SRR-CWDA-2015-00075
Revision 1

TANK 12 INVENTORY DETERMINATION

August 2015

Prepared by: Savannah River Remediation LLC
Waste Disposal Authority
Aiken, SC 29808

Prepared for U.S. Department of Energy Under Contract No. DE-AC09-09SR22505

APPROVALS

Author:

8-26-15

Dara Dixon
Waste Disposal Authority
Savannah River Remediation LLC

Date

Technical Review (per ENG.51):

8/26/15

David Watkins
Waste Disposal Authority
Savannah River Remediation LLC
Technical Review Method: Document Review

Date

Reviewer:

8/26/15

Mark Layton
Waste Disposal Authority
Savannah River Remediation LLC

Date

Management Review:

8/26/2015

Steve Thomas
Waste Disposal Authority, Manager
Savannah River Remediation LLC

Date

REVISION SUMMARY

REV. #	DESCRIPTION	DATE OF ISSUE
0	Initial issue	July/16/2015
1	Corrected transcription error for Mo inventory in Table 5.1-2	August/26/2015

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS/ABBREVIATIONS

CVAA	Cold Vapor Atomic Absorption
DQA	Data Quality Assessment
ICP-ES	Inductively Coupled Plasma-Atomic Emission Spectroscopy
HTF	H-Area Tank Farm
LWTRSAPP	Liquid Waste Tank Residuals Sampling and Analysis Program Plan
MDC	Minimum Detectable Concentration
RM&A	Regulatory Management & Administration
SA	Special Analysis
SRNL	Savannah River National Laboratory
SRR	Savannah River Remediation LLC
TDL	Target Detection Limit
TSAP	Tank-Specific Sampling and Analysis Plan
WDA	Waste Disposal Authority
Wt %	Weight Percent
UCL95	Upper 95% Confidence Limit

1.0 PURPOSE

The Tank 12 residual inventory is the radiological and chemical source term that will remain in the waste tank at the time of closure. This inventory will be used to update the H-Area Tank Farm (HTF) closure inventory for future HTF fate and transport modeling and the Tank 12 Special Analysis (SA). The inventory will also be used for other Tank 12 closure documents including the Tank 12 Closure Module Addendum and Class C calculation.

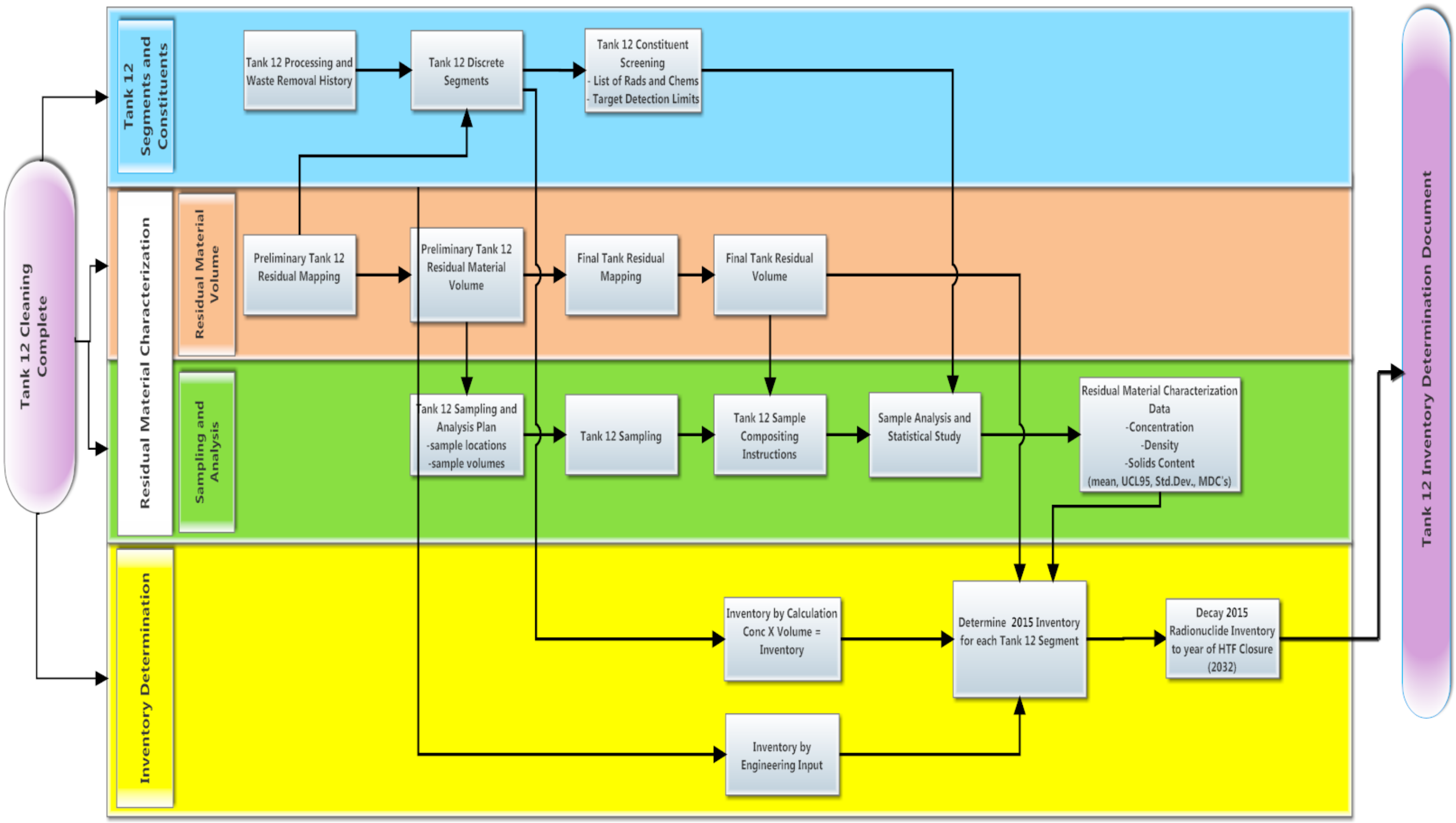
This document presents the methodology and calculations used to determine the Tank 12 inventory in year 2015 and for the radionuclide inventory decayed to year 2032, the assumed year of HTF closure.

2.0 METHODOLOGY

The methodology used to develop the Tank 12 inventory is shown in Figure 2.0-1. Figure 2.0-1 is divided into swim lanes representing the combination of activities that occur to determine the inventory of the residual material left in a tank following permission to cease waste removal. The inventory determination is the summation of those inventories determined for various segments of residual materials that will remain in the tank at closure. Some segment inventories are determined by sampling and analysis while others are based on process knowledge. The initial radionuclide inventory determined at the date of sampling is then decayed to the assumed year of HTF closure. The chemical inventory is not decayed.

