02E-04	7.03E-05	2.08E-04	No	N/A	N/A
	^{243}Cm	Ci	2.25E-06	1.07E-05	3.17E-05	No	N/A	N/A
	^{244}Cm	Ci	5.06E-05	2.27E-04	6.72E-04	No	N/A	N/A

[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

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-110 waste retrieval operations, provides recommendations for further actions, and addresses opportunities to refine waste retrieval technologies based on lessons learned from the tank C-110 retrieval operation. The format of this section is to provide brief discussions of the major Lessons-Learned topic areas; some of those areas are taken from other tank waste retrieval activities.

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-110 retrieval operation.

Improvements implemented during the retrieval of tank C-110 are as follows.

- Based on lessons learned from tank 241-C-109 retrieval, the off-riser sampler/crawler was removed from tank C-110 before retrieval commenced.
- Transfer switch boards were used to eliminate the need to change wiring and to automate valve alignment to transfer waste to different tanks.
- Towards the end of retrieval, hot water was effective at dissolving waste after sluicing with larger volumes of water. Hot water was used to cover the waste during displacement measurements, allowing it to soak in the water pool for at least one shift before pumping it down.
- The Cold Test Facility was used to practice insertion of the MRT, which directly resulted in improving the construction testing and installation in the field.
- Modifications to the MRT, such as track and connections and fittings enhancements, worked well as a result of extensive testing at the Cold Test Facility.
- The MRT was most effective using hot water at a maximum flow and pressure.
- Pump-down efficiency appeared to be enhanced by the use of the MRT to apply high-pressure water near the pump during the pumping.
- Hard heel sluicing using supernate was most effective when the MRT and high-pressure water were used in parallel.
- Sluicing efficiency and pump uptake were enhanced by using the high-pressure flow from the MRT as a backstop.

- In order to reduce particle size enough for pump in-take, the MRT was used to grind the waste against the tank bottom. Using the MRT flow nozzles as a backstop appeared to be more efficient and required less time compared to grinding waste against the tank bottom.

6.1 MOBILE RETRIEVAL TOOL POTENTIAL ENHANCEMENTS

Dropping the full length of umbilical to the floor as required by the current winch design resulted in the cord forming dams, impacting slurry drainage and flow of solids to the pump; more drag on the cord may also have led to earlier wear of the cord and hydraulic leaks at the connection with the MRT. Therefore, more MRT movement and maneuvering was required to get around the cord and push the waste toward the pump. A modification to the winch design is needed to optimize the length of the MRT umbilical cord placed on the tank floor.

The cause(s) of the hydraulic leak near the MRT during right track reverse movement and later during left track movement needs to be evaluated, and changes implemented as needed, to minimize or prevent hydraulic leaks from the MRT.

The MRT umbilical cord was bent at the Cold Test Facility and needed to be straightened before installation. Care should be taken to avoid excessive bends/looping in the umbilical cord prior to installation.

Mechanical problems with the control pressure on the high-pressure water skid (e.g., Pulsation dampener and failed pressure switch) could possibly have been identified and fixed sooner. The design may be more complicated than needed and a better way to control the pressure should be identified.

The following additional MRT design changes were identified:

- A heavy duty pig-tail type of spring and/or angled fittings should be incorporated to protect hydraulic hoses at FoldTrack® Vehicle/Umbilical connection point to reduce hose stress and increase bend radius

- Hydraulic rams for the blade "UP" and "DOWN" functions should be modified to "push" to raise the blade and "pull" to lower the blade

- All parts should be constructed to be compliant with American Standards (e.g., fittings, fasteners, hoses, seals)

- Blade should be modified to be able to lower several degrees beyond horizontal to allow for more effective "back-blading/dragging"

- All bearings should be fully sealed to protect against corrosive liquid

- Incorporation of hydraulic line air bleed valves on the umbilical interface (highest elevation point in lines) would be beneficial.

6.2 SLUICING EQUIPMENT AND OPERATION

At times, the sluicers pushed waste from one side of the tank to the other, but did not always move waste to the pump effectively. Improved directions and changing of sluicers used may have enhanced sluicing effectiveness.

6.3 OTHER POTENTIAL ENHANCEMENTS

Use of the same riser for the camera and light resulted in wrapping the camera around the light and limiting or impacting camera mobility. Use of separate risers for each should be considered for future retrievals.

Volume balance results need to be more consistent and complete. The volume balance estimates had to be revised and reset several times. The key reasons identified were inaccurate low flow meter measurements and neglecting evaporation.

a. Before retrieval starts, need to ensure meters are calibrated for accurate low flow meter measurements and use meters capable of providing accurate low flow.

b. Although the original plan was to use little or no water during mechanical removal (<2 gpm, just enough to prevent plugging of the nozzles), the MRT flow rate had to be increased to >5 gpm for the flow meter provided to work correctly.

c. When using hot water, evaporation during retrieval is high and must be considered in volume balance estimates.

The hot water skid was designed for high flow. A better low flow design (e.g., Flow meters) should be considered for future retrievals.

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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, or minimize leak volumes.

The operational history and decades of waste and liquid level monitoring indicate that tank C-110 had not leaked and was sound before starting retrieval (HNF-EP-0182, *Waste Tank Summary Report for Month Ending January 31, 2014*, Rev. 310). Additionally, there was no evidence of a leak during retrieval of waste from tank C-110.

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-110 waste retrieval were as follows.

a. Drywell moisture and gamma logging showed no evidence of leaks during the tank C-110 waste retrieval.

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

c. Material balance calculations showed no evidence of leaks during the tank C-110 waste retrieval.

d. A high-resolution resistivity (HRR) system was deployed with drywells and the tank thermocouple as electrodes to detect changes in baseline soil moisture levels.

Retrieval of tank C-110 was begun and the majority of the waste in the tank was removed under work plan RPP-33116, Revision 2. Work plan RPP-33116, Revision 3 (and any additional revisions to this work plan) was applicable to the remaining tank C-110 waste retrieval operations.

7.1 REQUIREMENTS

Details of the LDMM program are presented in RPP-33116. 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-110 LDM functions and requirements.

Table 7-1. Tank 241-C-110 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 RP103DT.	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.

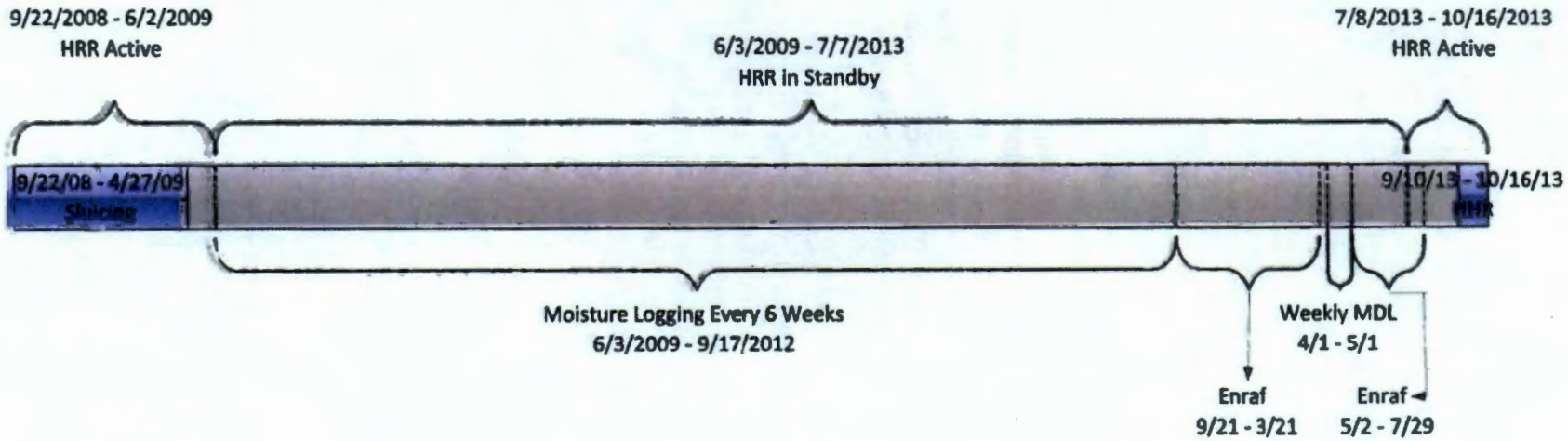
CFR = *Code of Federal Regulations* DOE = U.S. Department of Energy SST = single-shell tank

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 the sluicing retrieval of tank C-110, HRR was used as the primary leak detection method with drywell moisture logging as a backup. Between sluicing and hard heel retrieval, Enraf® level measurements and drywell moisture loggings were used for leak detection. When hard heel retrieval operations started, HRR was again used as the primary leak detection method. Figure 7-1 is a timeline of retrieval operations and the leak detection methods used. Leak detection and monitoring was accomplished by the use of 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 7.2.3.

Figure 7-1. Tank 241-C-110 Leak Detection Monitoring Timeline.



HHR = hard heel retrieval
HRR = high-resolution resistivity
MDL = minimum detection limit

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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-110	Drywells, liquid level indicators, visual inspection, material balance and high-resolution resistivity
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

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 has less credibility. It cannot be proven that an electrical pathway exists through the thermocouple and tank structure, although it is likely a pathway exists through structural rebar. Before sluicing finished in tank C-110, the thermocouple tree was not in contact with the waste and WTW resistivity measurements were relied on more heavily for leak determinations. At times during hard heel retrieval operations the thermocouple tree may have once again been in contact with the waste, but a break was observed in the thermocouple tree, so electrical pathway contact with the waste was not assumed from the time of the observation until the completion of retrieval. During sluicing and hard heel retrieval, a leak determination was made for each day of operation.

During the first phase of retrieval when sluicing was the main retrieval technology, several anomalous results were evaluated. Table 7-3 identifies the anomalies and provides a description of the anomaly and the resolution for both the sluicing and hard heel retrieval phases. None of the anomalous data indicated a leak of the tank.

For a short time prior to the start of hard heel retrieval, level measurements with an Enraf® were used for leak detection. Liquid was added to the tank to precondition/soften the waste by soaking the hard solids. Level measurements were used for leak detection from September 21, 2012 to March 21, 2013 and again from May 2, 2013 to July 29, 2013. An extended electrical power outage de-energized the Enraf® so level measurements were not available, and weekly drywell moisture logging was used to monitor for leaks until power was restored to the Enraf®. The HRR system was operated during hard heel retrieval which started August 14, 2013 and

completed October 16, 2013. During most of the hard heel retrieval period, the tank thermocouple was not in contact with the waste and the WTW measurements were relied upon for leak determination. The WTW HRR data was reviewed every day during hard heel retrieval; no leaks were indicated.

Table 7-3. High-Resolution Resistivity Anomaly Evaluation During and After Sluicing.

Number	Date	Anomaly Description	Resolution/Comments
2008-12	11/6/08	Unusual WTT and WTW exceedance values were noted. Plots were made and evaluated and there were no trends indicating a leak.	No leak indicated. The HRR service provider was able to find that erroneous data files had been used to calculate the exceedance values. After the erroneous data files were removed the exceedance values returned to normal.
2009-1	1/2/09	High WTW exceedance values.	No leak indicated. The WTT exceedance values and plots were normal. There was a correlation to rain.
2009-1, Rev. 1	1/5/09	Same description as 2009-1.	No leak indicated. An update was provided stating that WTT values remained unchanged and that the WTW exceedance values had returned to normal. A stronger conclusion was made that the high WTW exceedance values were due to rain.
2009-2	1/8/09	High WTW exceedance values.	No leak indicated. The WTT exceedance values and plots were normal. There was a correlation to rain.
2013-04	9/17/13	Both WTT and WTW leak potential values went high.	No leak indicated. The abrupt shifts were correlated to rain, stopping and starting the system to protect from lightning, and the cathodic protection system being turned back on.
2013-05	10/2/13	Tank electrode (thermocouple tree) failed.	No leak indicated. During hard heel retrieval a break was observed in the thermocouple tree that was being used for the tank electrode. The thermocouple tree is a sealed pipe with internal wires and thermocouples. The internal wires were still connected but the pipe was separated and the lower portion was standing on the waste or tank bottom. The tank electrode was not touching the waste after sluicing retrieval and would not have been in contact with the waste during most of the hard heel retrieval so there was no proven reduction in the quality of the HRR data. Even with the break in the thermocouple tree pipe a connection to the tank and waste could have existed through the dome re-bar.

HRR = high-resolution resistivity WTT = drywell-to-tank WTW = drywell-to-drywell

Subsequent to tank C-110 retrieval, additional drywell logging was performed by a subcontractor [RPP-RPT-57321, *241-C-110 Tank Waste Retrieval Project Final Report of Drywell Monitoring Data (HGLP-MBL-014, Rev. 0)*]. None of the drywells around tank C-110 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-110

7.2.2.1 Liquid Level Monitoring. The overall waste retrieval operating strategy for tank C-110 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.

No active retrieval occurred during the following stagnant periods:

a. 2009: April 27, 2009 through December 31, 2009
b. All of 2010 through 2012
c. 2013: January 1, 2013 through April 14, 2013.

During these stagnant periods, liquid levels in tanks C-110 and AN-106 did not decrease, indicating that no leaks occurred.

7.2.2.2 Visual Inspection. Before initiating waste retrieval operations, a visual assessment and documentation of in-tank conditions in tank C-110 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-110 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-110 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-110.

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-110 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. Tank C-110 was retrieved from the center out

c. Liquid was 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 additions were minimized and liquid pools were removed as practical.

b. Tank C-110 was retrieved from the center out.

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

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

7.3.1 Single-Shell Tank 241-C-110

A summary of the tank C-110 mitigation actions to minimize or prevent a leak were as follows.

a. The addition of water to the retrieval tank was minimized to the extent practical.

b. 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-110 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-33116), Sections 4.6.1 and 4.6.2.

7.3.2 Double-Shell Tank 241-AN-106

Mitigating actions for a leak from AN-106 primary tank piping into the secondary DST containment system during a waste transfer from tank C-110 would have included (1) stopping the flow of waste into the tank system (stopping the transfer), (2) pumping waste in the primary tank to another DST until the liquid level in the secondary containment was no longer increasing, and (3) removing the waste from the secondary containment system as soon as practicable. Leaks at or near the AN-106 tank bottom might have required saltwell jet pumping to remove trapped liquids from between solid layers in the tank. Transfer line leakage would have drained to a common point for collection, detection, and removal.

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-110 waste retrieval operations. The tank C-110 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-110 as set forth in RPP-33116 was achieved.

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APPENDIX A

SINGLE-SHELL TANK 241-C-110 INVENTORY PRE- AND POST-SLUICING TECHNOLOGY RETRIEVAL

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APPENDIX A

SINGLE-SHELL TANK 241-C-110 INVENTORY PRE- AND POST-SLUICING TECHNOLOGY RETRIEVAL

Table A-1. Single-Shell Tank 241-C-110 Best-Basis Inventory Pre-Retrieval Inventory and Post-Sluicing Operations. (2 sheets)

Constituent Name	BBI February 2005[a]	BBI April 2014[b]			Constituent Name	BBI February 2005[a]	BBI April 2014[b]	
Volume (Kgal)	178	2.1						
Analyte	Inventory	Inventory	Unit		Analyte	Inventory	Inventory	Unit
Al	1.31E+04	1.29E+03	Kg		^{99}Tc	3.18E+01	4.46E-02	Ci
Bi	1.48E+04	3.63E+01	Kg		^{106}Ru	3.86E-11	4.80E-14	Ci
Ca	1.05E+03	5.84E+00	Kg		^{113m}Cd	4.56E-02	7.01E-04	Ci
Cl	9.91E+02	6.26E-01	Kg		^{125}Sb	6.07E-04	4.17E-06	Ci
CN	2.87E+00	4.89E+02	Kg		^{126}Sn	3.79E-03	2.38E-02	Ci
Cr	4.20E+02	1.12E+00	Kg		^{129}I	4.00E-04	2.65E-04	Ci
F	6.75E+03	1.38E+02	Kg		^{134}Cs	4.62E-07	2.27E-09	Ci
Fe	9.84E+03	1.90E+02	Kg		^{137}Cs	1.35E+04	2.66E+01	Ci
Hg	3.98E-01	1.07E-01	Kg		^{137m}Ba	1.27E+04	2.51E+01	Ci
K	5.11E+02	4.46E-01	Kg		^{151}Sm	7.98E+01	1.45E+00	Ci
La	1.33E+00	9.98E-03	Kg		^{152}Eu	2.55E-03	3.90E-05	Ci
Mn	4.76E+01	7.61E-01	Kg		^{154}Eu	1.72E-01	2.34E-03	Ci
Na	7.53E+04	1.20E+03	Kg		^{155}Eu	7.43E-02	7.77E-04	Ci
Ni	2.17E+01	4.13E-01	Kg		^{226}Ra	5.01E-06	9.32E-08	Ci
NO_2	6.53E+03	2.74E+00	Kg		^{227}Ac	4.28E-05	1.41E-06	Ci
NO_3	9.80E+04	6.73E+00	Kg		^{228}Ra	5.61E-11	2.48E-12	Ci
Oxalate	7.94E+02	1.02E+00	Kg		^{229}Th	1.58E-08	2.95E-10	Ci
Pb	2.20E+02	5.62E+00	Kg		^{231}Pa	3.20E-04	5.96E-06	Ci
PO_4	5.68E+04	1.40E+03	Kg		^{232}Th	1.33E-10	2.48E-12	Ci
Si	6.33E+03	2.05E+01	Kg		^{232}U	8.05E-06	2.15E-08	Ci
SO_4	1.11E+04	7.46E+00	Kg		^{233}U	6.70E-07	1.86E-09	Ci
Sr	1.12E+02	5.63E+01	Kg		^{234}U	6.46E-01	2.64E-03	Ci
TIC as CO_3	9.42E+03	4.89E+02	Kg		^{235}U	2.89E-02	1.14E-04	Ci
TOC	4.12E+02	1.20E+01	Kg		^{236}U	7.22E-03	2.93E-05	Ci

Table A-1. Single-Shell Tank 241-C-110 Best-Basis Inventory Pre-Retrieval Inventory and Post-Sluicing Operations. (2 sheets)

Constituent Name	BBI February 2005[a]	BBI April 2014[b]			Constituent Name	BBI February 2005[a]	BBI April 2014[b]	
Volume (Kgal)	178	2.1						
Analyte	Inventory	Inventory	Unit		Analyte	Inventory	Inventory	Unit
U_{TOTAL}	1.97E+03	5.49E+00	Kg		^{237}Np	1.74E-03	1.09E-03	Ci
Zr	1.50E+02	3.62E-01	Kg		^{238}Pu	4.56E-01	1.72E-02	Ci
^{3}H	5.70E-01	3.53E-03	Ci		^{238}U	6.59E-01	2.59E-03	Ci
^{14}C	3.33E-01	1.51E-03	Ci		^{239}Pu	6.48E+01	1.17E+00	Ci
^{59}Ni	9.81E-03	1.83E-04	Ci		^{240}Pu	7.05E+00	1.27E-01	Ci
^{60}Co	6.22E-02	6.90E-04	Ci		^{241}Am	3.86E+01	5.04E-02	Ci
^{63}Ni	1.36E+00	4.43E-01	Ci		^{241}Pu	1.18E+01	6.38E-01	Ci
^{79}Se	1.24E-03	4.21E-05	Ci		^{242}Cm	6.79E-03	9.28E-06	Ci
^{90}Sr	3.45E+03	3.50E+03	Ci		^{242}Pu	9.80E-05	1.77E-06	Ci
^{90}Y	3.45E+03	3.50E+03	Ci		^{243}Am	3.98E-03	5.55E-06	Ci
^{93m}Nb	1.16E+00	2.21E-02	Ci		^{243}Cm	7.58E-05	9.61E-08	Ci
^{93}Zr	1.28E+00	2.41E-02	Ci		^{244}Cm	1.70E-03	2.04E-06	Ci

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

[a] RPP-33116, 2013, *241-C-110 Tank Waste Retrieval Work Plan*, Rev. 3, Washington River Protection Solutions, LLC, Richland, Washington.