The inventory determination activities on Figure 2.0-1 are discussed in the following sections.

Figure 2.0-1: Methodology for Tank 12 Inventory Determination



3.0 INVENTORY DETERMINATION ACTIVITIES

The following sections describe in detail the activities outlined in Figure 2.0-1. These activities are done to develop and calculate the final Tank 12 inventory.

3.1 Tank 12 Discrete Segments for Residual Material Characterization

The residuals in Tank 12 have been divided into discrete segments for characterization. These segments added together make the total inventory. The following segments were used to determine the final Tank 12 inventory.

- Primary waste tank floor residual solids
- Cooling coil surface solids
- Waste tank internal surfaces (support column and wall surfaces)
- Free-liquid in the primary tank at the time of floor sampling
- Equipment hold-up (e.g., pumps)
- Cooling coil internal liquid hold-up
- Annulus residuals

3.2 Tank 12 Residual Material Sampling and Characterization

The residuals sampling and analysis plan for Tank 12 residuals characterization was based on:

- Tank 12 Preliminary Volume Estimate [U-ESR-H-00109]
- Tank 12 Sample Accessibility Evaluation [SRR-LWE-2012-00226]
- Tank 12 Sample Location Verification Document [SRR-LWE-2014-00083]
- Tank 12 Final Volume Determination and Uncertainty Estimate [U-ESR-H-00125]
- Liquid Waste Tank Residuals Sampling and Analysis Program Plan (LWTRSAPP) [SRR-CWDA-2011-00050]

The Tank 12 preliminary mapping showed residual solids on the tank floor and in a mound behind the tank valve house piping. The preliminary mapping also showed a scale material on the cooling coils. Residual liquid was also present above the residual floor solids. Based on the preliminary mapping, 1,000 gallons of residual solids was estimated in the primary tank (780 gallons for the floor and 220 gallons for the mound), and 400 gallons of solids for the cooling coil scale. [U-ESR-H-00109, M-CLC-H-03256, SRR-LWE-2014-00074] The Tank 12 annulus was estimated to contain 25 gallons of dried material. [C-ESR-G-00003] The liquid volume was not estimated at that time because it was decreasing slowly as the tank drying continued.

A Tank 12 sampling recommendation team composed of Savannah River Remediation LLC (SRR) Management, Waste Removal & Tank Closure Engineering, Waste Disposal Authority (WDA), Regulatory Management & Administration (RM&A), and Tank Farm Operations personnel evaluated the Tank 12 residuals distribution, volumes, and accessibility. Final sample locations were chosen after considering the results of a Savannah River National Laboratory (SRNL) statistical evaluation of sampling options that incorporated possible heterogeneity in the cooling coil scale and in the mound behind the valve house piping. [SRNL-STI-2014-00263]

The LWTRSAPP sampling approach was used to develop the *Tank 12 Sampling and Analysis Plan* (TSAP), SRR-LWE-2014-00074. Six samples from the waste tank floor, six samples from the mound behind the valve house piping, and three samples from cooling coils were designated for composite sample creation in the TSAP. The TSAP recommended that if free liquid was present during the sampling, a liquid sample should be collected for analysis. [SRR-CWDA-2011-00050, SRR-LWE-2014-00074]

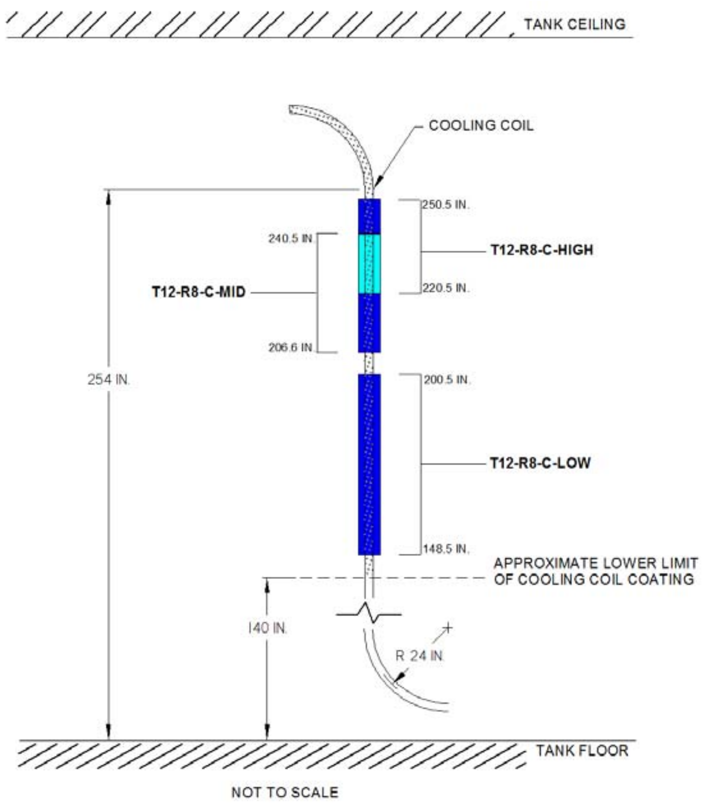
3.2.1 Tank 12 Tank Sampling

During the Tank 12 sampling, adjustments to the sampling plan were required to meet the objective of characterizing the residual material. The changes are explained and described in the revised TSAP. [SRR-LWE-2014-00074]

3.2.2 Tank 12 Cooling Coil Sampling and Analysis

The cooling coil scale sampling was performed first. Samples were collected from three height intervals as shown on Figure 3.2-1. Material for each sample interval was collected by scraping two adjacent coils. Because of the difficulty manipulating the sampling tool, there was an overlap of the middle and high intervals as shown on Figure 3.2-1.

Figure 3.2-1: Final Tank 12 Cooling Coil Sample Intervals



To identify the material encrusting the cooling coils, scoping analyses were conducted on the T12-R8-C-MID sample. The sample was processed and analyzed by SRNL as described in the *Tank 12H Residual Sample Analysis Report*, SRNL-STI-2015-00241. The preliminary analytical results indicated the material had a density of approximately 4 g/ml, and a very high mercury content. [SRNL-STI-2015-00241]

Because the characterization sample compositing is mass-based, use of the coil material in the compositing scheme would bias the characterization samples and ultimately the Tank 12 inventory. The decision was made not to use the material in the compositing with the floor sample, and to develop a separate inventory for the estimated 400 gallons of cooling coil material.