[b] RPP-RPT-56703, 2014, *Tank 241-C-110 Residual Waste Inventory Estimates for Component Closure Risk Assessment*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

APPENDIX B

MEAN CONCENTRATIONS AND RELATIVE STANDARD DEVIATIONS FOR TANK 241-C-110 RESIDUAL SOLIDS

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APPENDIX B

MEAN CONCENTRATIONS AND RELATIVE STANDARD DEVIATIONS FOR TANK 241-C-110 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-110 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-56703, *Tank 241-C-110 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-110. 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. Mean Concentrations[1] and Relative Standard Deviations for Selected Constituents in Tank 241-C-110 Residual Solids. (4 Sheets)

Constituent Name	Chemical Abstract Services Number	< Detection Limit	Mean Concentration[1]	Units	Relative Standard Deviation[2]
^{125}Sb	14234-35-6	<	4.25E-01	µCi/g	1.00E+00
^{126}Sn	15832-50-5		2.41E-03	µCi/g	2.06E-01
^{129}I	15046-84-1	<	2.33E-05	µCi/g	1.00E+00
^{137}Cs	10045-97-3		2.70E+00	µCi/g	2.57E-01
^{137m}Ba	N/A		2.54E+00	µCi/g	2.57E-01
^{14}C	14762-75-5	<	1.53E-04	µCi/g	1.00E+00
^{152}Eu	14683-23-9	<	1.12E-01	µCi/g	1.00E+00
^{154}Eu	15585-10-1	<	1.24E-01	µCi/g	1.00E+00
^{155}Eu	14391-16-3	<	2.90E-01	µCi/g	1.00E+00
^{228}Th	14274-82-9	<	2.16E-05	µCi/g	1.00E+00
^{230}Th	14269-63-7	<	2.91E-04	µCi/g	1.00E+00
^{231}Pa	14331-85-2	<	6.67E-04	µCi/g	1.00E+00
^{232}Th	N/A	<	1.17E-07	µCi/g	1.00E+00
^{233}U	13968-55-3	<	9.73E-04	µCi/g	1.00E+00
^{234}U	13966-29-5		2.67E-04	µCi/g	1.81E-01
^{235}U	15117-96-1		1.16E-05	µCi/g	1.16E-01
^{236}U	13982-70-2		2.96E-06	µCi/g	5.78E-02
^{237}Np	13994-20-2		1.10E-04	µCi/g	9.72E-02
^{238}Pu	13981-16-3		1.74E-03	µCi/g	1.61E-01
^{238}U	N/A		2.62E-04	µCi/g	1.15E-01
^{239}Pu	15117-48-3		1.18E-01	µCi/g	1.88E-01
^{240}Pu	14119-33-6		1.29E-02	µCi/g	1.88E-01
^{241}Am	14596-10-2		5.10E-03	µCi/g	1.23E-01
^{241}Pu	14119-32-5		6.46E-02	µCi/g	7.76E-02
^{242}Cm	15510-73-3	<	7.03E-05	µCi/g	1.00E+00
^{242}Pu	13982-10-0		1.79E-07	µCi/g	1.88E-01
^{243}Cm	15757-87-6	<	1.07E-05	µCi/g	1.00E+00
^{244}Cm	13981-15-2	<	2.27E-04	µCi/g	1.00E+00
2-Butanone	78-93-3	<	1.55E-02	µg/g	1.00E+00
^{3}H	15086-10-9		3.58E-04	µCi/g	1.36E-01
^{60}Co	10198-40-0	<	6.22E-02	µCi/g	1.00E+00

Table B-1. Mean Concentrations[1] and Relative Standard Deviations for Selected Constituents in Tank 241-C-110 Residual Solids. (4 Sheets)

Constituent Name	Chemical Abstract Services Number	< Detection Limit	Mean Concentration[1]	Units	Relative Standard Deviation[2]
^{63}Ni	13981-37-8		4.48E-02	µCi/g	1.02E-01
^{79}Se	15758-45-9	<	5.09E-04	µCi/g	1.00E+00
^{90}Sr	10098-97-2		3.55E+02	µCi/g	1.59E-01
^{90}Y	10098-91-6		3.55E+02	µCi/g	1.59E-01
^{99}Tc	14133-76-7		4.52E-03	µCi/g	2.63E-01
1,2,4-Trichlorobenzene	120-82-1		3.01E-03	µg/g	2.55E-01
1,2-Dichlorobenzene	95-50-1		1.28E-03	µg/g	3.02E-01
1,4-Dichlorobenzene	106-46-7	<	7.07E-04	µg/g	1.00E+00
Acetate	71-50-1	<	1.11E+02	µg/g	1.00E+00
Acetone	67-64-1	<	2.01E-02	µg/g	1.00E+00
Ag	7440-22-4		2.52E+01	µg/g	3.10E-01
Al	7429-90-5		1.31E+05	µg/g	1.19E-01
Aroclors (Total PCB dry weight basis)	1336-36-3		1.61E-02	µg/g	3.88E-01
As	7440-38-2		6.01E+00	µg/g	6.80E-02
B	7440-42-8		2.36E+00	µg/g	4.51E-01
Ba	7440-39-3		5.06E+01	µg/g	2.41E-01
Be	7440-41-7	<	1.01E+00	µg/g	1.00E+00
Bi	7440-69-9		3.68E+03	µg/g	8.51E-02
Br	24959-67-9	<	5.94E+01	µg/g	1.00E+00
Ca	7440-70-2		5.91E+02	µg/g	7.02E-02
Cd	7440-43-9	<	1.01E+00	µg/g	1.00E+00
Ce	7440-45-1	<	1.31E+03	µg/g	1.00E+00
Cl	16887-00-6	<	6.33E+01	µg/g	1.00E+00
CN	57-12-5		8.22E-01	µg/g	7.32E-02
Co	7440-48-4		2.38E+00	µg/g	9.06E-02
Cr	7440-47-3		1.13E+02	µg/g	1.84E-01
Cu	7440-50-8		3.18E+02	µg/g	4.13E-01
Ethylbenzene	100-41-4	<	1.23E-03	µg/g	1.00E+00
Eu	7440-53-1	<	1.01E+00	µg/g	1.00E+00
F	16984-48-8		1.40E+04	µg/g	1.08E-01
Fe	7439-89-6		1.92E+04	µg/g	1.63E-01

Table B-1. Mean Concentrations[1] and Relative Standard Deviations for Selected Constituents in Tank 241-C-110 Residual Solids. (4 Sheets)

Constituent Name	Chemical Abstract Services Number	< Detection Limit	Mean Concentration[1]	Units	Relative Standard Deviation[2]
Formate	12311-97-6	<	1.66E+02	µg/g	1.00E+00
Free OH	N/A		1.29E+02	µg/g	1.17E-01
Glycolate	666-14-8	<	6.33E+01	µg/g	1.00E+00
Hexone	108-10-1	<	1.35E-02	µg/g	1.00E+00
Hg	7439-97-6		1.08E+01	µg/g	2.37E-01
K	7440-09-7		4.52E+01	µg/g	2.20E-01
La	7439-91-0	<	1.01E+00	µg/g	1.00E+00
Li	7439-93-2		1.36E+01	µg/g	1.02E-01
Mg	7439-95-4		2.85E+02	µg/g	3.25E-02
Mn	7439-96-5		7.70E+01	µg/g	1.37E-01
Mo	7439-98-7		2.19E+00	µg/g	2.01E-01
Na	7440-23-5		1.21E+05	µg/g	9.30E-02
Nb	7440-03-1	<	6.06E+00	µg/g	1.00E+00
Nd	7440-00-8	<	1.51E+01	µg/g	1.00E+00
NH_3	7664-41-7		1.67E+00	µg/g	1.48E-01
Ni	7440-02-0		4.18E+01	µg/g	8.87E-02
NO_2	14797-65-0	<	2.77E+02	µg/g	1.00E+00
NO_3	14797-55-8		6.82E+02	µg/g	4.66E-01
Oxalate	338-70-5	<	1.03E+02	µg/g	1.00E+00
Pb	7439-92-1		5.69E+02	µg/g	8.75E-02
Pd	7440-05-3	<	1.21E+01	µg/g	1.00E+00
Phenol	108-95-2		8.43E-01	µg/g	4.45E-01
PO_4	14265-44-2		1.41E+05	µg/g	9.30E-02
Pr	7440-10-0	<	2.63E+01	µg/g	1.00E+00
Rb	7440-17-7	<	5.76E+01	µg/g	1.00E+00
Rh	7440-16-6	<	9.09E+00	µg/g	1.00E+00
Ru	7440-18-8	<	4.04E+00	µg/g	1.00E+00
Sb	7440-36-0	<	6.06E+00	µg/g	1.00E+00
Se	7782-49-2	<	4.04E+00	µg/g	1.00E+00
Si	7440-21-3		2.07E+03	µg/g	1.25E-01
Sm	7440-19-9	<	1.72E+01	µg/g	1.00E+00

Table B-1. Mean Concentrations[1] and Relative Standard Deviations for Selected Constituents in Tank 241-C-110 Residual Solids. (4 Sheets)

Constituent Name	Chemical Abstract Services Number	< Detection Limit	Mean Concentration[1]	Units	Relative Standard Deviation[2]
Sn	7440-31-5		8.53E+01	µg/g	9.34E-02
SO_4	14808-79-8		7.55E+02	µg/g	2.62E-02
Sr	7440-24-6		5.70E+03	µg/g	2.65E-01
Ta	7440-25-7	<	5.05E+00	µg/g	1.00E+00
Te	13494-80-9	<	8.08E+00	µg/g	1.00E+00
Th	7440-29-1	<	1.06E+00	µg/g	1.57E-01
Ti	7440-32-6		4.33E+00	µg/g	8.57E-02
Tl	7440-28-0	<	4.34E+00	µg/g	1.00E+00
Tributyl phosphate	126-73-8		1.03E+01	µg/g	5.43E-01
Trichloroethene	79-01-6	<	9.54E-04	µg/g	1.00E+00
U	7440-61-1		5.56E+02	µg/g	1.36E-01
V	7440-62-2	<	1.24E+00	µg/g	1.00E+00
W	7440-33-7	<	1.62E+01	µg/g	1.00E+00
Xylene (m & p)	108-28-3M		3.40E-03	µg/g	4.23E-01
Xylene (o)	95-47-6		1.69E-03	µg/g	4.05E-01
Xylenes (total)	1330-20-7		5.00E-03	µg/g	4.38E-01
Y	7440-65-5	<	1.08E+00	µg/g	1.00E+00
Zn	7440-66-6		2.15E+02	µg/g	9.74E-02
Zr	7440-67-7		3.66E+01	µg/g	6.77E-02

µg/g = micrograms per gram µCi/g = microcurie per gram N/A = not available

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

[2] In accordance with the Best-Basis Inventory protocol, the relative standard deviation is assumed to be 1 if the constituent was not detected.

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-56703, 2014, *Tank 241-C-110 Residual Waste Inventory Estimates for Component Closure Risk Assessment*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

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

APPENDIX C

COMPARISON OF SINGLE-SHELL TANK 241-C-110 FINAL INVENTORY TO SINGLE-SHELL TANK 241-C-110 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-110 FINAL INVENTORY TO SINGLE-SHELL TANK 241-C-110 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-110 Final Inventory to Single-Shell Tank 241-C-110 Inventory Used in DOE/ORP-2005-01.

Analyte	Units	DOE/ORP-2005-01, Rev. 0	RPP-RPT-56703, Rev. 0 Average Inventory	RPP-RPT-56703, Rev. 0 Upper Bounding Inventory
Tritium	Ci	1.68E-03	3.53E-03	4.52E-03
C-14	Ci	1.18E-03	1.51E-03	4.53E-03
I-129	Ci	1.18E-06	2.30E-04	6.90E-04
Tc-99	Ci	1.67E-01	4.46E-02	6.81E-02
Cr	kg	7.83E+00	1.12E+00	1.54E+00
F	kg	1.40E+02	1.38E+02	1.69E+02
NO_2	kg	3.39E+01	2.74E+00	8.22E+00
NO_3	kg	5.62E+02	6.73E+00	1.30E+01
U	kg	6.09E+01	5.49E+00	7.02E+00

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-56703, 2014, *Tank 241-C-110 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-110

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APPENDIX D

RISK ASSESSMENT INFORMATION FOR RESIDUAL WASTES REMAINING IN SINGLE-SHELL TANK 241-C-110

This appendix provides risk assessment information related to post-retrieval inventories estimated to remain in single-shell tank (SST) 241-C-110 (C-110). The potential risk impacts to human health posed by the residual waste in SST C-110 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-110 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-110, 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-110 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-110 (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-110 (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-110 (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-110 (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-110 (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-110 (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-110 (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-110 (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-110 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-110 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-110.