This decision decreased the number of samples used for compositing from 15 to 12. This impact is discussed in Section 3.3.

3.2.3 Tank 12 Floor and Mound Sampling and Analysis

Because of material recovery and accessibility problems, resampling was necessary at the first three planned locations and only five of the six floor samples were collected. The floor samples were collected while the tank was still "wet" and all samples contained liquid. The liquid was separated for analysis as described in Section 3.2.4.

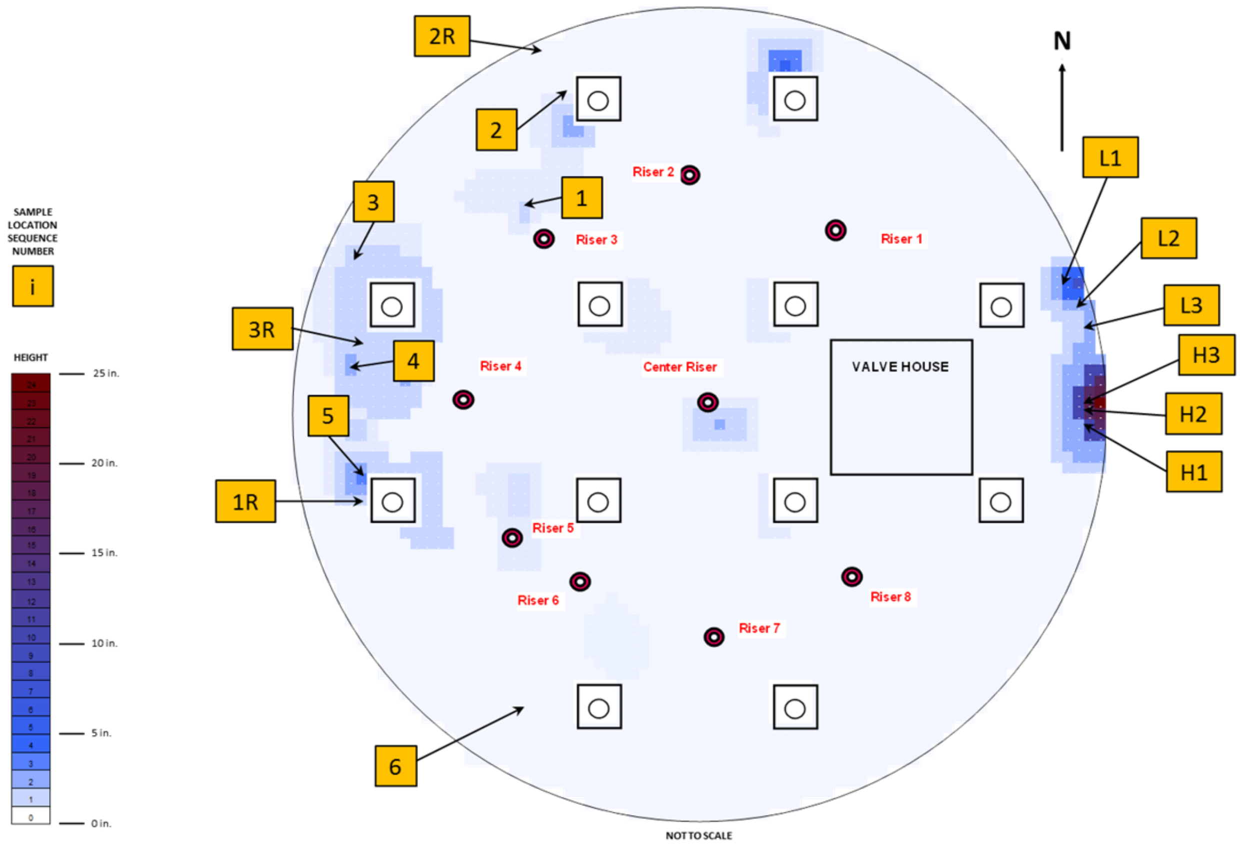
The six mound samples were collected as described in the revised Tank 12 TSAP. Additional details on the sample collection are presented in the Tank 12 TSAP. [SRR-LWE-2014-00074] The sample locations, sample collection dates, and approximate sample masses are shown in Table 3.2-1. The final floor sample locations are shown on Figure 3-2-2. The samples were processed and analyzed by SRNL as described in the *Tank 12H Residual Sample Analysis Report*, SRNL-STI-2015-00241.

Table 3.2-1: Tank 12 Floor and Mound Sampling Results

Sample Location	Date Sampled	Approximate Sample Mass[a] (grams)
T12-F-1	08/04/2014	--
T12-F-2	08/04/2014	--
T12-F-3	08/04/2014	--
T12-F-4	08/06/2014	130
T12-F-5	08/07/2014	170
T12-F-6	08/08/2014	--
T12-F-1R	08/13/2014	148
T12-F-2R	08/13/2014	20
T12-F-3R	08/13/2014	68
T12-M-L1	08/23/2014	55
T12-M-L2	08/23/2014	53
T12-M-L3	08/23/2014	70
T12-M-H1	08/26/2014	79
T12-M-H2	08/26/2014	97
T12-M-H3	08/26/2014	88

[a]SRNL-L3100-2014-00245. The samples all required a period of air-drying to permit material removal from the sample collection cup.

Figure 3-2-2: Final Tank 12 Floor Sampling Locations



3.2.4 Tank 12 Liquid Sampling and Analysis

To characterize the liquid phase present in the primary tank, the liquid present in the floor samples was decanted, filtered, and combined for analysis. Approximately 170 milliliters of liquid was collected for scoping analyses as described in the TSAP. [SRR-LWE-2014-00074] The sample was analyzed by SRNL as described in the *Tank 12H Residual Sample Analysis Report*, SRNL-STI-2015-00241.

3.2.5 Tank 12 Final Residual Material Volumes

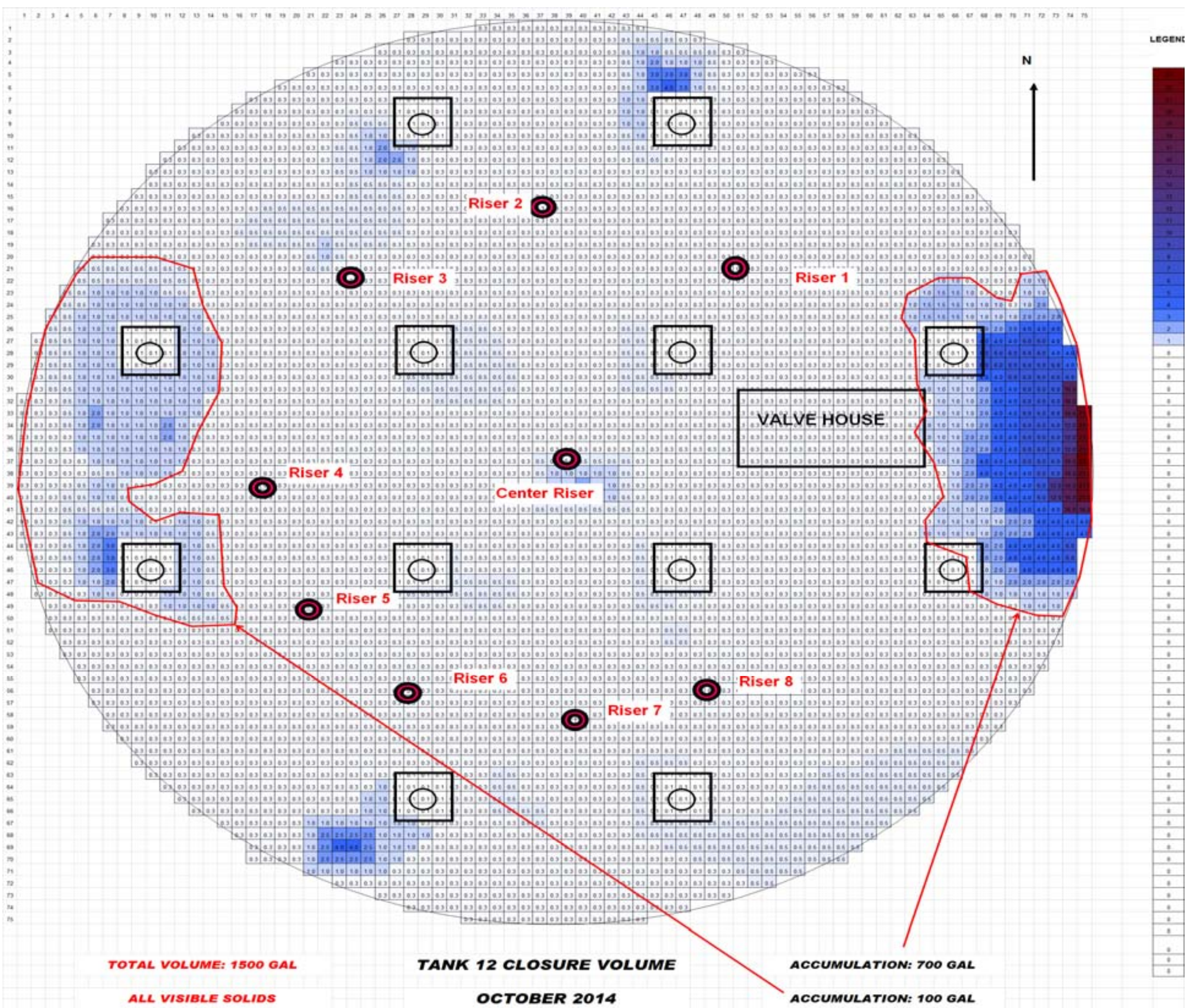
The final floor and mound residual solids volumes were determined after evaluating additional visual information in the video footage taken by the on-board crawler camera during the floor residual solids sampling. An estimated 3,500 gallons of free liquid was evaluated to be present above the residual floor solids at the time of sampling. [U-ESR-H-00125] Table 3.2-2 shows the preliminary and final solids material volume determinations. Figure 3.2-3 presents the final residual floor solids map.

Table 3.2-2: Tank 12 Preliminary and Final Residual Solids Volumes

Residual Material Segment	Preliminary Volume Estimate[a] (gal)	Final Volume Determination[b] (gal)
Cooling Coils	400	400
General Tank Floor	780	800
Mound Behind the Valve House Piping	220	700
Total	**1,400**	**1,900**

[a]U-ESR-H-00109
[b]U-ESR-H-00125

Figure 3.2-3: Tank 12 Final Residual Floor Solids Map



3.3 Tank 12 Residual Material Sample Compositing, Analysis and Statistical Study

The Tank 12 residual material samples were composited and analyzed as discussed in the following sections. The statistical study and the Data Quality Assessment (DQA) on the sample analyses analytical results are discussed in the following sections.

3.3.1 Tank 12 Residual Material Sample Compositing

The sample compositing plan was updated to account for the recovery of only five of the six floor samples and the exclusion of the cooling coil samples.

Three possible compositing options using the 11 available floor and mound samples were evaluated by an SRNL statistician. The compositing options evaluation considered the sampling variability and the impact on the variance of the sample means for the composite sample creation. [SRNL-STI-2014-00551] The decision was made to use four instead of the typical five samples per analytical composite and to split one sample (T12-F-4) for use in two of the composites. The final compositing scheme is shown in Table 3.3-1.

Table 3.3-1: Tank 12 Analytical Sample Compositing Scheme

Material Segment	Composite No. 1	Composite No. 2	Composite No. 3
Mound	T12-M-L-1	T12-M-L-2	T12-M-L-3
Mound	T12-M-H-1	T12-M-H-2	T12-M-H-3
Floor	T-12-F-4	T12-F-2R	T12-F-1R
Floor	T12-F-5	T-12-F-3R	T12-F-4

The final compositing calculation is presented in the *Tank 12H Sample Compositing Determination*, SRR-CWDA-2014-00103. The final sample masses were 70 grams for Composites No. 1 and No. 3, while Composite No. 2 was limited to 60 grams by the amount of Sample F-2R. The 60 gram mass was sufficient for full analyte list determination at the requested Target Detection Limits (TDLs).

3.3.2 Tank 12 Sample Analyses and Statistical Study

The Tank 12 composite samples were analyzed by SRNL to characterize the residual materials. The screening and selection of the radionuclide and chemical analytes for Tank 12 can be found in the *Recommended Radionuclide and Chemical Analyte List for Tank 12*, SRR-CWDA-2014-00052. The analyte list is also provided in Table 3.3-2.

The cooling coil sample was analyzed as shown in Table 3.3-3 and the liquid sample was analyzed as shown in Table 3.3-4. [G-TTR-H-00008] The analyte list for the cooling coil sample and the liquid sample was not comprehensive, but was focused on the major radiological dose drivers, mercury, and metals. These samples were analyzed once (no replicates), therefore a statistical study was not done on the cooling coil and liquid sample analytical results. For additional details on the cooling coil and liquid sample analyses refer to the *Tank 12H Residual Sample Analysis Report*, SRNL-STI-2015-00241.