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-110. (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		
Antimony-125	No	2.10E+00	0.00E+00	DNA	1.00E+00	2.73E+00	NE	NE	NE	NE
Americium-241	Yes	5.04E-02	0.00E+00	DNA	3.00E+00	4.33E+02	NE	NE	NE	NE
Barium-137m	Yes	2.51E+01	0.00E+00	DNA	0.00E+00	4.86E-06	NE	NE	NE	NE
Carbon-14	No	7.55E-04	1.16E-03	9.78E+03	0.00E+00	5.73E+03	9.03E-12	6.53E-11	5.63E-06	2.33E-06
Cesium-137 + Daughters	Yes	2.66E+01	0.00E+00	DNA	2.50E+01	3.00E+01	NE	NE	NE	NE
Cobalt-60	No	3.07E-01	0.00E+00	DNA	1.00E-01	5.27E+00	NE	NE	NE	NE
Curium-242	No	3.47E-04	0.00E+00	DNA	3.00E+00	4.46E-01	NE	NE	NE	NE
Curium-243	No	5.30E-05	0.00E+00	DNA	3.00E+00	2.85E+01	NE	NE	NE	NE
Curium-244	No	1.12E-03	0.00E+00	DNA	3.00E+00	1.81E+01	NE	NE	NE	NE
Europium-152	No	5.55E-01	0.00E+00	DNA	1.00E+00	1.33E+01	NE	NE	NE	NE
Europium-154	No	6.10E-01	0.00E+00	DNA	1.00E+00	8.59E+00	NE	NE	NE	NE
Europium-155	No	1.43E+00	0.00E+00	DNA	1.00E+00	4.68E+00	NE	NE	NE	NE
Iodine-129	No	1.15E-04	<1.00E-03	1.20E+04	2.00E-01	1.57E+07	NE	NE	NE	NE
Neptunium-237 + D	Yes	1.09E-03	0.00E+00	DNA	2.00E+00	2.14E+06	NE	NE	NE	NE
Nickel-63	Yes	4.43E-01	0.00E+00	DNA	4.80E+01	1.00E+02	NE	NE	NE	NE
Plutonium-238	Yes	1.72E-02	0.00E+00	DNA	3.00E+00	8.77E+01	NE	NE	NE	NE
Plutonium-239	Yes	1.17E+00	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-110. (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	1.27E-01	0.00E+00	DNA	3.00E+00	6.56E+03	NE	NE	NE	NE
Plutonium-241 + D	Yes	6.38E-01	0.00E+00	DNA	3.00E+00	1.44E+01	NE	NE	NE	NE
Plutonium-242	Yes	1.77E-06	0.00E+00	DNA	3.00E+00	3.74E+05	NE	NE	NE	NE
Protactinium-231	No	3.30E-03	0.00E+00	DNA	5.50E+02	3.28E+04	NE	NE	NE	NE
Selenium-79	No	2.52E-03	0.00E+00	DNA	3.10E+00	8.05E+05	NE	NE	NE	NE
Strontium-90 + D	Yes	3.50E+03	0.00E+00	DNA	1.61E+01	2.81E+01	NE	NE	NE	NE
Technetium-99	Yes	4.46E-02	1.78E-01	1.05E+04	0.00E+00	2.11E+05	2.45E-09	5.98E-08	3.12E-04	7.91E-04
Thorium-228 + D	No	1.07E-04	0.00E+00	DNA	3.00E+00	1.91E+00	NE	NE	NE	NE
Thorium-230	No	1.44E-03	0.00E+00	DNA	3.00E+00	7.54E+04	NE	NE	NE	NE
Thorium-232	No	5.80E-07	0.00E+00	DNA	3.00E+00	1.41E+10	NE	NE	NE	NE
Tin-126	Yes	2.38E-02	0.00E+00	DNA	1.00E+00	2.46E+05	NE	NE	NE	NE
Tritium	Yes	3.53E-03	0.00E+00	DNA	0.00E+00	1.23E+01	NE	NE	NE	NE
Uranium-233	No	4.81E-03	0.00E+00	DNA	6.00E-01	1.59E+05	NE	NE	NE	NE
Uranium-234	Yes	2.64E-03	0.00E+00	DNA	6.00E-01	2.46E+05	NE	NE	NE	NE
Uranium-235 + D	Yes	1.14E-04	0.00E+00	DNA	6.00E-01	7.04E+08	NE	NE	NE	NE
Uranium-236	Yes	2.93E-05	0.00E+00	DNA	6.00E-01	2.34E+07	NE	NE	NE	NE
Uranium-238 + D	Yes	2.59E-03	0.00E+00	DNA	6.00E-01	4.47E+09	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-110. (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	3.50E+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-110. (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	1.29E+03	0.00E+00	DNA	1.00E+00	NE	NE
Ammonia	Yes	1.65E-02	<1.00E-03	1.05E+04	9.30E-04	NE	NE
Antimony[a]	No	3.00E-02	0.00E+00	DNA	1.00E+00	NE	NE
Arsenic[a]	Yes	5.93E-02	0.00E+00	DNA	3.90E+01	NE	NE
Barium[a]	Yes	5.00E-01	0.00E+00	DNA	6.00E+01	NE	NE
Beryllium[a]	No	4.99E-03	0.00E+00	DNA	7.00E+01	NE	NE
Bismuth	Yes	3.63E+01	1.49E-01	1.05E+04	0.00E+00	No CPF	No Rfd
Boron	Yes	2.33E-02	0.00E+00	DNA	3.00E+00	NE	NE
Bromide	No	2.94E-01	1.20E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Cadmium[a]	No	4.99E-03	0.00E+00	DNA	1.26E+00	NE	NE
Calcium	Yes	5.84E+00	0.00E+00	DNA	4.00E+00	NE	NE
Cerium	No	6.50E+00	2.67E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Chloride	No	3.13E-01	1.29E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Chromium, Total[a]	Yes	1.12E+00	4.60E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Cobalt	Yes	2.35E-02	<1.00E-03	1.20E+04	1.00E-01	NE	NE
Copper	Yes	3.15E+00	0.00E+00	DNA	3.50E+01	NE	NE
Cyanide[a]	Yes	8.12E-03	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-110. (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	
Ethylbenzene	No	6.05E-06	<1.00E-03	1.20E+04	6.00E-02	NE	NE
Europium	No	4.99E-03	0.00E+00	DNA	5.00E+01	NE	NE
Fluoride	Yes	1.38E+02	5.67E-01	1.05E+04	0.00E+00	No CPF	5.90E-04
Formate+A_2	No	8.20E-01	3.37E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Iron	Yes	1.90E+02	0.00E+00	DNA	2.50E+01	NE	NE
Lanthanum	No	4.99E-03	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Lead[a]	Yes	5.62E+00	0.00E+00	DNA	5.20E+00	NE	NE
Lithium	Yes	1.35E-01	0.00E+00	DNA	3.00E+02	NE	NE
Magnesium	Yes	2.81E+00	0.00E+00	DNA	4.50E+00	NE	NE
Manganese	Yes	7.61E-01	0.00E+00	DNA	1.00E+00	NE	NE
Mercury[a]	Yes	1.07E-01	0.00E+00	DNA	5.20E+00	NE	NE
Molybdenum	Yes	2.16E-02	0.00E+00	DNA	4.00E+00	NE	NE
Neodymium	No	7.50E-02	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Nickel[a]	Yes	4.13E-01	0.00E+00	DNA	4.80E+01	NE	NE
Niobium	No	3.00E-02	0.00E+00	DNA	1.00E+02	NE	NE
Nitrate	Yes	6.73E+00	2.76E-02	1.05E+04	0.00E+00	No CPF	1.08E-06
Nitrite	No	1.37E+00	5.62E-03	1.05E+04	0.00E+00	No CPF	3.52E-06
o-Dichlorobenzene[a]	Yes	1.27E-05	<1.00E-03	1.20E+04	1.14E-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-110. (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	5.10E-01	2.09E-03	1.05E+04	0.00E+00	No CPF	No Rfd
o-Xylene	Yes	1.67E-05	<1.00E-03	1.20E+04	7.23E-02	NE	NE
Palladium	No	6.00E-02	0.00E+00	DNA	5.00E+01	NE	NE
Phenol[a]	Yes	8.33E-03	<1.00E-03	1.05E+04	8.64E-03	NE	NE
Phosphate	Yes	1.40E+03	5.75E+00	1.05E+04	0.00E+00	No CPF	No Rfd
Potassium	Yes	4.46E-01	1.83E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Praseodymium	No	1.30E-01	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Rhodium	No	4.49E-02	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Rubidium	No	2.85E-01	1.17E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Ruthenium	No	2.00E-02	0.00E+00	DNA	1.00E+00	NE	NE
Samarium	No	8.50E-02	0.00E+00	DNA	1.00E+00	NE	NE
Selenium[a]	No	2.00E-02	0.00E+00	DNA	5.00E+00	NE	NE
Silicon	Yes	2.05E+01	0.00E+00	DNA	3.00E+01	NE	NE
Silver[a]	Yes	2.49E-01	0.00E+00	DNA	2.70E+00	NE	NE
Sodium	Yes	1.20E+03	4.93E+00	1.05E+04	0.00E+00	No CPF	No Rfd
Strontium	Yes	5.63E+01	0.00E+00	DNA	1.61E+01	NE	NE
Sulfate	Yes	7.46E+00	3.06E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Tantalum	No	2.50E-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-110. (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	3.99E-02	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Thallium[a]	No	2.15E-02	0.00E+00	DNA	7.10E+01	NE	NE
Thorium	No	5.25E-03	0.00E+00	DNA	1.00E+00	NE	NE
Tin	Yes	8.42E-01	0.00E+00	DNA	2.50E+02	NE	NE
Titanium	Yes	4.27E-02	0.00E+00	DNA	1.00E+03	NE	NE
Tungsten	No	8.00E-02	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Uranium	Yes	5.49E+00	0.00E+00	DNA	6.00E-01	NE	NE
Vanadium	No	6.15E-03	0.00E+00	DNA	5.00E+01	NE	NE
Yttrium	No	5.30E-03	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Zinc	Yes	2.13E+00	0.00E+00	DNA	6.20E+01	NE	NE
Zirconium	Yes	3.62E-01	0.00E+00	DNA	5.00E+02	NE	NE
1, 1, 2-Trichloroethylene	No	4.72E-06	<1.00E-03	1.20E+04	2.82E-02	NE	NE
1, 2, 4-Trichlorobenzene[a]	Yes	2.98E-05	<1.00E-03	1.20E+04	4.98E-01	NE	NE
1, 4-Dichlorobenzene	No	3.50E-06	<1.00E-03	1.20E+04	1.85E-01	NE	NE
2-Butanone(MEK)	No	7.65E-05	<1.00E-03	1.05E+04	1.35E-03	NE	NE
2-Propanone (Acetone)	No	9.90E-05	<1.00E-03	1.05E+04	1.73E-04	NE	NE
4-Methyl-2-pentanone (MIBK)	No	6.65E-05	<1.00E-03	1.20E+04	4.02E-02	NE	NE
Acetate	No	5.50E-01	2.26E-03	1.05E+04	3.00E-04	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-110. (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	
Glycolate $C_2H_3O_3$	No	3.13E-01	1.29E-03	1.05E+04	0.00E+00	No CPF	No Rfd
m-Xylene	Yes	3.36E-05	<1.00E-03	1.20E+04	5.88E-02	NE	NE
Polychlorinated Biphenyls[a]	Yes	1.59E-04	0.00E+00	DNA	9.27E+01	NE	NE
Tributyl phosphate	Yes	1.01E-01	<1.00E-03	1.20E+04	5.67E-01	NE	NE
Xylenes	Yes	4.94E-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 Dose for Single-Shell Tank 241-C-110 per Radionuclide Contaminants of Potential Concern Using the 95% Upper Confidence Level Concentration Based 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		
Antimony-125	No	6.30E+00	0.00E+00	DNA	1.00E+00	2.73E+00	NE	NE	NE	NE
Americium-241	Yes	6.32E-02	0.00E+00	DNA	3.00E+00	4.33E+02	NE	NE	NE	NE
Barium-137m	Yes	3.81E+01	0.00E+00	DNA	0.00E+00	4.86E-06	NE	NE	NE	NE
Carbon-14	No	2.27E-03	3.49E-03	9.78E+03	0.00E+00	5.73E+03	2.71E-11	1.96E-10	1.69E-05	6.98E-06
Cesium-137 + Daughters	Yes	4.04E+01	0.00E+00	DNA	2.50E+01	3.00E+01	NE	NE	NE	NE
Cobalt-60	No	9.20E-01	0.00E+00	DNA	1.00E-01	5.27E+00	NE	NE	NE	NE
Curium-242	No	1.04E-03	0.00E+00	DNA	3.00E+00	4.46E-01	NE	NE	NE	NE
Curium-243	No	1.59E-04	0.00E+00	DNA	3.00E+00	2.85E+01	NE	NE	NE	NE
Curium-244	No	3.36E-03	0.00E+00	DNA	3.00E+00	1.81E+01	NE	NE	NE	NE
Europium-152	No	1.67E+00	0.00E+00	DNA	1.00E+00	1.33E+01	NE	NE	NE	NE
Europium-154	No	1.83E+00	0.00E+00	DNA	1.00E+00	8.59E+00	NE	NE	NE	NE
Europium-155	No	4.29E+00	0.00E+00	DNA	1.00E+00	4.68E+00	NE	NE	NE	NE
Iodine-129	No	3.45E-04	<1.00E-03	1.20E+04	2.00E-01	1.57E+07	NE	NE	NE	NE
Neptunium-237 + D	Yes	1.31E-03	0.00E+00	DNA	2.00E+00	2.14E+06	NE	NE	NE	NE
Nickel-63	Yes	5.37E-01	0.00E+00	DNA	4.80E+01	1.00E+02	NE	NE	NE	NE
Plutonium-238	Yes	2.28E-02	0.00E+00	DNA	3.00E+00	8.77E+01	NE	NE	NE	NE

Table D-3. Incremental Lifetime Cancer Risk, Radiological Dose, and Drinking Water Dose for Single-Shell Tank 241-C-110 per Radionuclide Contaminants of Potential Concern Using the 95% Upper Confidence Level Concentration Based 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-239	Yes	1.61E+00	0.00E+00	DNA	3.00E+00	2.41E+04	NE	NE	NE	NE
Plutonium-240	Yes	1.75E-01	0.00E+00	DNA	3.00E+00	6.56E+03	NE	NE	NE	NE
Plutonium-241 + D	Yes	7.45E-01	0.00E+00	DNA	3.00E+00	1.44E+01	NE	NE	NE	NE
Plutonium-242	Yes	2.44E-06	0.00E+00	DNA	3.00E+00	3.74E+05	NE	NE	NE	NE
Protactinium-231	No	9.90E-03	0.00E+00	DNA	5.50E+02	3.28E+04	NE	NE	NE	NE
Selenium-79	No	7.55E-03	0.00E+00	DNA	3.10E+00	8.05E+05	NE	NE	NE	NE
Strontium-90 + D	Yes	4.63E+03	0.00E+00	DNA	1.61E+01	2.81E+01	NE	NE	NE	NE
Technetium-99	Yes	6.81E-02	2.72E-01	1.05E+04	0.00E+00	2.11E+05	3.75E-09	9.13E-08	4.76E-04	1.21E-03
Thorium-228 + D	No	3.20E-04	0.00E+00	DNA	3.00E+00	1.91E+00	NE	NE	NE	NE
Thorium-230	No	4.32E-03	0.00E+00	DNA	3.00E+00	7.54E+04	NE	NE	NE	NE
Thorium-232	No	1.74E-06	0.00E+00	DNA	3.00E+00	1.41E+10	NE	NE	NE	NE
Tin-126	Yes	3.37E-02	0.00E+00	DNA	1.00E+00	2.46E+05	NE	NE	NE	NE
Tritium	Yes	4.52E-03	0.00E+00	DNA	0.00E+00	1.23E+01	NE	NE	NE	NE
Uranium-233	No	1.45E-02	0.00E+00	DNA	6.00E-01	1.59E+05	NE	NE	NE	NE
Uranium-234	Yes	3.61E-03	0.00E+00	DNA	6.00E-01	2.46E+05	NE	NE	NE	NE
Uranium-235 + D	Yes	1.41E-04	0.00E+00	DNA	6.00E-01	7.04E+08	NE	NE	NE	NE
Uranium-236	Yes	3.32E-05	0.00E+00	DNA	6.00E-01	2.34E+07	NE	NE	NE	NE

Table D-3. Incremental Lifetime Cancer Risk, Radiological Dose, and Drinking Water Dose for Single-Shell Tank 241-C-110 per Radionuclide Contaminants of Potential Concern Using the 95% Upper Confidence Level Concentration Based 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		
Uranium-238 + D	Yes	3.21E-03	0.00E+00	DNA	6.00E-01	4.47E+09	NE	NE	NE	NE
Yttrium-90	Yes	4.63E+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 for Single-Shell Tank 241-C-110 per Nonradionuclide Contaminants of Potential Concern Using the 95% Upper Confidence Level Concentration Based 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	1.61E+03	0.00E+00	DNA	1.00E+00	NE	NE
Ammonia	Yes	2.15E-02	<1.00E-03	1.05E+04	9.30E-04	NE	NE
Antimony[a]	No	9.00E-02	0.00E+00	DNA	1.00E+00	NE	NE
Arsenic[a]	Yes	6.82E-02	0.00E+00	DNA	3.90E+01	NE	NE
Barium[a]	Yes	7.43E-01	0.00E+00	DNA	6.00E+01	NE	NE
Beryllium[a]	No	1.50E-02	0.00E+00	DNA	7.00E+01	NE	NE
Bismuth	Yes	4.29E+01	1.76E-01	1.05E+04	0.00E+00	No CPF	No Rfd
Boron	Yes	4.44E-02	0.00E+00	DNA	3.00E+00	NE	NE
Bromide	No	8.80E-01	3.61E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Cadmium[a]	No	1.50E-02	0.00E+00	DNA	1.26E+00	NE	NE
Calcium	Yes	6.74E+00	0.00E+00	DNA	4.00E+00	NE	NE
Cerium	No	1.95E+01	8.01E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Chloride	No	9.40E-01	3.86E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Chromium, Total[a]	Yes	1.54E+00	6.32E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Cobalt	Yes	2.80E-02	<1.00E-03	1.20E+04	1.00E-01	NE	NE
Copper	Yes	5.76E+00	0.00E+00	DNA	3.50E+01	NE	NE
Cyanide[a]	Yes	9.41E-03	0.00E+00	DNA	9.90E+00	NE	NE
Ethylbenzene	No	1.82E-05	<1.00E-03	1.20E+04	6.00E-02	NE	NE

Table D-4. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index for Single-Shell Tank 241-C-110 per Nonradionuclide Contaminants of Potential Concern Using the 95% Upper Confidence Level Concentration Based 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	
Europium	No	1.50E-02	0.00E+00	DNA	5.00E+01	NE	NE
Fluoride	Yes	1.69E+02	6.94E-01	1.05E+04	0.00E+00	No CPF	7.23E-04
Formate+A_2	No	2.46E+00	1.01E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Iron	Yes	2.53E+02	0.00E+00	DNA	2.50E+01	NE	NE
Lanthanum	No	1.50E-02	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Lead[a]	Yes	6.66E+00	0.00E+00	DNA	5.20E+00	NE	NE
Lithium	Yes	1.64E-01	0.00E+00	DNA	3.00E+02	NE	NE
Magnesium	Yes	3.06E+00	0.00E+00	DNA	4.50E+00	NE	NE
Manganese	Yes	9.74E-01	0.00E+00	DNA	1.00E+00	NE	NE
Mercury[a]	Yes	1.58E-01	0.00E+00	DNA	5.20E+00	NE	NE
Molybdenum	Yes	3.04E-02	0.00E+00	DNA	4.00E+00	NE	NE
Neodymium	No	2.25E-01	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Nickel[a]	Yes	4.91E-01	0.00E+00	DNA	4.80E+01	NE	NE
Niobium	No	9.00E-02	0.00E+00	DNA	1.00E+02	NE	NE
Nitrate	Yes	1.30E+01	5.34E-02	1.05E+04	0.00E+00	No CPF	2.08E-06
Nitrite	No	4.11E+00	1.69E-02	1.05E+04	0.00E+00	No CPF	1.05E-05
o-Dichlorobenzene[a]	Yes	2.04E-05	<1.00E-03	1.20E+04	1.14E-01	NE	NE
Oxalate	No	1.53E+00	6.28E-03	1.05E+04	0.00E+00	No CPF	No Rfd
o-Xylene	Yes	3.03E-05	<1.00E-03	1.20E+04	7.23E-02	NE	NE

Table D-4. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index for Single-Shell Tank 241-C-110 per Nonradionuclide Contaminants of Potential Concern Using the 95% Upper Confidence Level Concentration Based 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	
Palladium	No	1.80E-01	0.00E+00	DNA	5.00E+01	NE	NE
Phenol[a]	Yes	1.58E-02	<1.00E-03	1.05E+04	8.64E-03	NE	NE
Phosphate	Yes	1.67E+03	6.86E+00	1.05E+04	0.00E+00	No CPF	No Rfd
Potassium	Yes	6.44E-01	2.64E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Praseodymium	No	3.89E-01	1.59E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Rhodium	No	1.35E-01	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Rubidium	No	8.55E-01	3.51E-03	1.05E+04	0.00E+00	No CPF	No Rfd
Ruthenium	No	6.00E-02	0.00E+00	DNA	1.00E+00	NE	NE
Samarium	No	2.55E-01	0.00E+00	DNA	1.00E+00	NE	NE
Selenium[a]	No	6.00E-02	0.00E+00	DNA	5.00E+00	NE	NE
Silicon	Yes	2.58E+01	0.00E+00	DNA	3.00E+01	NE	NE
Silver[a]	Yes	4.04E-01	0.00E+00	DNA	2.70E+00	NE	NE
Sodium	Yes	1.44E+03	5.91E+00	1.05E+04	0.00E+00	No CPF	No Rfd
Strontium	Yes	8.64E+01	0.00E+00	DNA	1.61E+01	NE	NE
Sulfate	Yes	8.07E+00	3.31E-02	1.05E+04	0.00E+00	No CPF	No Rfd
Tantalum	No	7.50E-02	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Tellurium	No	1.20E-01	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Thallium[a]	No	6.45E-02	0.00E+00	DNA	7.10E+01	NE	NE
Thorium	No	6.95E-03	0.00E+00	DNA	1.00E+00	NE	NE