The analytical results provide the concentrations of the radionuclides and chemicals in the residual material as well as providing the density and percentage of solids in the residual material. The characterization results are presented in Section 4.0 and are documented in the *Tank 12H Residual Sample Analysis Report,* SRNL-STI-2015-00241.

Table 3.3-2: Tank 12 Residual Material Analytes

Radionuclides				Chemicals		
Am-241	I-129	Ra-226	U-234	Ag	F	PO_4
Am-242m	Nb-94	Ra-228	U-235	Al	Fe	Sb
Am-243	Ni-59	Sn-126	U-238	As	Hg	Se
Ba-137m	Ni-63	Sr-90	Y-90	B	I	SO_4
C-14	Np-237	Tc-99	Zr-93	Ba	Mn	Sr
Cm-243	Pa-231	Th-229	--	Cd	Mo	Th
Cm-244	Pu-238	Th-230	--	Cl	Ni	Zn
Cm-245	Pu-239	Th-232	--	Co	NO_2	Zr
Cs-135	Pu-240	U-232	--	Cr	NO_3	U
Cs-137	Pu-241	U-233	--	Cu	Pb	

Table 3.3-3: Cooling Coil Material Analyses and Target Detection Limits

Analysis	Target Detection Limit (TDL)
Gamma spectroscopy for Cs-137 and other radionuclides determined by the method	200 pCi/g
Cs-removed gamma spectroscopy	200 pCi/g
Gross alpha/beta	N/A
Alpha Spectroscopy for plutonium isotopes	200 pCi/g
ICP-ES[a] for metals, CVAA[b] for mercury (Hg)	TDL is analyte dependent
X-ray Fluorescence (on undigested solids)	N/A
X-ray Diffraction (on undigested solids)	N/A
Density, Weight Percent Solids	N/A

[G-TTR-H-00008]
[a]ICP-ES - Inductively Coupled Plasma-Atomic Emission Spectroscopy
[b]CVAA - Cold Vapor Atomic Absorption

Table 3.3-4: Liquid Sample Analyses and Target Detection Limits

Analysis	Target Detection Limit (TDL)
Gamma spectroscopy for Cs-137 and other radionuclides determined by the method	20 pCi/ml
Cs-removed gamma spectroscopy	20 pCi/ml
Gross alpha/beta	N/A
Alpha Spectroscopy for plutonium isotopes	20 pCi/ml
Tc-99	13 pCi/ml
ICP-ES for metals, CVAA for mercury (Hg)	TDL is analyte dependent
Anions	TDL is analyte dependent

[G-TTR-H-00008]

A statistical study of the composite sample analytical results was performed and for those constituents with measured concentrations it provided the mean, standard deviation, and upper 95% confidence limit (UCL95) of the mean for the concentration values. For those constituents where the concentration was non-detectable or less than the TDL, the lowest and highest Minimum Detectable Concentrations (MDCs) were used to bound the concentration values for the constituent. The statistical study refers to these constituents as having concentrations less than their MDC. For those constituents with a mixture of detected and non-detected concentrations, the constituents were treated as either those with measured values or those with non-detected values. Additional details on how the constituents with a mixture of detected and non-detected concentrations were treated are in the *Tank 12H Residual Sample Analysis Report,* SRNL-STI-2015-00241. The mean, standard deviation, and UCL95 of the mean for the composite sample densities and weight percent (wt %) solids were also provided in the statistical study.

3.3.3 Data Quality Assessment

A Data Quality Assessment (DQA) was performed to evaluate and document the usability and acceptability of the analytical data. The *Tank 12 Final Characterization Data Quality Assessment,* SRR-CWDA-2015-00084, determined the characterization data found in the *Tank 12H Residual Sample Analysis Report,* SRNL-STI-2015-00241, for the waste tank floor residual solids, the cooling coil surface solids, and the waste tank liquid to be acceptable for use for the Tank 12 inventory determination.

3.4 Final Inventory Determination

The Tank 12 final residual inventory is the total of the radionuclide and chemical constituents that will remain in the waste tank at the time of closure. The constituents present in the waste tank residual material segments are determined by sampling, analysis, and calculation or by engineering evaluation. The final Tank 12 inventory is the summation of all the segment inventories listed below.

- Primary waste tank floor residual solids
- Cooling coil surface solids
- Waste tank internal surfaces (support column and wall surfaces)
- Primary waste tank liquid
- Equipment hold-up
- Cooling coil internal liquid hold-up
- Annulus residuals

For residual solids that are sampled and analyzed, the constituent concentrations are reported in terms of dry solids mass. These constituent concentrations in the segment are calculated by multiplying the dry solids mass result by the sample density and the solids content (dry basis) using the relationship:

$$c_{ij} = m_{ij} \times \rho_{ij} \times s_{ij}$$

Where:

c_{ij}	=	Constituent concentration, j, in segment, i
m_{ij}	=	Dried solids mass of constituent j, in segment i
ρ_{ij}	=	Density of constituent, j, in segment, i

s_{ij}	=	Solids content of constituent, j, in segment, i

For liquids, the constituent concentration is reported as a concentration per volume and no correction for density or solids content is made/needed.

Taking the individual calculated constituent concentrations, the inventory for the segment sampled and analyzed is determined by:

$$T_j = \sum (V_i \times c_{ij})$$

Where:

T_j	=	Total Inventory for constituent j
V_i	=	Volume (or surface area) of segment i
c_{ij}	=	Concentration of constituent, j, in segment, i

This is repeated for the individual radionuclide and chemical constituents analyzed within each segment.

In practice, the inventory for solids, such as those on the waste tank floor, is determined using the following formulas:

Radionuclides

$$I_{Fi} = c_{Fi} \times \frac{1Ci}{10^6 \mu Ci} \times V_F \times \frac{3.785L}{gal} \times \frac{1000mL}{L} \times \rho \times \frac{s}{100}$$

Where:

I_{Fi}	=	Inventory for constituent i (Ci)
c_{Fi}	=	Concentration for constituent i (µCi/g)
V_F	=	Segment (floor) volume (gal)
ρ	=	Residual material density (g/mL)
s	=	Residual material solids content (wt %)

Chemicals

$$I_{Fi} = c_{Fi} \times \frac{10mg}{1cg} \times \frac{1kg}{10^6 mg} \times V_F \times \frac{3.785L}{gal} \times \frac{1000mL}{L} \times \rho \times \frac{s}{100}$$

Where:

I_{Fi}	=	Inventory for constituent i (kg)
c_{Fi}	=	Concentration for constituent i (wt % or cg/g)
V_F	=	Segment (floor) volume (gal)
ρ	=	Residual material density (g/mL)
s	=	Residual material solids content (wt %)

The solids samples are typically analyzed in triplicate, so for three composite samples, a maximum of nine results can be reported. The results are statistically evaluated and for the constituent concentration in the above formulas, the UCL95 of the mean for all nine results is typically used to determine the inventory. For constituents where all nine results are non-detects, the lowest MDC result is used to determine the inventory. For constituent results having a mixture of detects and non-detects, the constituents are treated as detects if there are a sufficient number of detectable results. A UCL95 is calculated for these constituents using statistical methods. If there is not a sufficient number of detectable results then the constituents are treated as non-detects and the lowest MDC result is used to determine the inventory. More details on the statistical methods are found in the *Tank 12H Residual Sample Analysis Report*, SRNL-STI-2015-00241.

For segments not sampled and analyzed, alternate methods are used to estimate the constituent content. The alternate methods used are discussed in the individual segment evaluations.

4.0 INVENTORY DETERMINATION INPUTS

This section describes each of the inputs used to calculate the inventories for each of the Tank 12 residual material discrete segments. The inputs are the segment residual volume and the radionuclide and chemical constituent concentrations within each segment.

4.1 Waste Tank Floor Residual Solids

The tank floor residual solids inventory was developed using the final residual solids material volume, the composite sample densities, solids content, and the radionuclide and chemical analytical results. Three composite samples were analyzed to determine the average concentrations of the floor material. [SRR-LWE-2014-00074] Because the floor samples were collected while the tank had a layer of liquid, conservatisms in the material density and solids content were used to convert the analytical results to inventory values.

4.1.2 Waste Tank Floor Residual Material Density and Solids Content

Because the floor samples were collected while the material was covered with liquid, the actual sample density and wt % solids of the in-situ material were not known. The mean of the composite sample air-dried densities and wt % solids was used for the conversion of residual material mass to volume basis. These values are shown in Table 4.1-1 and are found in the *Tank 12H Residual Sample Analysis Report,* SRNL-STI-2015-00241. The floor samples contained liquid that was subsequently removed; therefore, in-situ density would be lower than the air-dried density. The use of the air-dried density is conservative.

Table 4.1-1: Tank 12 Floor Residual Material Density and Weight Percent Solids

Measure	Density (g/ml)	Wt % Solids
Mean	1.28	86.5

4.1.3 Waste Tank Floor Residual Material Volume

The method used to determine the final Tank 12 floor residual volume is presented in the *Tank 12 Final Volume Determination and Uncertainty Estimate*, U-ESR-H-00125. The final floor residual volume was estimated to be approximately 1,500 gallons. Conservative high and low residual volumes were estimated, but 1,500 gallons was recommended as the best residual volume. Therefore, a final floor residual volume of 1,500 gallons was used for the inventory determination.

4.1.4 Waste Tank Floor Residual Material Concentrations

The three composite samples from the Tank 12 primary floor were characterized and the results reported in the *Tank 12H Residual Sample Analysis Report*, SRNL-STI-2015-00241. Constituents with measured concentrations are presented in Table 4.1-2. Constituents with concentrations less than the MDC are shown in Table 4.1-3.

Table 4.1-2: Tank 12 Floor Residual Material with Measured Constituent Concentrations

Constituent	Concentration			Constituent	Concentration		
	Mean (µCi/g)	UCL95 (µCi/g)	Standard Deviation (µCi/g)		Mean (wt %)	UCL95 (wt %)	Standard Deviation (wt %)
Am-241	1.24E+01	2.13E+01	5.25E+00	Ag	6.06E-02	1.06E-01	2.71E-02
Am-242m	3.08E-03	5.17E-03	1.24E-03	Al	7.08E+00	1.06E+01	2.14E+00
Am-243	1.84E-02	2.60E-02	4.78E-03	As	2.16E-04	2.62E-04	2.96E-05
Ba-137m	8.25E+00	1.24E+01	2.60E+00	B	9.67E-02	1.41E-01	2.65E-02
Cs-137	8.72E+00	1.31E+01	2.74E+00	Ba	6.88E-02	7.09E-02	3.30E-03
I-129	4.55E-03	5.04E-03	7.96E-04	Cd	2.50E-03	3.49E-03	5.92E-04
Ni-59	1.90E-01	3.13E-01	7.36E-02	Cl	1.62E-02	1.69E-02	1.11E-03
Ni-63	1.97E+01	3.04E+01	6.37E+00	Co	4.36E-03	6.72E-03	1.41E-03
Np-237	1.25E-02	2.52E-02	7.54E-03	Cr	5.00E-02	7.57E-02	1.53E-02
Pa-231	1.29E-03	2.44E-03	6.78E-04	Cu	1.54E-01	1.98E-01	2.69E-02
Pu-238	8.94E+01	1.55E+02	3.95E+01	Fe	3.01E+01	4.20E+01	7.12E+00
Pu-239	3.80E+00	6.68E+00	1.73E+00	Hg	1.56E+01	2.21E+01	3.88E+00
Pu-240	1.37E+00	2.47E+00	6.60E-01	I**	2.72E-03	3.03E-03	4.95E-04
Pu-241	2.06E+01	3.73E+01	1.02E+01	Mn	1.36E+00	1.71E+00	2.09E-01
Ra-228	4.70E-03	7.82E-03	1.91E-03	Mo	1.37E-03	1.51E-03	1.71E-04
Sn-126	1.73E-02	2.22E-02	3.04E-03	Ni	7.72E-01	1.18E+00	2.43E-01
Sr-90	1.53E+04	1.94E+04	2.61E+03	NO_2	5.78E-03	1.02E-02	2.67E-03
Tc-99	4.12E-03	4.48E-03	5.77E-04	NO_3	1.46E-02	1.57E-02	1.78E-03
Th-232	5.46E-03	1.06E-02	3.05E-03	Pb	3.44E-02	3.87E-02	2.81E-03
U-232	3.38E-03	4.09E-03	1.14E-03	SO_4	7.88E-02	1.22E-01	2.62E-02
U-234	5.70E-03	8.73E-03	1.81E-03	Sr	4.45E-02	5.44E-02	6.01E-03
U-235	2.90E-05	5.45E-05	1.52E-05	Th	4.96E+00	9.66E+00	2.79E+00
U-238	4.42E-04	9.38E-04	2.95E-04	U	8.78E-02	1.82E-01	5.61E-02
Y-90*	1.53E+04	1.94E+04	2.61E+03	Zn	3.31E-02	3.72E-02	2.60E-03
Zr-93	4.56E-01	6.34E-01	1.07E-01	Zr	1.19E-01	1.66E-01	2.84E-02

*Based on equilibrium relationship with Sr-90.