Table D-4. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index for Single-Shell Tank 241-C-110 per Nonradionuclide Contaminants of Potential Concern Using the 95% Upper Confidence Level Concentration Based 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	
Tin	Yes	1.01E+00	0.00E+00	DNA	2.50E+02	NE	NE
Titanium	Yes	5.05E-02	0.00E+00	DNA	1.00E+03	NE	NE
Tungsten	No	2.40E-01	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Uranium	Yes	7.02E+00	0.00E+00	DNA	6.00E-01	NE	NE
Vanadium	No	1.85E-02	0.00E+00	DNA	5.00E+01	NE	NE
Yttrium	No	1.59E-02	<1.00E-03	1.05E+04	0.00E+00	NE	NE
Zinc	Yes	2.56E+00	0.00E+00	DNA	6.20E+01	NE	NE
Zirconium	Yes	4.16E-01	0.00E+00	DNA	5.00E+02	NE	NE
1, 1, 2-Trichloroethylene	No	1.42E-05	<1.00E-03	1.20E+04	2.82E-02	NE	NE
1, 2, 4-Trichlorobenzene[a]	Yes	4.51E-05	<1.00E-03	1.20E+04	4.98E-01	NE	NE
1, 4-Dichlorobenzene	No	1.05E-05	<1.00E-03	1.20E+04	1.85E-01	NE	NE
2-Butanone(MEK)	No	2.30E-04	<1.00E-03	1.05E+04	1.35E-03	NE	NE
2-Propanone (Acetone)	No	2.97E-04	<1.00E-03	1.05E+04	1.73E-04	NE	NE
4-Methyl-2-pentanone (MIBK)	No	2.00E-04	<1.00E-03	1.20E+04	4.02E-02	NE	NE
Acetate	No	1.65E+00	6.77E-03	1.05E+04	3.00E-04	No CPF	No Rfd
Glycolate $C_2H_3O_3$	No	9.40E-01	3.86E-03	1.05E+04	0.00E+00	No CPF	No Rfd
m-Xylene	Yes	6.21E-05	<1.00E-03	1.20E+04	5.88E-02	NE	NE
Polychlorinated Biphenyls[a]	Yes	2.83E-04	0.00E+00	DNA	9.27E+01	NE	NE
Tributyl phosphate	Yes	2.11E-01	<1.00E-03	1.20E+04	5.67E-01	NE	NE

Table D-4. Maximum Value for Incremental Lifetime Cancer Risk and Hazard Index for Single-Shell Tank 241-C-110 per Nonradionuclide Contaminants of Potential Concern Using the 95% Upper Confidence Level Concentration Based 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	
Xylenes	Yes	9.28E-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-110 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
Americium-241	2.58E-03	2.20E-03	1.88E-03	1.60E-03	1.36E-03	1.16E-03	9.89E-04	8.43E-04	7.18E-04	6.12E-04
Antimony-125	3.41E-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
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	1.25E-08	1.23E-08	1.22E-08	1.20E-08	1.19E-08	1.17E-08	1.16E-08	1.15E-08	1.13E-08	1.12E-08
Cesium-137 + Daughters	1.97E-01	1.95E-02	1.93E-03	1.92E-04	1.90E-05	1.89E-06	1.87E-07	1.86E-08	1.84E-09	1.83E-10
Cobalt-60	1.28E-08	2.49E-14	4.84E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Curium-242	3.48E-08	1.58E-08	7.17E-09	3.25E-09	1.48E-09	6.71E-10	3.05E-10	1.39E-10	6.42E-11	3.01E-11
Curium-243	1.78E-07	1.90E-08	4.99E-09	3.75E-09	3.63E-09	3.61E-09	3.60E-09	3.59E-09	3.58E-09	3.57E-09
Curium-244	4.87E-07	1.82E-07	1.74E-07	1.72E-07	1.70E-07	1.68E-07	1.66E-07	1.65E-07	1.63E-07	1.61E-07
Europium-152	2.18E-04	1.20E-06	6.63E-09	3.66E-11	2.02E-13	1.48E-15	3.68E-16	3.62E-16	3.62E-16	3.62E-16
Europium-154	7.23E-06	2.27E-09	7.11E-13	2.23E-16	6.99E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	1.33E-10	4.92E-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
Iodine-129	3.43E-07	3.43E-07	3.43E-07	3.43E-07	3.43E-07	3.43E-07	3.43E-07	3.43E-07	3.43E-07	3.43E-07
Neptunium-237 + D	1.33E-04	1.33E-04	1.33E-04	1.33E-04	1.33E-04	1.33E-04	1.33E-04	1.33E-04	1.33E-04	1.33E-04
Nickel-63	8.42E-07	4.21E-07	2.11E-07	1.05E-07	5.28E-08	2.64E-08	1.32E-08	6.61E-09	3.31E-09	1.65E-09
Plutonium-238	3.38E-04	1.53E-04	6.95E-05	3.15E-05	1.43E-05	6.51E-06	2.96E-06	1.36E-06	6.27E-07	2.97E-07
Plutonium-239	6.76E-02	6.74E-02	6.72E-02	6.70E-02	6.68E-02	6.66E-02	6.64E-02	6.62E-02	6.61E-02	6.59E-02
Plutonium-240	7.27E-03	7.19E-03	7.11E-03	7.04E-03	6.97E-03	6.89E-03	6.82E-03	6.75E-03	6.68E-03	6.61E-03

Table D-5. Well Driller Scenario Doses (mrem) for Single-Shell Tank 241-C-110 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-241 + D	1.12E-03	9.56E-04	8.14E-04	6.94E-04	5.91E-04	5.04E-04	4.29E-04	3.66E-04	3.12E-04	2.66E-04
Plutonium-242	9.79E-08	9.79E-08	9.78E-08	9.78E-08	9.78E-08	9.78E-08	9.78E-08	9.77E-08	9.77E-08	9.77E-08
Protactinium-231	1.65E-03	1.67E-03	1.67E-03	1.66E-03	1.66E-03	1.65E-03	1.65E-03	1.65E-03	1.64E-03	1.64E-03
Selenium-79	1.69E-07	1.69E-07	1.69E-07	1.69E-07	1.69E-07	1.69E-07	1.69E-07	1.69E-07	1.69E-07	1.69E-07
Strontium-90 + D	3.67E-01	3.13E-02	2.67E-03	2.27E-04	1.94E-05	1.65E-06	1.41E-07	1.20E-08	1.02E-09	8.71E-11
Technetium-99	8.46E-07	8.46E-07	8.46E-07	8.46E-07	8.45E-07	8.45E-07	8.45E-07	8.44E-07	8.44E-07	8.44E-07
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	6.82E-05	9.54E-05	1.21E-04	1.46E-04	1.70E-04	1.93E-04	2.15E-04	2.36E-04	2.55E-04	2.75E-04
Thorium-232	4.16E-07	4.16E-07	4.16E-07	4.16E-07	4.16E-07	4.16E-07	4.16E-07	4.16E-07	4.16E-07	4.16E-07
Tin-126	1.11E-02	1.11E-02	1.11E-02	1.11E-02	1.11E-02	1.11E-02	1.11E-02	1.10E-02	1.10E-02	1.10E-02
Tritium	1.53E-12	5.55E-15	2.01E-17	7.26E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Uranium-233	2.64E-05	3.64E-05	4.64E-05	5.63E-05	6.61E-05	7.58E-05	8.54E-05	9.49E-05	1.04E-04	1.14E-04
Uranium-234	7.31E-06	7.45E-06	7.63E-06	7.85E-06	8.12E-06	8.42E-06	8.76E-06	9.14E-06	9.55E-06	1.00E-05
Uranium-235 + D	4.53E-06	4.66E-06	4.78E-06	4.90E-06	5.02E-06	5.14E-06	5.26E-06	5.38E-06	5.50E-06	5.63E-06
Uranium-236	7.57E-08	7.57E-08	7.57E-08	7.57E-08	7.57E-08	7.57E-08	7.57E-08	7.57E-08	7.57E-08	7.57E-08
Uranium-238 + D	2.06E-05	2.06E-05	2.06E-05	2.06E-05	2.06E-05	2.06E-05	2.06E-05	2.06E-05	2.06E-05	2.06E-05
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
Total Dose	**6.56E-01**	**1.42E-01**	**9.47E-02**	**8.99E-02**	**8.89E-02**	**8.83E-02**	**8.79E-02**	**8.74E-02**	**8.70E-02**	**8.66E-02**

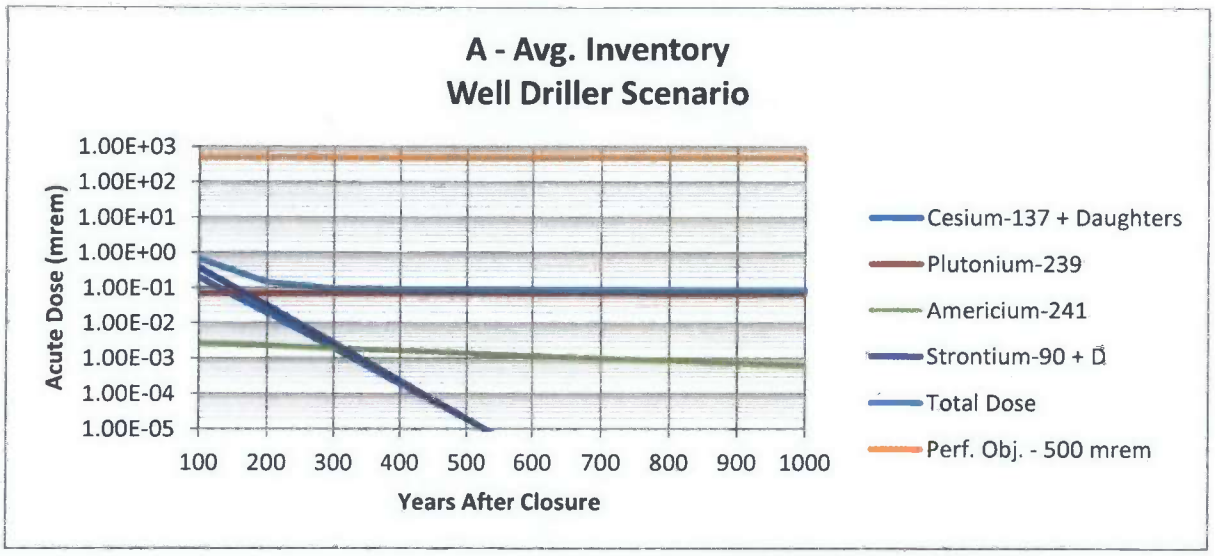
Table D-5. Well Driller Scenario Doses (mrem) for Single-Shell Tank 241-C-110 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

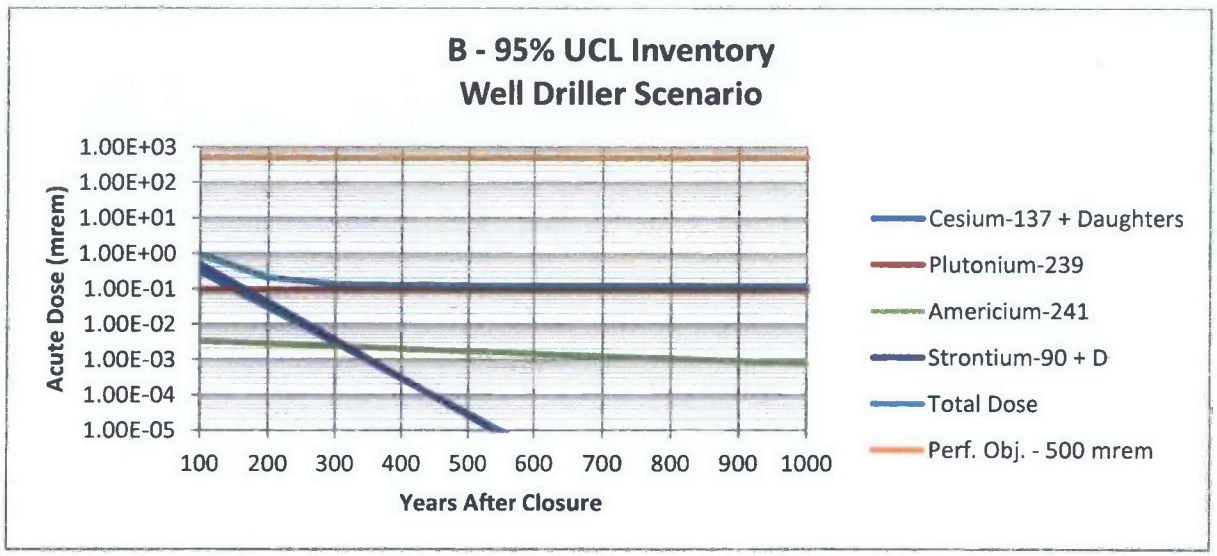
B – 95% Upper Confidence Level Inventory										
	Years After Site Closure (January 1, 2032)									
Nuclide	100	200	300	400	500	600	700	800	900	1,000
Americium-241	3.24E-03	2.76E-03	2.35E-03	2.00E-03	1.71E-03	1.46E-03	1.24E-03	1.06E-03	9.00E-04	7.67E-04
Antimony-125	1.02E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
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	3.74E-08	3.70E-08	3.65E-08	3.61E-08	3.56E-08	3.52E-08	3.48E-08	3.44E-08	3.40E-08	3.36E-08
Cesium-137 + Daughters	2.98E-01	2.96E-02	2.94E-03	2.91E-04	2.89E-05	2.87E-06	2.85E-07	2.82E-08	2.80E-09	2.78E-10
Cobalt-60	3.83E-08	7.45E-14	1.45E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Curium-242	1.04E-07	4.74E-08	2.15E-08	9.75E-09	4.43E-09	2.01E-09	9.15E-10	4.18E-10	1.92E-10	9.01E-11
Curium-243	5.34E-07	5.69E-08	1.50E-08	1.13E-08	1.09E-08	1.08E-08	1.08E-08	1.08E-08	1.07E-08	1.07E-08
Curium-244	1.46E-06	5.46E-07	5.21E-07	5.15E-07	5.10E-07	5.04E-07	4.99E-07	4.94E-07	4.89E-07	4.83E-07
Europium-152	6.53E-04	3.60E-06	1.99E-08	1.10E-10	6.06E-13	4.43E-15	1.11E-15	1.09E-15	1.09E-15	1.09E-15
Europium-154	2.17E-05	6.80E-09	2.13E-12	6.69E-16	2.10E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	3.99E-10	1.48E-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
Iodine-129	1.03E-06	1.03E-06	1.03E-06	1.03E-06	1.03E-06	1.03E-06	1.03E-06	1.03E-06	1.03E-06	1.03E-06
Neptunium-237 + D	1.60E-04	1.60E-04	1.60E-04	1.60E-04	1.60E-04	1.60E-04	1.60E-04	1.60E-04	1.60E-04	1.60E-04
Nickel-63	1.02E-06	5.11E-07	2.55E-07	1.28E-07	6.40E-08	3.20E-08	1.60E-08	8.01E-09	4.01E-09	2.01E-09
Plutonium-238	4.48E-04	2.03E-04	9.21E-05	4.18E-05	1.90E-05	8.62E-06	3.93E-06	1.80E-06	8.31E-07	3.93E-07
Plutonium-239	9.30E-02	9.27E-02	9.25E-02	9.22E-02	9.20E-02	9.17E-02	9.14E-02	9.12E-02	9.09E-02	9.06E-02
Plutonium-240	1.00E-02	9.91E-03	9.80E-03	9.70E-03	9.60E-03	9.50E-03	9.40E-03	9.30E-03	9.20E-03	9.10E-03

Table D-5. Well Driller Scenario Doses (mrem) for Single-Shell Tank 241-C-110 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-241 + D	1.31E-03	1.12E-03	9.51E-04	8.10E-04	6.90E-04	5.88E-04	5.01E-04	4.27E-04	3.64E-04	3.10E-04
Plutonium-242	1.35E-07	1.35E-07	1.35E-07	1.35E-07	1.35E-07	1.35E-07	1.35E-07	1.35E-07	1.35E-07	1.35E-07
Protactinium-231	4.96E-03	5.01E-03	5.00E-03	4.99E-03	4.98E-03	4.97E-03	4.96E-03	4.95E-03	4.94E-03	4.93E-03
Selenium-79	5.08E-07	5.07E-07	5.07E-07	5.07E-07	5.07E-07	5.07E-07	5.07E-07	5.07E-07	5.07E-07	5.07E-07
Strontium-90 + D	4.85E-01	4.14E-02	3.53E-03	3.01E-04	2.56E-05	2.18E-06	1.86E-07	1.59E-08	1.35E-09	1.15E-10
Technetium-99	1.29E-06	1.29E-06	1.29E-06	1.29E-06	1.29E-06	1.29E-06	1.29E-06	1.29E-06	1.29E-06	1.29E-06
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	2.05E-04	2.86E-04	3.64E-04	4.39E-04	5.10E-04	5.79E-04	6.44E-04	7.07E-04	7.66E-04	8.24E-04
Thorium-232	1.25E-06	1.25E-06	1.25E-06	1.25E-06	1.25E-06	1.25E-06	1.25E-06	1.25E-06	1.25E-06	1.25E-06
Tin-126	1.57E-02	1.57E-02	1.57E-02	1.57E-02	1.57E-02	1.57E-02	1.56E-02	1.56E-02	1.56E-02	1.56E-02
Tritium	1.96E-12	7.10E-15	2.57E-17	9.30E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Uranium-233	7.92E-05	1.09E-04	1.39E-04	1.69E-04	1.99E-04	2.28E-04	2.57E-04	2.85E-04	3.13E-04	3.41E-04
Uranium-234	1.00E-05	1.02E-05	1.04E-05	1.07E-05	1.11E-05	1.15E-05	1.20E-05	1.25E-05	1.31E-05	1.37E-05
Uranium-235 + D	5.61E-06	5.76E-06	5.91E-06	6.06E-06	6.21E-06	6.36E-06	6.51E-06	6.66E-06	6.81E-06	6.96E-06
Uranium-236	8.57E-08	8.57E-08	8.57E-08	8.57E-08	8.57E-08	8.57E-08	8.57E-08	8.57E-08	8.57E-08	8.57E-08
Uranium-238 + D	2.55E-05	2.55E-05	2.55E-05	2.56E-05	2.56E-05	2.56E-05	2.56E-05	2.56E-05	2.56E-05	2.56E-05
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
Total Dose	**9.14E-01**	**1.99E-01**	**1.34E-01**	**1.27E-01**	**1.26E-01**	**1.25E-01**	**1.24E-01**	**1.24E-01**	**1.23E-01**	**1.23E-01**

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-110.