**I is the total iodine value in the SRNL statistical analysis report. The total iodine value consists of I-129 and I-127. [SRNL-STI-2015-00241]

Table 4.1-3: Tank 12 Floor Residual Material Below Minimum Detectable Concentrations

Constituent	Lowest Minimum Detectable Concentration (µCi/g)	Highest Minimum Detectable Concentration (µCi/g)	Constituent	Lowest Minimum Detectable Concentration (wt %)	Highest Minimum Detectable Concentration (wt %)
C-14	<5.05E-04	<8.83E-04	F	<2.93E-03	<3.06E-03
Cm-243	<1.22E-02	<1.88E-02	PO_4	<2.93E-03	<3.06E-03
Cm-244	<3.34E-01	<6.98E-01	Sb	<1.92E-04	<2.00E-04
Cs-135	<1.00E-05	<8.06E-05	Se	<2.88E-04	<2.99E-04
Nb-94	<4.36E-04	<1.23E-03			
Ra-226	<4.68E-04	<7.75E-04			
Th-229	<2.04E-04	<4.10E-03			
Th-230	<3.52E-04	<1.62E-03			
U-233	<3.23E-02	<8.53E-02			

4.2 Cooling Coil Surface Solids

Three samples of the material coating the cooling coils were collected and one sample was used for scoping analysis as described in Section 3.2.2. The characterization results and additional information is presented in the *Tank 12H Residual Sample Analysis Report,* SRNL-STI-2015-00241.

4.2.1 Cooling Coil Surface Material Density and Weight Percent Solids

The scale material samples were hard solids and the density and wt % solids measurements were made without additional drying. The mean value of the sample density and wt % solids measurements for all three samples collected are shown in Table 4.2-1.

Table 4.2-1: Cooling Coil Surface Material Density and Weight Percent Solids

Measure	Density (g/ml)	Wt % Solids
Mean	3.08	98.0

4.2.2 Cooling Coil Surface Solids Material Volume

The volume of solids material coating the surface of the cooling coils was determined to be 400 gallons in the *Tank 12 Internal Component Solid Coating Volume*, M-CLC-H-03256. As mentioned earlier, a separate inventory for this material was calculated and added to the final Tank 12 inventory.

4.2.3 Cooling Coil Surface Solids Material Concentration

The constituent concentrations of the material coating the cooling coils are presented in Table 4.2-2. In the scoping analysis, all analytical measurements were determined only once so no UCL95 or standard deviation was determined. The combined Sr-90 and Y-90 concentrations in Table 4.2-2 are assumed to be equal to the beta concentration (split evenly between Sr-90 and Y-90).

Table 4.2-2: Tank 12 Cooling Coil Surface Solids Material Concentrations

Constituent	Concentration (µCi/g or wt %)	Constituent	Concentration (wt %)
Am-241	5.77E-01	Cr	2.68E-03
Cs-137	1.34E+00	Cu	2.75E-03
I-129	1.29E-03	Fe	8.07E-02
Pu-238	8.38E+00	Hg	9.82E+01
Pu-239	1.84E-01	Mn	2.71E-02
Pu-240	1.84E-01	Mo	1.40E-02
Sr-90	9.08E+01	Ni	6.35E-03
Tc-99	9.64E-03	Pb	1.01E-01
Y-90	9.08E+01	Sb	3.20E-02
Ag	1.00E-02	Sr	1.00E-03
Al	2.33E-01	Th	9.03E-03
B	1.69E-02	U	5.44E-02
Ba	1.96E-03	Zn	1.47E-03
Cd	9.88E-04	Zr	2.45E-03
Co	1.36E-03		

4.3 Waste Tank Internal Surfaces (Support Columns and Walls)

Internal inspections and tank mapping showed small amounts of solids visible on the Tank 12 support columns and primary tank liner wall. These solids accumulations were considered to be accounted for within the conservatism of the estimated cooling coil surface residual material volume of 400 gallons. [M-CLC-H-03256]

4.4 Primary Waste Tank Liquid

As discussed in Section 3.2.4, to characterize the liquid phase present in the Tank 12 primary tank during sampling, the liquid in the floor samples was decanted, filtered, and combined for scoping analyses. Approximately 170 ml was collected. [SRNL-STI-2015-00241] The liquid was analyzed by SRNL for the constituents in Table 3.3-4.

4.4.1 Primary Waste Tank Liquid Concentrations

The Tank 12 liquid was characterized and the results reported in the *Tank 12H Residual Sample Analysis Report*, SRNL-STI-2015-00241. The results are presented in Table 4.4-1. The estimated liquid volume at the time of sampling was 3,500 gallons on top of the floor solids. [U-ESR-H-00125] The combined Sr-90 and Y-90 concentrations in Table 4.4-1 are assumed to be equal to the beta concentration (split evenly between Sr-90 and Y-90).

Table 4.4-1: Tank 12 Primary Waste Tank Liquid Concentrations

Constituent	Concentration (µCi/L)	Constituent	Concentration (mg/L)	Constituent	Concentration (mg/L)	Constituent	Concentration (µg/mL)
Am-241	<1.30E+01	Ag	<3.90E-02	Mn	9.05E-02	F	<1.00E+01
Cs-137	2.17E+02	Al	1.12E+00	Mo	<3.59E-01	Cl	3.00E+01
I-129	8.8E-03	B	<4.35E-01	Ni	<1.02E-01	NO_2	2.00E+01
Pu-238	8.33E-01	Ba	<2.00E-02	Pb	<2.60E+00	NO_3	1.13E+02
Pu-239	6.49E-02	Cd	<2.50E-02	Sb	<8.22E-01	PO_4	<1.00E+01
Pu-240	6.49E-02	Co	<3.50E-02	Sr	1.17E-02	SO_4	5.70E+01
Sr-90	4.64E+02	Cr	1.68E-01	Th	<1.00E+00		
Tc-99	2.25E-02	Cu	<7.10E-02	U	3.78E+01		
Y-90	4.64E+02	Fe	1.04E+00	Zn	<2.10E-02		
		Hg	2.21E+01	Zr	<1.20E-02		

4.5 Waste Tank Equipment Residual Material Hold-up

Tank 12 contains various pieces of equipment in the primary tank and annulus used during the operational life and the waste removal process. The equipment in the primary tank includes a transfer pump, a transfer jet, and two robotic crawlers. [SRR-LWE-2014-00161] There is potential for material hold-up in the transfer pump and transfer jet. The two robotic crawlers were used for final residual sampling and were placed into Tank 12 after the acid cleaning phase. The *Tank 12 Internal Equipment Evaluation*, SRR-LWE-2014-00161, states that the crawlers do not contain any residual material. The estimated residual waste hold-up volume in the transfer pump and transfer jet is approximately 10 gallons. [SRR-LWE-2014-00161]

The surface inventory of the equipment is expected to be minimal since this equipment would have experienced similar treatment conditions to the residual material on the floor. This treatment process used an acid cleaning phase, which was expected to reduce any surface residuals inventory on the equipment.