UCL = upper confidence level

Table D-6. Rural Pasture Doses (mrem/y) for Single-Shell Tank 241-C-110 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
Americium-241	7.12E-04	6.06E-04	5.17E-04	4.40E-04	3.75E-04	3.20E-04	2.72E-04	2.32E-04	1.98E-04	1.68E-04
Antimony-125	3.57E-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
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	1.37E-06	1.36E-06	1.34E-06	1.33E-06	1.31E-06	1.29E-06	1.28E-06	1.26E-06	1.25E-06	1.23E-06
Cesium-137 + Daughters	5.29E-02	5.24E-03	5.20E-04	5.16E-05	5.12E-06	5.08E-07	5.04E-08	5.00E-09	4.96E-10	4.92E-11
Cobalt-60	1.46E-09	2.84E-15	5.52E-21	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E-00
Curium-242	9.88E-09	4.48E-09	2.04E-09	9.24E-10	4.20E-10	1.91E-10	8.72E-11	4.01E-11	1.87E-11	9.04E-12
Curium-243	3.84E-08	4.32E-09	1.32E-09	1.06E-09	1.03E-09	1.02E-09	1.02E-09	1.02E-09	1.02E-09	1.01E-09
Curium-244	1.40E-07	5.19E-08	4.94E-08	4.89E-08	4.84E-08	4.79E-08	4.74E-08	4.69E-08	4.64E-08	4.59E-08
Europium-152	2.46E-05	1.36E-07	7.50E-10	4.14E-12	2.29E-14	2.28E-16	1.03E-16	1.02E-16	1.02E-16	1.02E-16
Europium-154	8.17E-07	2.56E-10	8.04E-14	2.52E-17	7.90E-21	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	1.14E-11	4.22E-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
Iodine-129	3.49E-06	3.49E-06	3.49E-06	3.49E-06	3.49E-06	3.49E-06	3.49E-06	3.49E-06	3.49E-06	3.49E-06
Neptunium-237 + D	2.83E-05	2.83E-05	2.83E-05	2.83E-05	2.83E-05	2.83E-05	2.83E-05	2.83E-05	2.83E-05	2.83E-05
Nickel-63	2.24E-05	1.12E-05	5.61E-06	2.81E-06	1.40E-06	7.03E-07	3.52E-07	1.76E-07	8.80E-08	4.40E-08
Plutonium-238	9.58E-05	4.35E-05	1.97E-05	8.96E-06	4.07E-06	1.85E-06	8.46E-07	3.89E-07	1.83E-07	8.89E-08
Plutonium-239	1.92E-02	1.92E-02	1.91E-02	1.91E-02	1.90E-02	1.90E-02	1.89E-02	1.89E-02	1.88E-02	1.88E-02
Plutonium-240	2.07E-03	2.05E-03	2.03E-03	2.00E-03	1.98E-03	1.96E-03	1.94E-03	1.92E-03	1.90E-03	1.88E-03
Plutonium-241 + D	3.09E-04	2.63E-04	2.24E-04	1.91E-04	1.63E-04	1.39E-04	1.18E-04	1.01E-04	8.59E-05	7.32E-05

Table D-6. Rural Pasture Doses (mrem/y) for Single-Shell Tank 241-C-110 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-242	2.79E-08	2.79E-08	2.79E-08	2.78E-08	2.78E-08	2.78E-08	2.78E-08	2.78E-08	2.78E-08	2.78E-08
Protactinium-231	4.22E-04	4.26E-04	4.25E-04	4.24E-04	4.23E-04	4.22E-04	4.21E-04	4.20E-04	4.19E-04	4.19E-04
Selenium-79	8.07E-07	8.07E-07	8.07E-07	8.07E-07	8.07E-07	8.07E-07	8.07E-07	8.06E-07	8.06E-07	8.06E-07
Strontium-90 + D	2.12E+01	1.81E+00	1.54E-01	1.31E-02	1.12E-03	9.53E-05	8.12E-06	6.92E-07	5.90E-08	5.03E-09
Technetium-99	1.54E-04	1.54E-04	1.54E-04	1.54E-04	1.54E-04	1.54E-04	1.54E-04	1.54E-04	1.54E-04	1.54E-04
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	1.65E-05	2.23E-05	2.79E-05	3.32E-05	3.83E-05	4.32E-05	4.79E-05	5.23E-05	5.66E-05	6.07E-05
Thorium-232	7.53E-08	7.53E-08	7.53E-08	7.53E-08	7.53E-08	7.53E-08	7.53E-08	7.53E-08	7.53E-08	7.53E-08
Tin-126	1.26E-03	1.26E-03	1.25E-03	1.25E-03	1.25E-03	1.25E-03	1.25E-03	1.25E-03	1.25E-03	1.25E-03
Tritium	5.69E-11	2.06E-13	7.45E-16	2.70E-18	9.76E-21	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Uranium-233	1.07E-05	1.30E-05	1.53E-05	1.76E-05	1.98E-05	2.20E-05	2.42E-05	2.64E-05	2.86E-05	3.07E-05
Uranium-234	4.20E-06	4.23E-06	4.28E-06	4.33E-06	4.38E-06	4.45E-06	4.53E-06	4.61E-06	4.70E-06	4.80E-06
Uranium-235 + D	6.14E-07	6.45E-07	6.77E-07	7.08E-07	7.39E-07	7.70E-07	8.00E-07	8.31E-07	8.62E-07	8.93E-07
Uranium-236	4.40E-08	4.40E-08	4.40E-08	4.40E-08	4.40E-08	4.40E-08	4.40E-08	4.40E-08	4.40E-08	4.40E-08
Uranium-238 + D	5.32E-06	5.32E-06	5.33E-06	5.33E-06	5.33E-06	5.33E-06	5.33E-06	5.33E-06	5.33E-06	5.33E-06
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
Total Dose	**2.13E+01**	**1.84E+00**	**1.78E-01**	**3.68E-02**	**2.46E-02**	**2.34E-02**	**2.32E-02**	**2.31E-02**	**2.29E-02**	**2.28E-02**

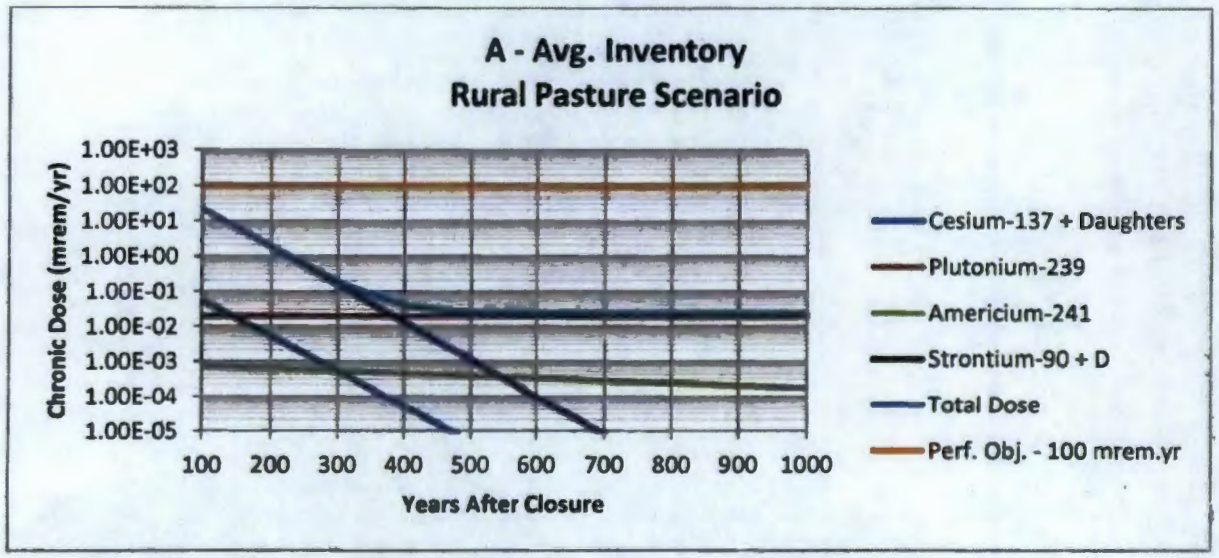
Table D-6. Rural Pasture Doses (mrem/y) for Single-Shell Tank 241-C-110 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

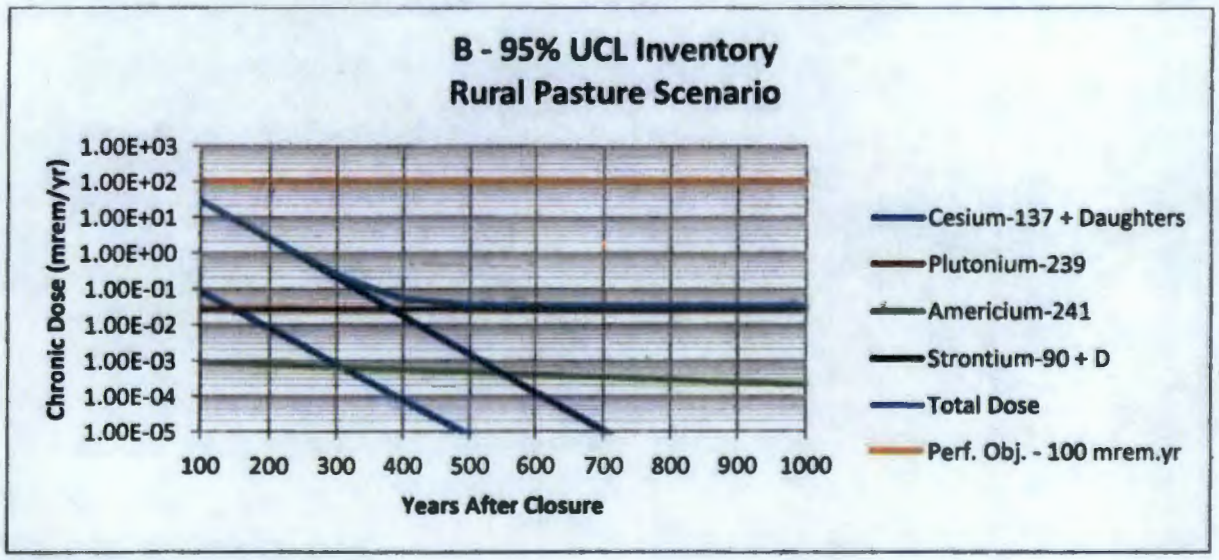
B – 95% Upper Confidence Level Inventory										
	Years After Site Closure (January 1, 2032)									
Nuclide	100	200	300	400	500	600	700	800	900	1,000
Americium-241	8.92E-04	7.60E-04	6.48E-04	5.52E-04	4.70E-04	4.01E-04	3.41E-04	2.91E-04	2.48E-04	2.11E-04
Antimony-125	1.07E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
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	4.12E-06	4.07E-06	4.03E-06	3.98E-06	3.93E-06	3.88E-06	3.84E-06	3.79E-06	3.74E-06	3.70E-06
Cesium-137 + Daughters	8.03E-02	7.96E-03	7.90E-04	7.84E-05	7.78E-06	7.71E-07	7.65E-08	7.59E-09	7.53E-10	7.47E-11
Cobalt-60	4.37E-09	8.50E-15	1.66E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Curium-242	2.96E-08	1.34E-08	6.10E-09	2.77E-09	1.26E-09	5.72E-10	2.61E-10	1.20E-10	5.61E-11	2.71E-11
Curium-243	1.15E-07	1.29E-08	3.96E-09	3.17E-09	3.09E-09	3.07E-09	3.06E-09	3.06E-09	3.05E-09	3.04E-09
Curium-244	4.19E-07	1.56E-07	1.48E-07	1.47E-07	1.45E-07	1.44E-07	1.42E-07	1.41E-07	1.39E-07	1.38E-07
Europium-152	7.39E-05	4.08E-07	2.25E-09	1.24E-11	6.88E-14	6.84E-16	3.09E-16	3.07E-16	3.07E-16	3.07E-16
Europium-154	2.45E-06	7.69E-10	2.41E-13	7.56E-17	2.37E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	3.43E-11	1.27E-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
Iodine-129	1.05E-05	1.05E-05	1.05E-05	1.05E-05	1.05E-05	1.05E-05	1.05E-05	1.05E-05	1.05E-05	1.05E-05
Neptunium-237 + D	3.40E-05	3.40E-05	3.40E-05	3.40E-05	3.40E-05	3.40E-05	3.40E-05	3.40E-05	3.40E-05	3.40E-05
Nickel-63	2.72E-05	1.36E-05	6.80E-06	3.40E-06	1.70E-06	8.52E-07	4.26E-07	2.13E-07	1.07E-07	5.34E-08
Plutonium-238	1.27E-04	5.76E-05	2.62E-05	1.19E-05	5.39E-06	2.45E-06	1.12E-06	5.16E-07	2.42E-07	1.18E-07
Plutonium-239	2.65E-02	2.64E-02	2.63E-02	2.63E-02	2.62E-02	2.61E-02	2.60E-02	2.60E-02	2.59E-02	2.58E-02
Plutonium-240	2.85E-03	2.82E-03	2.79E-03	2.76E-03	2.73E-03	2.70E-03	2.68E-03	2.65E-03	2.62E-03	2.59E-03
Plutonium-241 + D	3.60E-04	3.07E-04	2.62E-04	2.23E-04	1.90E-04	1.62E-04	1.38E-04	1.18E-04	1.00E-04	8.54E-05

Table D-6. Rural Pasture Doses (mrem/y) for Single-Shell Tank 241-C-110 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-242	3.84E-08	3.84E-08	3.84E-08	3.84E-08	3.84E-08	3.84E-08	3.84E-08	3.84E-08	3.84E-08	3.83E-08
Protactinium-231	1.27E-03	1.28E-03	1.28E-03	1.27E-03	1.27E-03	1.27E-03	1.27E-03	1.26E-03	1.26E-03	1.26E-03
Selenium-79	2.42E-06	2.42E-06	2.42E-06	2.42E-06	2.42E-06	2.42E-06	2.42E-06	2.42E-06	2.42E-06	2.42E-06
Strontium-90 + D	2.80E+01	2.39E+00	2.04E-01	1.74E-02	1.48E-03	1.26E-04	1.07E-05	9.16E-07	7.80E-08	6.65E-09
Technetium-99	2.36E-04	2.36E-04	2.36E-04	2.35E-04	2.35E-04	2.35E-04	2.35E-04	2.35E-04	2.35E-04	2.35E-04
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	4.96E-05	6.70E-05	8.37E-05	9.97E-05	1.15E-04	1.30E-04	1.44E-04	1.57E-04	1.70E-04	1.82E-04
Thorium-232	2.26E-07	2.26E-07	2.26E-07	2.26E-07	2.26E-07	2.26E-07	2.26E-07	2.26E-07	2.26E-07	2.26E-07
Tin-126	1.78E-03	1.78E-03	1.78E-03	1.78E-03	1.78E-03	1.78E-03	1.77E-03	1.77E-03	1.77E-03	1.77E-03
Tritium	7.29E-11	2.64E-13	9.54E-16	3.45E-18	1.25E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Uranium-233	3.22E-05	3.91E-05	4.60E-05	5.28E-05	5.95E-05	6.62E-05	7.28E-05	7.93E-05	8.58E-05	9.22E-05
Uranium-234	5.75E-06	5.79E-06	5.85E-06	5.92E-06	6.00E-06	6.09E-06	6.19E-06	6.31E-06	6.43E-06	6.56E-06
Uranium-235 + D	7.60E-07	7.98E-07	8.37E-07	8.75E-07	9.14E-07	9.52E-07	9.90E-07	1.03E-06	1.07E-06	1.10E-06
Uranium-236	4.99E-08	4.99E-08	4.99E-08	4.99E-08	4.99E-08	4.99E-08	4.99E-08	4.99E-08	4.99E-08	4.99E-08
Uranium-238 + D	6.60E-06	6.60E-06	6.60E-06	6.60E-06	6.60E-06	6.61E-06	6.61E-06	6.61E-06	6.61E-06	6.61E-06
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
Total Dose	**2.81E+01**	**2.43E+00**	**2.38E-01**	**5.07E-02**	**3.46E-02**	**3.30E-02**	**3.28E-02**	**3.26E-02**	**3.24E-02**	**3.23E-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-110.





UCL = upper confidence level

Table D-7. Suburban Garden Doses (mrem/y) for Single-Shell Tank 241-C-110 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

Nuclide	Years After Site Closure (January 1, 2032)									
	100	200	300	400	500	600	700	800	900	1,000
Americium-241	1.56E-02	1.33E-02	1.13E-02	9.64E-03	8.22E-03	7.01E-03	5.97E-03	5.09E-03	4.34E-03	3.70E-03
Antimony-125	3.47E-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
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	2.41E-05	2.38E-05	2.35E-05	2.33E-05	2.30E-05	2.27E-05	2.24E-05	2.22E-05	2.19E-05	2.16E-05
Cesium-137 + Daughters	5.12E-01	5.08E-02	5.04E-03	5.00E-04	4.96E-05	4.92E-06	4.88E-07	4.84E-08	4.81E-09	4.77E-10
Cobalt-60	1.46E-08	2.84E-14	5.53E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Curium-242	2.19E-07	9.92E-08	4.50E-08	2.05E-08	9.31E-09	4.25E-09	1.95E-09	9.12E-10	4.40E-10	2.25E-10
Curium-243	7.34E-07	8.54E-08	2.84E-08	2.33E-08	2.28E-08	2.27E-08	2.26E-08	2.26E-08	2.25E-08	2.24E-08
Curium-244	3.01E-06	1.15E-06	1.10E-06	1.08E-06	1.07E-06	1.06E-06	1.05E-06	1.04E-06	1.03E-06	1.02E-06
Europium-152	2.37E-04	1.31E-06	7.21E-09	3.98E-11	2.21E-13	2.66E-15	1.46E-15	1.45E-15	1.45E-15	1.45E-15
Europium-154	7.86E-06	2.47E-09	7.73E-13	2.42E-16	7.60E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	1.12E-10	4.15E-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
Iodine-129	1.73E-05	1.73E-05	1.73E-05	1.73E-05	1.73E-05	1.73E-05	1.73E-05	1.73E-05	1.73E-05	1.73E-05
Neptunium-237 + D	1.96E-03	1.96E-03	1.96E-03	1.96E-03	1.96E-03	1.96E-03	1.96E-03	1.96E-03	1.96E-03	1.96E-03
Nickel-63	1.52E-04	7.60E-05	3.80E-05	1.90E-05	9.52E-06	4.77E-06	2.38E-06	1.19E-06	5.97E-07	2.99E-07
Plutonium-238	2.12E-03	9.62E-04	4.37E-04	1.98E-04	9.02E-05	4.12E-05	1.90E-05	8.86E-06	4.28E-06	2.21E-06
Plutonium-239	4.27E-01	4.26E-01	4.24E-01	4.23E-01	4.22E-01	4.21E-01	4.20E-01	4.18E-01	4.17E-01	4.16E-01
Plutonium-240	4.59E-02	4.54E-02	4.49E-02	4.45E-02	4.40E-02	4.35E-02	4.31E-02	4.26E-02	4.22E-02	4.17E-02

Table D-7. Suburban Garden Doses (mrem/y) for Single-Shell Tank 241-C-110 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-241 + D	6.76E-03	5.77E-03	4.91E-03	4.19E-03	3.57E-03	3.04E-03	2.59E-03	2.21E-03	1.88E-03	1.61E-03
Plutonium-242	6.16E-07	6.16E-07	6.16E-07	6.16E-07	6.16E-07	6.16E-07	6.16E-07	6.16E-07	6.15E-07	6.15E-07
Protactinium-231	8.94E-03	9.01E-03	9.00E-03	8.98E-03	8.96E-03	8.94E-03	8.92E-03	8.90E-03	8.88E-03	8.87E-03
Selenium-79	1.31E-05	1.31E-05	1.31E-05	1.31E-05	1.31E-05	1.31E-05	1.31E-05	1.31E-05	1.31E-05	1.31E-05
Strontium-90 + D	3.01E+02	2.56E+01	2.18E+00	1.86E-01	1.59E-02	1.35E-03	1.15E-04	9.82E-06	8.37E-07	7.13E-08
Technetium-99	1.18E-02	1.18E-02	1.18E-02	1.17E-02	1.17E-02	1.17E-02	1.17E-02	1.17E-02	1.17E-02	1.17E-02
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	2.82E-04	4.17E-04	5.46E-04	6.69E-04	7.88E-04	9.01E-04	1.01E-03	1.11E-03	1.21E-03	1.31E-03
Thorium-232	8.72E-07	8.72E-07	8.72E-07	8.72E-07	8.72E-07	8.72E-07	8.72E-07	8.72E-07	8.72E-07	8.72E-07
Tin-126	1.21E-02	1.21E-02	1.21E-02	1.21E-02	1.21E-02	1.21E-02	1.21E-02	1.21E-02	1.21E-02	1.21E-02
Tritium	4.97E-10	1.80E-12	6.51E-15	2.36E-17	8.53E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Uranium-233	4.11E-04	4.44E-04	4.76E-04	5.07E-04	5.39E-04	5.70E-04	6.01E-04	6.31E-04	6.62E-04	6.91E-04
Uranium-234	1.99E-04	2.00E-04	2.01E-04	2.02E-04	2.03E-04	2.04E-04	2.06E-04	2.07E-04	2.09E-04	2.11E-04
Uranium-235 + D	1.27E-05	1.34E-05	1.41E-05	1.47E-05	1.54E-05	1.60E-05	1.67E-05	1.73E-05	1.80E-05	1.86E-05
Uranium-236	2.10E-06	2.10E-06	2.10E-06	2.10E-06	2.10E-06	2.10E-06	2.10E-06	2.10E-06	2.10E-06	2.10E-06
Uranium-238 + D	1.99E-04	1.99E-04	1.99E-04	1.99E-04	1.99E-04	1.99E-04	1.99E-04	1.99E-04	1.99E-04	1.99E-04
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
Total Dose	**3.02E+02**	**2.62E+01**	**2.71E+00**	**7.05E-01**	**5.30E-01**	**5.12E-01**	**5.08E-01**	**5.05E-01**	**5.03E-01**	**5.00E-01**

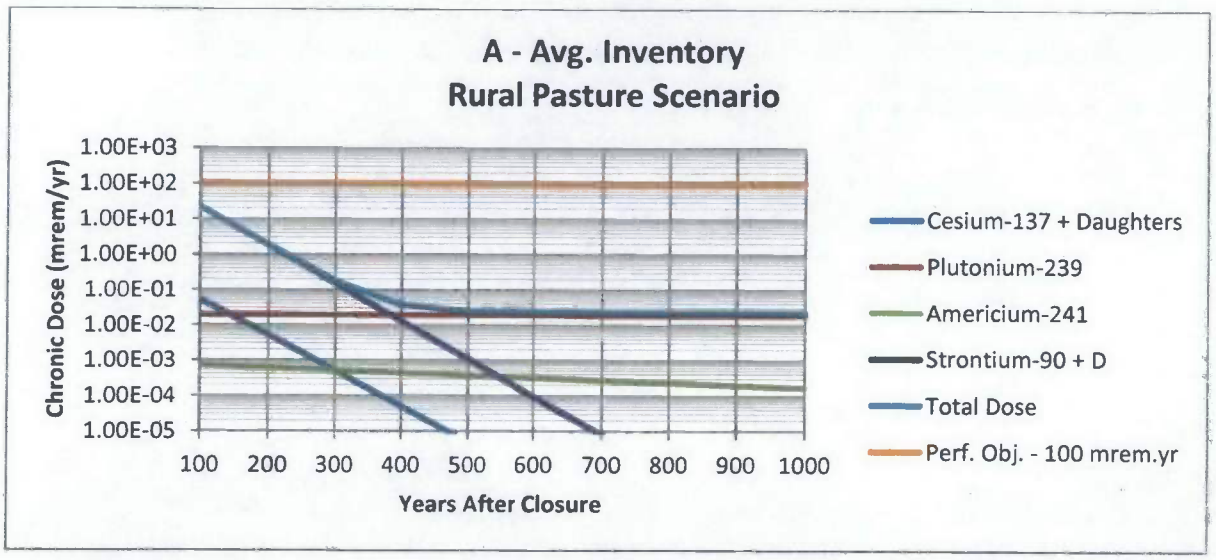
Table D-7. Suburban Garden Doses (mrem/y) for Single-Shell Tank 241-C-110 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2007) and Pathways. (4 sheets)

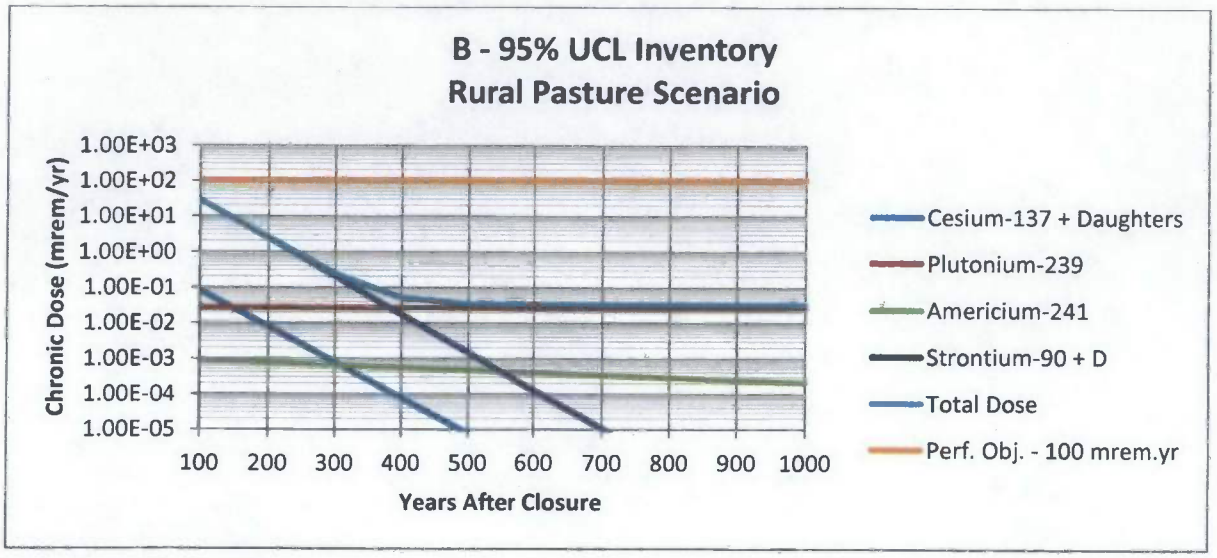
B – 95% Upper Confidence Level Inventory										
	Years After Site Closure (January 1, 2032)									
Nuclide	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1,000**
Americium-241	1.95E-02	1.67E-02	1.42E-02	1.21E-02	1.03E-02	8.78E-03	7.49E-03	6.38E-03	5.44E-03	4.64E-03
Antimony-125	1.04E-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
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	7.23E-05	7.15E-05	7.06E-05	6.98E-05	6.89E-05	6.81E-05	6.73E-05	6.65E-05	6.57E-05	6.49E-05
Cesium-137 + Daughters	7.78E-01	7.72E-02	7.66E-03	7.60E-04	7.54E-05	7.48E-06	7.42E-07	7.36E-08	7.30E-09	7.24E-10
Cobalt-60	4.37E-08	8.51E-14	1.66E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Curium-242	6.55E-07	2.97E-07	1.35E-07	6.13E-08	2.79E-08	1.27E-08	5.85E-09	2.73E-09	1.32E-09	6.75E-10
Curium-243	2.20E-06	2.56E-07	8.52E-08	6.99E-08	6.84E-08	6.81E-08	6.79E-08	6.77E-08	6.75E-08	6.73E-08
Curium-244	9.04E-06	3.45E-06	3.29E-06	3.25E-06	3.22E-06	3.19E-06	3.15E-06	3.12E-06	3.09E-06	3.05E-06
Europium-152	7.10E-04	3.92E-06	2.16E-08	1.19E-10	6.62E-13	7.98E-15	4.37E-15	4.35E-15	4.35E-15	4.35E-15
Europium-154	2.36E-05	7.40E-09	2.32E-12	7.27E-16	2.28E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	3.37E-10	1.24E-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
Iodine-129	5.19E-05	5.19E-05	5.19E-05	5.19E-05	5.19E-05	5.19E-05	5.19E-05	5.19E-05	5.19E-05	5.19E-05
Neptunium-237 + D	2.35E-03	2.35E-03	2.35E-03	2.35E-03	2.35E-03	2.35E-03	2.35E-03	2.35E-03	2.35E-03	2.35E-03
Nickel-63	1.84E-04	9.22E-05	4.61E-05	2.31E-05	1.15E-05	5.78E-06	2.89E-06	1.45E-06	7.24E-07	3.62E-07
Plutonium-238	2.81E-03	1.28E-03	5.79E-04	2.63E-04	1.20E-04	5.46E-05	2.51E-05	1.17E-05	5.68E-06	2.93E-06
Plutonium-239	5.87E-01	5.86E-01	5.84E-01	5.82E-01	5.81E-01	5.79E-01	5.77E-01	5.76E-01	5.74E-01	5.72E-01
Plutonium-240	6.32E-02	6.26E-02	6.19E-02	6.13E-02	6.06E-02	6.00E-02	5.94E-02	5.87E-02	5.81E-02	5.75E-02

Table D-7. Suburban Garden Doses (mrem/y) for Single-Shell Tank 241-C-110 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-241 + D	7.89E-03	6.73E-03	5.74E-03	4.89E-03	4.17E-03	3.55E-03	3.03E-03	2.58E-03	2.20E-03	1.88E-03
Plutonium-242	8.50E-07	8.50E-07	8.49E-07	8.49E-07	8.49E-07	8.49E-07	8.49E-07	8.49E-07	8.48E-07	8.48E-07
Protactinium-231	2.68E-02	2.71E-02	2.70E-02	2.70E-02	2.69E-02	2.69E-02	2.68E-02	2.68E-02	2.67E-02	2.66E-02
Selenium-79	3.94E-05	3.94E-05	3.94E-05	3.94E-05	3.94E-05	3.94E-05	3.93E-05	3.93E-05	3.93E-05	3.93E-05
Strontium-90 + D	3.98E+02	3.39E+01	2.89E+00	2.46E-01	2.10E-02	1.79E-03	1.52E-04	1.30E-05	1.11E-06	9.43E-08
Technetium-99	1.80E-02	1.80E-02	1.79E-02	1.79E-02	1.79E-02	1.79E-02	1.79E-02	1.79E-02	1.79E-02	1.79E-02
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	8.47E-04	1.25E-03	1.64E-03	2.01E-03	2.36E-03	2.70E-03	3.03E-03	3.34E-03	3.63E-03	3.92E-03
Thorium-232	2.62E-06	2.62E-06	2.62E-06	2.62E-06	2.62E-06	2.62E-06	2.62E-06	2.62E-06	2.62E-06	2.62E-06
Tin-126	1.71E-02	1.71E-02	1.71E-02	1.71E-02	1.71E-02	1.71E-02	1.71E-02	1.71E-02	1.71E-02	1.71E-02
Tritium	6.37E-10	2.30E-12	8.34E-15	3.02E-17	1.09E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Uranium-233	1.24E-03	1.33E-03	1.43E-03	1.52E-03	1.62E-03	1.71E-03	1.81E-03	1.90E-03	1.99E-03	2.08E-03
Uranium-234	2.72E-04	2.73E-04	2.74E-04	2.76E-04	2.77E-04	2.79E-04	2.81E-04	2.84E-04	2.86E-04	2.89E-04
Uranium-235 + D	1.58E-05	1.66E-05	1.74E-05	1.82E-05	1.90E-05	1.98E-05	2.06E-05	2.14E-05	2.23E-05	2.31E-05
Uranium-236	2.38E-06	2.38E-06	2.38E-06	2.38E-06	2.38E-06	2.38E-06	2.38E-06	2.38E-06	2.38E-06	2.38E-06
Uranium-238 + D	2.46E-04	2.46E-04	2.46E-04	2.46E-04	2.47E-04	2.47E-04	2.47E-04	2.47E-04	2.47E-04	2.47E-04
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
Total Dose	**3.99E+02**	**3.47E+01**	**3.63E+00**	**9.76E-01**	**7.46E-01**	**7.23E-01**	**7.17E-01**	**7.14E-01**	**7.10E-01**	**7.07E-01**

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-110.





UCL = upper confidence level

Table D-8. Commercial Farm Doses (mrem/y) for Single-Shell Tank 241-C-110 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

Nuclide	Years After Site Closure (January 1, 2032)									
	100	200	300	400	500	600	700	800	900	1,000
Americium-241	2.01E-05	1.72E-05	1.46E-05	1.25E-05	1.06E-05	9.05E-06	7.71E-06	6.57E-06	5.60E-06	4.77E-06
Antimony-125	1.36E-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
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	6.66E-11	6.58E-11	6.50E-11	6.42E-11	6.34E-11	6.27E-11	6.19E-11	6.12E-11	6.04E-11	5.97E-11
Cesium-137 + Daughters	8.46E-04	8.39E-05	8.32E-06	8.26E-07	8.19E-08	8.13E-09	8.06E-10	8.00E-11	7.93E-12	7.87E-13
Cobalt-60	5.54E-11	1.08E-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
Curium-242	2.79E-10	1.27E-10	5.74E-11	2.60E-11	1.18E-11	5.37E-12	2.44E-12	1.11E-12	5.11E-13	2.38E-13
Curium-243	1.13E-09	1.26E-10	3.76E-11	2.98E-11	2.90E-11	2.89E-11	2.88E-11	2.87E-11	2.86E-11	2.86E-11
Curium-244	3.87E-09	1.46E-09	1.39E-09	1.38E-09	1.36E-09	1.35E-09	1.33E-09	1.32E-09	1.31E-09	1.29E-09
Europium-152	9.40E-07	5.19E-09	2.86E-11	1.58E-13	8.74E-16	8.38E-18	3.60E-18	3.57E-18	3.57E-18	3.57E-18
Europium-154	3.12E-08	9.78E-12	3.07E-15	9.61E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	4.35E-13	1.61E-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
Iodine-129	1.60E-09	1.60E-09	1.60E-09	1.60E-09	1.60E-09	1.60E-09	1.60E-09	1.60E-09	1.60E-09	1.60E-09
Neptunium-237 + D	8.48E-07	8.48E-07	8.48E-07	8.48E-07	8.48E-07	8.48E-07	8.48E-07	8.48E-07	8.48E-07	8.48E-07
Nickel-63	4.78E-09	2.39E-09	1.20E-09	5.99E-10	3.00E-10	1.50E-10	7.50E-11	3.75E-11	1.88E-11	9.39E-12
Plutonium-238	2.70E-06	1.23E-06	5.56E-07	2.53E-07	1.15E-07	5.21E-08	2.37E-08	1.08E-08	4.98E-09	2.34E-09
Plutonium-239	5.42E-04	5.41E-04	5.39E-04	5.38E-04	5.36E-04	5.34E-04	5.33E-04	5.31E-04	5.30E-04	5.28E-04
Plutonium-240	5.83E-05	5.77E-05	5.71E-05	5.65E-05	5.59E-05	5.53E-05	5.47E-05	5.41E-05	5.36E-05	5.30E-05
Plutonium-241 + D	8.74E-06	7.45E-06	6.35E-06	5.41E-06	4.61E-06	3.93E-06	3.35E-06	2.85E-06	2.43E-06	2.07E-06

Table D-8. Commercial Farm Doses (mrem/y) for Single-Shell Tank 241-C-110 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-242	7.86E-10	7.86E-10	7.86E-10	7.86E-10	7.86E-10	7.85E-10	7.85E-10	7.85E-10	7.85E-10	7.85E-10
Protactinium-231	1.20E-05	1.21E-05	1.21E-05	1.20E-05	1.20E-05	1.20E-05	1.20E-05	1.19E-05	1.19E-05	1.19E-05
Selenium-79	8.83E-10	8.83E-10	8.83E-10	8.83E-10	8.83E-10	8.83E-10	8.83E-10	8.83E-10	8.83E-10	8.83E-10
Strontium-90 + D	1.75E-03	1.49E-04	1.27E-05	1.08E-06	9.22E-08	7.86E-09	6.70E-10	5.71E-11	4.87E-12	4.15E-13
Technetium-99	3.83E-09	3.83E-09	3.83E-09	3.83E-09	3.82E-09	3.82E-09	3.82E-09	3.82E-09	3.82E-09	3.82E-09
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	4.71E-07	5.96E-07	7.16E-07	8.31E-07	9.40E-07	1.05E-06	1.15E-06	1.24E-06	1.33E-06	1.42E-06
Thorium-232	2.24E-09	2.24E-09	2.24E-09	2.24E-09	2.24E-09	2.24E-09	2.24E-09	2.24E-09	2.24E-09	2.24E-09
Tin-126	4.77E-05	4.77E-05	4.77E-05	4.77E-05	4.77E-05	4.76E-05	4.76E-05	4.76E-05	4.76E-05	4.76E-05
Tritium	1.99E-12	7.21E-15	2.61E-17	9.44E-20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Uranium-233	1.84E-07	2.62E-07	3.38E-07	4.14E-07	4.89E-07	5.64E-07	6.38E-07	7.11E-07	7.83E-07	8.54E-07
Uranium-234	4.66E-08	4.75E-08	4.86E-08	4.99E-08	5.14E-08	5.31E-08	5.49E-08	5.69E-08	5.90E-08	6.13E-08
Uranium-235 + D	1.85E-08	1.94E-08	2.03E-08	2.11E-08	2.20E-08	2.29E-08	2.38E-08	2.47E-08	2.55E-08	2.64E-08
Uranium-236	4.82E-10	4.82E-10	4.82E-10	4.82E-10	4.82E-10	4.82E-10	4.82E-10	4.82E-10	4.82E-10	4.81E-10
Uranium-238 + D	9.76E-08	9.77E-08	9.77E-08	9.77E-08	9.77E-08	9.77E-08	9.77E-08	9.77E-08	9.78E-08	9.78E-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
Total Dose	**3.29E-03**	**9.19E-04**	**7.01E-04**	**6.76E-04**	**6.70E-04**	**6.65E-04**	**6.61E-04**	**6.58E-04**	**6.54E-04**	**6.51E-04**

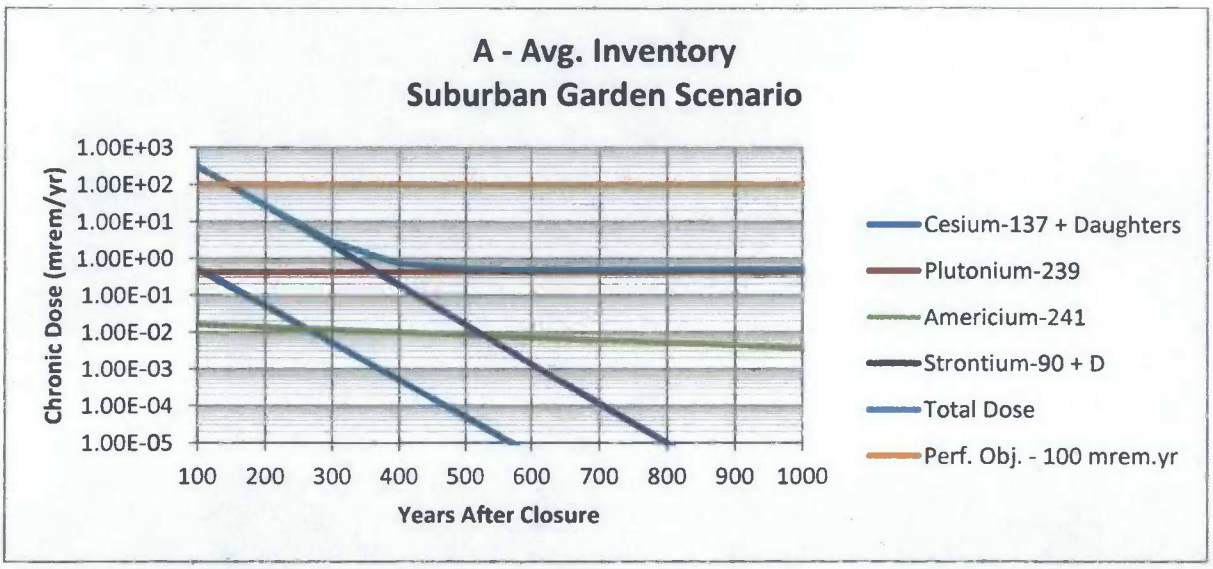
Table D-8. Commercial Farm Doses (mrem/y) for Single-Shell Tank 241-C-110 Showing Major Constituents for A) Average Inventory and B) 95% Upper Confidence Level Inventory (decayed as of January 2008) and Pathways. (4 sheets)

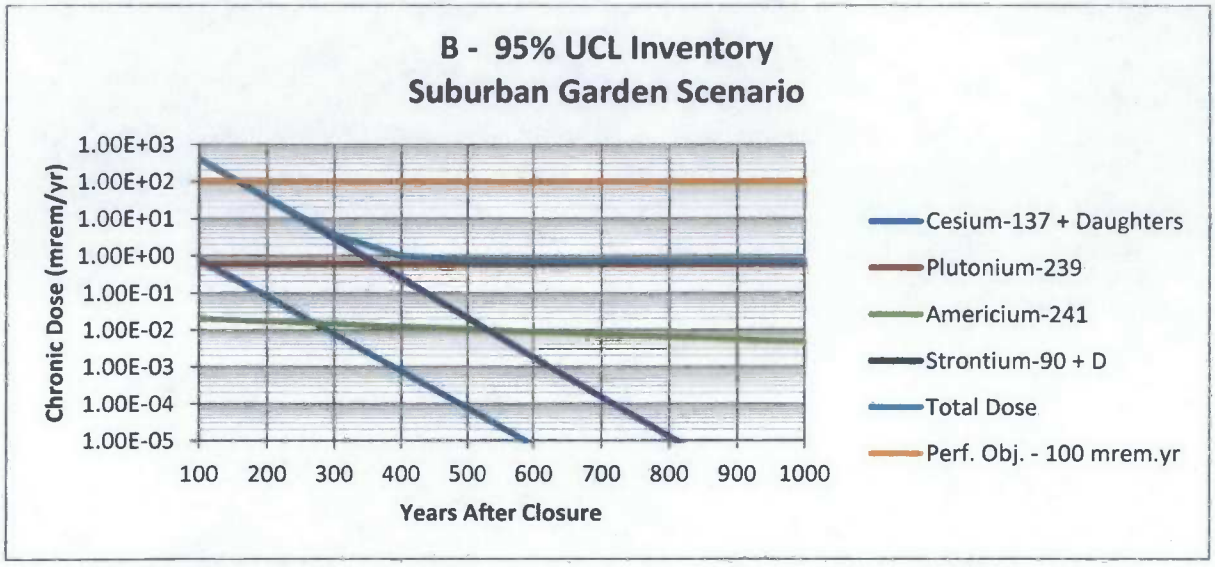
B – 95% Upper Confidence Level Inventory										
	Years After Site Closure (January 1, 2032)									
Nuclide	100	200	300	400	500	600	700	800	900	1,000
Americium-241	2.53E-05	2.15E-05	1.83E-05	1.56E-05	1.33E-05	1.13E-05	9.67E-06	8.24E-06	7.02E-06	5.98E-06
Antimony-125	4.08E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
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	2.00E-10	1.97E-10	1.95E-10	1.93E-10	1.90E-10	1.88E-10	1.86E-10	1.84E-10	1.81E-10	1.79E-10
Cesium-137 + Daughters	1.28E-03	1.27E-04	1.26E-05	1.25E-06	1.24E-07	1.23E-08	1.22E-09	1.21E-10	1.20E-11	1.20E-12
Cobalt-60	1.66E-10	3.23E-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
Curium-242	8.36E-10	3.79E-10	1.72E-10	7.81E-11	3.54E-11	1.61E-11	7.32E-12	3.34E-12	1.53E-12	7.13E-13
Curium-243	3.39E-09	3.78E-10	1.13E-10	8.94E-11	8.71E-11	8.67E-11	8.64E-11	8.62E-11	8.59E-11	8.57E-11
Curium-244	1.16E-08	4.38E-09	4.18E-09	4.13E-09	4.09E-09	4.05E-09	4.00E-09	3.96E-09	3.92E-09	3.88E-09
Europium-152	2.82E-06	1.56E-08	8.58E-11	4.74E-13	2.62E-15	2.51E-17	1.08E-17	1.07E-17	1.07E-17	1.07E-17
Europium-154	9.35E-08	2.93E-11	9.20E-15	2.88E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Europium-155	1.31E-12	4.83E-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
Iodine-129	4.81E-09	4.81E-09	4.81E-09	4.81E-09	4.81E-09	4.81E-09	4.81E-09	4.81E-09	4.81E-09	4.81E-09
Neptunium-237 + D	1.02E-06	1.02E-06	1.02E-06	1.02E-06	1.02E-06	1.02E-06	1.02E-06	1.02E-06	1.02E-06	1.02E-06
Nickel-63	5.79E-09	2.90E-09	1.45E-09	7.26E-10	3.63E-10	1.82E-10	9.09E-11	4.55E-11	2.28E-11	1.14E-11
Plutonium-238	3.58E-06	1.63E-06	7.38E-07	3.35E-07	1.52E-07	6.90E-08	3.14E-08	1.43E-08	6.60E-09	3.10E-09
Plutonium-239	7.46E-04	7.44E-04	7.42E-04	7.40E-04	7.38E-04	7.35E-04	7.33E-04	7.31E-04	7.29E-04	7.27E-04
Plutonium-240	8.03E-05	7.95E-05	7.86E-05	7.78E-05	7.70E-05	7.62E-05	7.54E-05	7.46E-05	7.38E-05	7.30E-05
Plutonium-241 + D	1.02E-05	8.70E-06	7.42E-06	6.32E-06	5.38E-06	4.59E-06	3.91E-06	3.33E-06	2.84E-06	2.42E-06

Table D-8. Commercial Farm Doses (mrem/y) for Single-Shell Tank 241-C-110 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-242	1.08E-09	1.08E-09	1.08E-09	1.08E-09	1.08E-09	1.08E-09	1.08E-09	1.08E-09	1.08E-09	1.08E-09
Protactinium-231	3.60E-05	3.63E-05	3.63E-05	3.62E-05	3.61E-05	3.60E-05	3.60E-05	3.59E-05	3.58E-05	3.57E-05
Selenium-79	2.65E-09	2.65E-09	2.65E-09	2.65E-09	2.65E-09	2.65E-09	2.65E-09	2.65E-09	2.65E-09	2.65E-09
Strontium-90 + D	2.31E-03	1.97E-04	1.68E-05	1.43E-06	1.22E-07	1.04E-08	8.86E-10	7.55E-11	6.44E-12	5.49E-13
Technetium-99	5.85E-09	5.84E-09	5.84E-09	5.84E-09	5.84E-09	5.84E-09	5.84E-09	5.83E-09	5.83E-09	5.83E-09
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	1.41E-06	1.79E-06	2.15E-06	2.49E-06	2.82E-06	3.14E-06	3.44E-06	3.72E-06	4.00E-06	4.26E-06
Thorium-232	6.73E-09	6.73E-09	6.73E-09	6.73E-09	6.73E-09	6.73E-09	6.73E-09	6.73E-09	6.73E-09	6.73E-09
Tin-126	6.76E-05	6.75E-05	6.75E-05	6.75E-05	6.75E-05	6.75E-05	6.74E-05	6.74E-05	6.74E-05	6.74E-05
Tritium	2.55E-12	9.23E-15	3.34E-17	1.21E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Uranium-233	5.53E-07	7.86E-07	1.02E-06	1.24E-06	1.47E-06	1.69E-06	1.92E-06	2.13E-06	2.35E-06	2.57E-06
Uranium-234	6.38E-08	6.50E-08	6.65E-08	6.83E-08	7.03E-08	7.25E-08	7.50E-08	7.78E-08	8.07E-08	8.39E-08
Uranium-235 + D	2.29E-08	2.40E-08	2.51E-08	2.62E-08	2.72E-08	2.83E-08	2.94E-08	3.05E-08	3.16E-08	3.27E-08
Uranium-236	5.46E-10	5.46E-10	5.46E-10	5.46E-10	5.46E-10	5.46E-10	5.46E-10	5.46E-10	5.46E-10	5.46E-10
Uranium-238 + D	1.21E-07	1.21E-07	1.21E-07	1.21E-07	1.21E-07	1.21E-07	1.21E-07	1.21E-07	1.21E-07	1.21E-07
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
Total Dose	**4.57E-03**	**1.29E-03**	**9.85E-04**	**9.51E-04**	**9.43E-04**	**9.37E-04**	**9.32E-04**	**9.28E-04**	**9.24E-04**	**9.20E-04**

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-110.





UCL = upper confidence level

Table D-9. Average and 95% Upper Confidence Levels for Waste Residuals within Tank 241-C-110, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (4 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	Above Detection Limits
1, 2, 4-Trichlorobenzene*	3.01E-03	4.51E-03	3.45E+01	4.53E+03	5.63E-02	Yes
Aluminum	1.31E+05	1.62E+05	8.00E+04	3.50E+06	4.80E+05	Yes
Arsenic*	6.01E+00	6.81E+00	6.67E-01	8.75E+01	3.41E-02	Yes
Barium*	5.06E+01	7.45E+01	1.60E+04	7.00E+05	1.65E+03	Yes
Bismuth	3.68E+03	4.29E+03	--	--	--	Yes
Boron	2.36E+00	4.45E+00	1.60E+04	7.00E+05	2.05E+02	Yes
Calcium	5.91E+02	6.72E+02	--	--	--	Yes
Chromium, Total*	1.13E+02	1.54E+02	1.20E+05	5.25E+06	2.00E+03	Yes
Cobalt	2.38E+00	2.80E+00	2.40E+01	1.05E+03	4.34E+00	Yes
Copper	3.18E+02	5.75E+02	3.20E+03	1.40E+05	2.84E+02	Yes
Cyanide*	8.22E-01	9.40E-01	4.80E+01	2.10E+03	9.70E-01	Yes
Fluoride	1.40E+04	1.70E+04	4.80E+03	2.10E+05	2.88E+03	Yes
Iron	1.92E+04	2.53E+04	5.60E+04	2.45E+06	5.64E+03	Yes
Lead*	5.69E+02	6.67E+02	--	1.00E+03	3.00E+03	Yes
Lithium	1.36E+01	1.63E+01	1.60E+02	7.00E+03	1.92E+02	Yes
Magnesium	2.85E+02	3.03E+02	--	--	--	Yes
Manganese	7.70E+01	9.77E+01	1.12E+04	4.90E+05	5.01E+02	Yes
Mercury*	1.08E+01	1.58E+01	2.40E+01	1.05E+03	2.09E+00	Yes
Molybdenum	2.19E+00	3.05E+00	4.00E+02	1.75E+04	3.23E+01	Yes
m-Xylene	3.40E-03	6.22E-03	1.60E+04	7.00E+05	1.35E+01	Yes
Nickel*	4.18E+01	4.91E+01	1.60E+03	7.00E+04	1.30E+02	Yes
Nitrate [c]	6.82E+02	1.30E+03	5.68E+05	2.49E+07	1.80E+02	Yes
o-Dichlorobenzene*	1.28E-03	2.04E-03	7.20E+03	3.15E+05	7.03E+00	Yes

Table D-9. Average and 95% Upper Confidence Levels for Waste Residuals within Tank 241-C-110, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (4 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	Above Detection Limits
o-Xylene	1.69E-03	3.03E-03	1.60E+04	7.00E+05	1.47E+01	Yes
Phenol*	8.43E-01	1.58E+00	2.40E+04	1.05E+06	1.10E+01	Yes
Phosphate	1.41E+05	1.67E+05	--	--	--	Yes
Polychlorinated Biphenyls*	1.61E-02	2.83E-02	5.00E-01	6.56E+01	--	Yes
Potassium	4.52E+01	6.47E+01	--	--	--	Yes
Silicon	2.07E+03	2.58E+03	--	--	--	Yes
Silver*	2.52E+01	4.05E+01	4.00E+02	1.75E+04	1.36E+01	Yes
Sodium	1.21E+05	1.43E+05	--	--	--	Yes
Strontium	5.70E+03	8.66E+03	4.80E+04	2.10E+06	6.76E+03	Yes
Sulfate	7.55E+02	7.94E+02	--	--	1.00E+03	Yes
Tin	8.53E+01	1.01E+02	4.80E+04	2.10E+06	4.80E+04	Yes
Titanium	4.33E+00	5.06E+00	--	--	--	Yes
Tributyl phosphate	1.03E+01	2.13E+01	1.11E+02	1.46E+04	4.96E-01	Yes
Uranium	5.56E+02	7.04E+02	2.40E+02	1.05E+04	2.70E+02	Yes
Xylenes	5.00E-03	9.29E-03	1.60E+04	7.00E+05	1.46E+01	Yes
Zinc	2.15E+02	2.56E+02	2.40E+04	1.05E+06	5.97E+03	Yes
Zirconium	3.66E+01	4.15E+01	--	--	--	Yes
1, 1, 2-Trichloroethylene	9.54E-04	2.82E-03	2.17E+01	1.75E+03	6.29E-03	No
1, 4-Dichlorobenzene	7.07E-04	2.09E-03	1.85E+02	2.43E+04	1.34E-01	No
2-Butanone(MEK)	1.55E-02	4.59E-02	4.80E+04	2.10E+06	1.97E+01	No
2-Propanone (Acetone)	2.01E-02	5.95E-02	7.20E+04	3.15E+06	2.89E+01	No
4-Methyl-2-pentanone (MIBK)	1.35E-02	4.00E-02	6.40E+03	2.80E+05	2.73E+00	No
Acetate	1.11E+02	3.29E+02	--	--	--	No

Table D-9. Average and 95% Upper Confidence Levels for Waste Residuals within Tank 241-C-110, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (4 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	Above Detection Limits
Antimony*	6.06E+00	1.79E+01	3.20E+01	1.40E+03	5.42E+00	No
Beryllium*	1.01E+00	2.99E+00	1.60E+02	7.00E+03	6.32E+01	No
Bromide	5.94E+01	1.76E+02	--	--	--	No
Cadmium*	1.01E+00	2.99E+00	8.00E+01	3.50E+03	6.90E-01	No
Cerium	1.31E+03	3.88E+03	--	--	--	No
Chloride	6.33E+01	1.87E+02	--	--	1.00E+03	No
Ethylbenzene	1.23E-03	3.64E-03	9.09E+01	1.19E+04	3.44E-02	No
Europium	1.01E+00	2.99E+00	--	--	--	No
Formate+A_2	1.66E+02	4.91E+02	--	--	--	No
Glycolate $C_2H_3O_3$	6.33E+01	1.87E+02	--	--	--	No
Lanthanum	1.01E+00	2.99E+00	--	--	--	No
Neodymium	1.51E+01	4.47E+01	--	--	--	No
Niobium	6.06E+00	1.79E+01	--	--	--	No
Nitrite [d]	2.77E+02	8.20E+02	2.40E+04	1.05E+06	1.32E+01	No
Oxalate	1.03E+02	3.05E+02	--	--	--	No
Palladium	1.21E+01	3.58E+01	--	--	--	No
Praseodymium	2.63E+01	7.78E+01	--	--	--	No
Rhodium	9.09E+00	2.69E+01	--	--	--	No
Rubidium	5.76E+01	1.70E+02	--	--	--	No
Ruthenium	4.04E+00	1.20E+01	--	--	--	No
Samarium	1.72E+01	5.09E+01	--	--	--	No
Selenium*	4.04E+00	1.20E+01	4.00E+02	1.75E+04	5.20E+00	No
Tantalum	5.05E+00	1.49E+01	--	--	--	No

Table D-9. Average and 95% Upper Confidence Levels for Waste Residuals within Tank 241-C-110, Soil Cleanup Levels for Method B and C Direct Contact Exposure, and Soil Concentrations Protective of Groundwater. (4 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	Above Detection Limits
Tellurium	8.08E+00	2.39E+01	--	--	--	No
Thallium*	4.34E+00	1.28E+01	--	--	2.28E-01	No
Thorium	1.06E+00	1.39E+00	--	--	--	No
Tungsten	1.62E+01	4.80E+01	--	--	--	No
Yttrium	1.08E+00	3.20E+00	--	--	--	No
Vanadium	1.24E+00	3.67E+00	4.00E+02	1.75E+04	1.60E+03	No

[a] Mean Concentrations taken from Table A-1, Appendix A of RPP-RPT-56703, *Tank 241-C-110 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-56703.

[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-110 Tank Residual Wastes. (4 sheets)

Analyte	Average Concentration (mg/kg)[a]	Ratio of Mean Concentrations in Tank 241-C-110 Upper Bound Inventory of Residual Wastes to Soil Cleanup Standards			
		Direct Contact Method B (mg/kg)	Direct Contact Method C (mg/kg)	Soil Concentrations Protective of Groundwater (mg/kg)	Above Detection Limits
1, 2, 4-Trichlorobenzene*	3.01E-03	8.73E-05	6.65E-07	5.35E-02	Yes
Aluminum	1.31E+05	1.64E+00	3.74E-02	2.73E-01	Yes
Arsenic*	6.01E+00	9.02E+00	6.87E-02	1.76E+02	Yes
Barium*	5.06E+01	3.16E-03	7.23E-05	3.07E-02	Yes
Bismuth	3.68E+03	--	--	--	Yes
Boron	2.36E+00	1.48E-04	3.37E-06	1.15E-02	Yes
Calcium	5.91E+02	--	--	--	Yes
Chromium, Total*	1.13E+02	9.42E-04	2.15E-05	5.65E-02	Yes
Cobalt	2.38E+00	9.92E-02	2.27E-03	5.48E-01	Yes
Copper	3.18E+02	9.94E-02	2.27E-03	1.12E+00	Yes
Cyanide*	8.22E-01	1.71E-02	3.91E-04	8.48E-01	Yes
Fluoride	1.40E+04	2.92E+00	6.67E-02	4.85E+00	Yes
Iron	1.92E+04	3.43E-01	7.84E-03	3.40E+00	Yes
Lead*	5.69E+02	--	5.69E-01	1.90E-01	Yes
Lithium	1.36E+01	8.50E-02	1.94E-03	7.08E-02	Yes
Magnesium	2.85E+02	--	--	--	Yes
Manganese	7.70E+01	6.88E-03	1.57E-04	1.54E-01	Yes
Mercury*	1.08E+01	4.50E-01	1.03E-02	5.17E+00	Yes
Molybdenum	2.19E+00	5.48E-03	1.25E-04	6.78E-02	Yes
m-Xylene	3.40E-03	2.13E-07	4.86E-09	2.52E-04	Yes
Nickel*	4.18E+01	2.61E-02	5.97E-04	3.21E-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-110 Tank Residual Wastes. (4 sheets)

Analyte	Average Concentration (mg/kg)[a]	Ratio of Mean Concentrations in Tank 241-C-110 Upper Bound Inventory of Residual Wastes to Soil Cleanup Standards			
		Direct Contact Method B (mg/kg)	Direct Contact Method C (mg/kg)	Soil Concentrations Protective of Groundwater (mg/kg)	Above Detection Limits
Nitrate [b]	6.82E+02	1.20E-03	2.74E-05	3.79E+00	Yes
o-Dichlorobenzene*	1.28E-03	1.78E-07	4.06E-09	1.82E-04	Yes
o-Xylene	1.69E-03	1.06E-07	2.41E-09	1.15E-04	Yes
Phenol*	8.43E-01	3.51E-05	8.03E-07	7.68E-02	Yes
Phosphate	1.41E+05	--	--	--	Yes
Polychlorinated Biphenyls*	1.61E-02	3.22E-02	2.45E-04	--	Yes
Potassium	4.52E+01	--	--	--	Yes
Silicon	2.07E+03	--	--	--	Yes
Silver*	2.52E+01	6.30E-02	1.44E-03	1.85E+00	Yes
Sodium	1.21E+05	--	--	--	Yes
Strontium	5.70E+03	1.19E-01	2.71E-03	8.43E-01	Yes
Sulfate	7.55E+02	--	--	7.55E-01	Yes
Tin	8.53E+01	1.78E-03	4.06E-05	1.78E-03	Yes
Titanium	4.33E+00	--	--	--	Yes
Tributyl phosphate	1.03E+01	9.27E-02	7.06E-04	2.08E+01	Yes
Uranium	5.56E+02	2.32E+00	5.30E-02	2.06E+00	Yes
Xylenes	5.00E-03	3.13E-07	7.14E-09	3.42E-04	Yes
Zinc	2.15E+02	8.96E-03	2.05E-04	3.60E-02	Yes
Zirconium	3.66E+01	--	--	--	Yes
1, 1, 2-Trichloroethylene	9.54E-04	4.39E-05	5.45E-07	1.52E-01	No
1, 4-Dichlorobenzene	7.07E-04	3.82E-06	2.91E-08	5.29E-03	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-110 Tank Residual Wastes. (4 sheets)

Analyte	Average Concentration (mg/kg)[a]	Ratio of Mean Concentrations in Tank 241-C-110 Upper Bound Inventory of Residual Wastes to Soil Cleanup Standards			
		Direct Contact Method B (mg/kg)	Direct Contact Method C (mg/kg)	Soil Concentrations Protective of Groundwater (mg/kg)	Above Detection Limits
2-Butanone(MEK)	1.55E-02	3.23E-07	7.38E-09	7.89E-04	No
2-Propanone (Acetone)	2.01E-02	2.79E-07	6.38E-09	6.95E-04	No
4-Methyl-2-pentanone (MIBK)	1.35E-02	2.11E-06	4.82E-08	4.95E-03	No
Acetate	1.11E+02	--	--	--	No
Antimony*	6.06E+00	1.89E-01	4.33E-03	1.12E+00	No
Beryllium*	1.01E+00	6.31E-03	1.44E-04	1.60E-02	No
Bromide	5.94E+01	--	--	--	No
Cadmium*	1.01E+00	1.26E-02	2.89E-04	1.46E+00	No
Cerium	1.31E+03	--	--	--	No
Chloride	6.33E+01	--	--	6.33E-02	No
Ethylbenzene	1.23E-03	1.35E-05	1.03E-07	3.58E-02	No
Europium	1.01E+00	--	--	--	No
Formate+A_2	1.66E+02	--	--	--	No
Glycolate $C_2H_3O_3$	6.33E+01	--	--	--	No
Lanthanum	1.01E+00	--	--	--	No
Neodymium	1.51E+01	--	--	--	No
Niobium	6.06E+00	--	--	--	No
Nitrite [c]	2.77E+02	1.15E-02	2.64E-04	2.10E+01	No
Oxalate	1.03E+02	--	--	--	No
Palladium	1.21E+01	--	--	--	No
Praseodymium	2.63E+01	--	--	--	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-110 Tank Residual Wastes. (4 sheets)

Analyte	Average Concentration (mg/kg)[a]	Ratio of Mean Concentrations in Tank 241-C-110 Upper Bound Inventory of Residual Wastes to Soil Cleanup Standards			
		Direct Contact Method B (mg/kg)	Direct Contact Method C (mg/kg)	Soil Concentrations Protective of Groundwater (mg/kg)	Above Detection Limits
Rhodium	9.09E+00	--	--	--	No
Rubidium	5.76E+01	--	--	--	No
Ruthenium	4.04E+00	--	--	--	No
Samarium	1.72E+01	--	--	--	No
Selenium*	4.04E+00	1.01E-02	2.31E-04	7.77E-01	No
Tantalum	5.05E+00	--	--	--	No
Tellurium	8.08E+00	--	--	--	No
Thallium*	4.34E+00	--	--	1.90E+01	No
Thorium	1.06E+00	--	--	--	No
Tungsten	1.62E+01	--	--	--	No
Vanadium	1.24E+00	3.10E-03	7.09E-05	7.75E-04	No
Yttrium	1.08E+00	--	--	--	No

[a] Mean Concentrations taken from Table A-1, Appendix A of RPP-RPT-56703, *Tank 241-C-110 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-110 Tank Residual Wastes. (5 sheets)

Analyte	95% Upper Confidence Level Concentration (mg/kg)[a]	Ratio of 95% Upper Confidence Level Concentrations in Tank 241-C-110 Upper Bound Inventory of Residual Wastes to Soil Cleanup Standards			
		Direct Contact Method B (mg/kg)	Direct Contact Method C (mg/kg)	Soil Concentrations Protective of Groundwater (mg/kg)	Above Detection Limits
1, 2, 4-Trichlorobenzene*	4.51E-03	1.31E-04	9.97E-07	8.02E-02	Yes
Aluminum	1.62E+05	2.02E+00	4.62E-02	3.37E-01	Yes
Arsenic*	6.81E+00	1.02E+01	7.78E-02	2.00E+02	Yes
Barium*	7.45E+01	4.66E-03	1.06E-04	4.52E-02	Yes
Bismuth	4.29E+03	--	--	--	Yes
Boron	4.45E+00	2.78E-04	6.35E-06	2.17E-02	Yes
Calcium	6.72E+02	--	--	--	Yes
Chromium, Total*	1.54E+02	1.28E-03	2.93E-05	7.69E-02	Yes
Cobalt	2.80E+00	1.17E-01	2.67E-03	6.46E-01	Yes
Copper	5.75E+02	1.80E-01	4.11E-03	2.02E+00	Yes
Cyanide*	9.40E-01	1.96E-02	4.48E-04	9.69E-01	Yes
Fluoride	1.70E+04	3.53E+00	8.08E-02	5.88E+00	Yes
Iron	2.53E+04	4.52E-01	1.03E-02	4.49E+00	Yes
Lead*	6.67E+02	--	6.67E-01	2.22E-01	Yes
Lithium	1.63E+01	1.02E-01	2.33E-03	8.49E-02	Yes
Magnesium	3.03E+02	--	--	--	Yes
Manganese	9.77E+01	8.72E-03	1.99E-04	1.95E-01	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-110 Tank Residual Wastes. (5 sheets)

Analyte	95% Upper Confidence Level Concentration (mg/kg)[a]	Ratio of 95% Upper Confidence Level Concentrations in Tank 241-C-110 Upper Bound Inventory of Residual Wastes to Soil Cleanup Standards			
		Direct Contact Method B (mg/kg)	Direct Contact Method C (mg/kg)	Soil Concentrations Protective of Groundwater (mg/kg)	Above Detection Limits
Mercury*	1.58E+01	6.59E-01	1.51E-02	7.58E+00	Yes
Molybdenum	3.05E+00	7.63E-03	1.74E-04	9.45E-02	Yes
m-Xylene	6.22E-03	3.89E-07	8.88E-09	4.60E-04	Yes
Nickel*	4.91E+01	3.07E-02	7.01E-04	3.76E-01	Yes
Nitrate [b]	1.30E+03	2.30E-03	5.25E-05	7.25E+00	Yes
o-Dichlorobenzene*	2.04E-03	2.83E-07	6.47E-09	2.90E-04	Yes
o-Xylene	3.03E-03	1.89E-07	4.33E-09	2.06E-04	Yes
Phenol*	1.58E+00	6.58E-05	1.50E-06	1.44E-01	Yes
Phosphate	1.67E+05	--	--	--	Yes
Polychlorinated Biphenyls*	2.83E-02	5.67E-02	4.32E-04	--	Yes
Potassium	6.47E+01	--	--	--	Yes
Silicon	2.58E+03	--	--	--	Yes
Silver*	4.05E+01	1.01E-01	2.31E-03	2.98E+00	Yes
Sodium	1.43E+05	--	--	--	Yes
Strontium	8.66E+03	1.80E-01	4.12E-03	1.28E+00	Yes
Sulfate	7.94E+02	--	--	7.94E-01	Yes
Tin	1.01E+02	2.10E-03	4.81E-05	2.10E-03	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-110 Tank Residual Wastes. (5 sheets)

Analyte	95% Upper Confidence Level Concentration (mg/kg)[a]	Ratio of 95% Upper Confidence Level Concentrations in Tank 241-C-110 Upper Bound Inventory of Residual Wastes to Soil Cleanup Standards			
		Direct Contact Method B (mg/kg)	Direct Contact Method C (mg/kg)	Soil Concentrations Protective of Groundwater (mg/kg)	Above Detection Limits
Titanium	5.06E+00	--	--	--	Yes
Tributyl phosphate	2.13E+01	1.91E-01	1.46E-03	4.29E+01	Yes
Uranium	7.04E+02	2.93E+00	6.71E-02	2.61E+00	Yes
Xylenes	9.29E-03	5.81E-07	1.33E-08	6.35E-04	Yes
Zinc	2.56E+02	1.07E-02	2.44E-04	4.29E-02	Yes
Zirconium	4.15E+01	--	--	--	Yes
1, 1, 2-Trichloroethylene	2.82E-03	1.30E-04	1.61E-06	4.49E-01	No
1, 4-Dichlorobenzene	2.09E-03	1.13E-05	8.61E-08	1.57E-02	No
2-Butanone(MEK)	4.59E-02	9.56E-07	2.18E-08	2.33E-03	No
2-Propanone (Acetone)	5.95E-02	8.26E-07	1.89E-08	2.06E-03	No
4-Methyl-2-pentanone (MIBK)	4.00E-02	6.24E-06	1.43E-07	1.47E-02	No
Acetate	3.29E+02	--	--	--	No
Antimony*	1.79E+01	5.61E-01	1.28E-02	3.31E+00	No
Beryllium*	2.99E+00	1.87E-02	4.27E-04	4.73E-02	No
Bromide	1.76E+02	--	--	--	No
Cadmium*	2.99E+00	3.74E-02	8.54E-04	4.33E+00	No
Cerium	3.88E+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-110 Tank Residual Wastes. (5 sheets)

Analyte	95% Upper Confidence Level Concentration (mg/kg)[a]	Ratio of 95% Upper Confidence Level Concentrations in Tank 241-C-110 Upper Bound Inventory of Residual Wastes to Soil Cleanup Standards			
		Direct Contact Method B (mg/kg)	Direct Contact Method C (mg/kg)	Soil Concentrations Protective of Groundwater (mg/kg)	Above Detection Limits
Chloride	1.87E+02	--	--	1.87E-01	No
Ethylbenzene	3.64E-03	4.00E-05	3.05E-07	1.06E-01	No
Europium	2.99E+00	--	--	--	No
Formate+A_2	4.91E+02	--	--	--	No
Glycolate $C_2H_3O_3$	1.87E+02	--	--	--	No
Lanthanum	2.99E+00	--	--	--	No
Neodymium	4.47E+01	--	--	--	No
Niobium	1.79E+01	--	--	--	No
Nitrite [c]	8.20E+02	3.42E-02	7.81E-04	6.21E+01	No
Oxalate	3.05E+02	--	--	--	No
Palladium	3.58E+01	--	--	--	No
Praseodymium	7.78E+01	--	--	--	No
Rhodium	2.69E+01	--	--	--	No
Rubidium	1.70E+02	--	--	--	No
Ruthenium	1.20E+01	--	--	--	No
Samarium	5.09E+01	--	--	--	No
Selenium*	1.20E+01	2.99E-02	6.83E-04	2.30E+00	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-110 Tank Residual Wastes. (5 sheets)

Analyte	95% Upper Confidence Level Concentration (mg/kg)[a]	Ratio of 95% Upper Confidence Level Concentrations in Tank 241-C-110 Upper Bound Inventory of Residual Wastes to Soil Cleanup Standards			
		Direct Contact Method B (mg/kg)	Direct Contact Method C (mg/kg)	Soil Concentrations Protective of Groundwater (mg/kg)	Above Detection Limits
Tantalum	1.49E+01	--	--	--	No
Tellurium	2.39E+01	--	--	--	No
Thallium*	1.28E+01	--	--	5.64E+01	No
Thorium	1.39E+00	--	--	--	No
Tungsten	4.80E+01	--	--	--	No
Vanadium	3.67E+00	9.18E-03	2.10E-04	2.29E-03	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-56703, *Tank 241-C-110 Residual Waste Inventory Estimates for Component Closure Risk Assessment.*

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

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

* 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, V.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

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
Zinc	Zn	Metal	µg/kg	67,800	366,000	DOE/RL-92-24, Vol. 1, Rev. 4
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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WAC 173-340, "Model Toxics Control Act – Cleanup," *Washington Administrative Code*, as amended.

WAC 173-340-705, "Use of Method B," *Washington Administrative Code*, as amended.