The Tank 12 annulus contains an annulus transfer jet used during the operational life of the waste tank. The estimated residual material hold-up in the annulus transfer jet is approximately 3 gallons. [SRR-LWE-2014-00161]

The total of approximately 13 gallons of residual material estimated for the equipment hold-up is small when compared to the 1,500 gallons of floor residuals. The 13 gallons is approximately 0.9% of the floor residuals volume and is considered represented in the Tank 12 floor residual inventory.

4.6 Waste Tank Cooling Coils Internal Liquid Hold-up

The Tank 12 cooling coils were flushed as part of waste removal. All chromate cooling water inside the coils was removed during the flushing. Therefore, there is no residual material present in the cooling coils and no inventory contribution was assigned to the cooling coil internals.

4.7 Waste Tank Annulus

Tank 12 has a total of 15 leak sites that have historically leaked salt waste into the annulus. The total estimated volume of dried salt waste in the annulus is 25 gallons. [C-ESR-G-00003] The 25 gallons of dried annulus waste represents only 2% of the 1,500 gallons estimated for the floor residuals volume and is considered represented in the Tank 12 floor residual inventory. Therefore, a separate annulus inventory is not determined.

In early 2015, water was noticed in the Tank 12 annulus. The water was thought to be related to rain water in-leakage. A liquid sample taken in May 2015 showed contamination, mainly Cs-137, probably resulting from dissolution of soluble annulus material. [SRR-CWDA-2015-00085] Because the liquid was transferred to Tank 10, and any additional in-leakage will also be transferred, no additional inventory will be determined for this liquid.

5.0 TOTAL RESIDUAL MATERIAL INVENTORIES

Using the inputs and assumptions presented in the preceding sections, an inventory was calculated or estimated for each of the residual material segments. The sum of the individual inventories is the final Tank 12 inventory.

5.1 Waste Tank Floor Residual Solids Material Inventory

The Tank 12 floor residual solids inventory values for the radionuclide constituents are presented in Table 5.1-1. The radionuclide values are for year 2015 and are not decayed to the anticipated year of HTF closure in 2032. Table 5.1-2 presents Tank 12 floor residual solids inventory values for the chemical constituents.

Table 5.1-1: Tank 12 Floor Residual Solids Material Radionuclide Inventory

Constituent	Units	Inventory (2015)
Am-241	Ci	1.3E+02
Am-242m	Ci	3.2E-02
Am-243	Ci	1.6E-01
Ba-137m*	Ci	7.8E+01
C-14	Ci	<3.2E-03
Cm-243	Ci	<7.7E-02
Cm-244	Ci	<2.1E+00
Cm-245	Ci	3.0E-04
Cs-135	Ci	<6.3E-05
Cs-137	Ci	8.2E+01
I-129	Ci	3.2E-02
Nb-94	Ci	<2.7E-03
Ni-59	Ci	2.0E+00
Ni-63	Ci	1.9E+02
Np-237	Ci	1.6E-01
Pa-231	Ci	1.5E-02
Pu-238	Ci	9.7E+02
Pu-239	Ci	4.2E+01
Pu-240	Ci	1.6E+01
Pu-241	Ci	2.3E+02
Ra-226	Ci	<2.9E-03
Ra-228	Ci	4.9E-02
Sn-126	Ci	1.4E-01
Sr-90	Ci	1.2E+05
Tc-99	Ci	2.8E-02
Th-229	Ci	<1.3E-03
Th-230	Ci	<2.2E-03
Th-232	Ci	6.6E-02
U-232	Ci	2.6E-02
U-233	Ci	<2.0E-01
U-234	Ci	5.5E-02
U-235	Ci	3.4E-04
U-238	Ci	5.9E-03
Y-90**	Ci	1.2E+05
Zr-93	Ci	4.0E+00

*Based on equilibrium relationship with Cs-137
**Based on equilibrium relationship with Sr-90

Table 5.1-2: Tank 12 Floor Residual Solids Material Chemical Inventory

Constituent	Units	Inventory
Ag	kg	6.7E+00
Al	kg	6.6E+02
As	kg	1.6E-02
B	kg	8.8E+00
Ba	kg	4.4E+00
Cd	kg	2.2E-01
Cl	kg	1.1E+00
Co	kg	4.2E-01
Cr	kg	4.7E+00
Cu	kg	1.2E+01
F	kg	<1.8E-01
Fe	kg	2.6E+03
Hg	kg	1.4E+03
I	kg	1.9E-01
Mn	kg	1.1E+02
Mo	kg	9.5E-02
Ni	kg	7.4E+01
NO_2	kg	6.4E-01
NO_3	kg	9.9E-01
Pb	kg	2.4E+00
PO_4	kg	<1.8E-01
Sb	kg	<1.2E-02
Se	kg	<1.8E-02
SO_4	kg	7.6E+00
Sr	kg	3.4E+00
Th	kg	6.1E+02
U	kg	1.1E+01
Zn	kg	2.3E+00
Zr	kg	1.0E+01

5.2 Waste Tank Cooling Coil Surface Solids Material Inventory

The inventory for the cooling coil surface solids material was determined using the formulas in Section 3.4 and the input values from Section 4.2. Because each analysis was only performed once, the mean constituent concentrations were used to determine the inventory. For constituents that were not detected, the lowest MDC was used to determine the inventory.

The cooling coil surface solids material inventory values for the radionuclide constituents are presented in Table 5.2-1. The radionuclide values are for year 2015 and are not decayed to the anticipated year of HTF closure in 2032. Table 5.2-2 presents cooling coil surface residual solids material inventory values for the chemical constituents.

Table 5.2-1: Tank 12 Cooling Coil Surface Solids Material Radionuclide Inventory

Constituent	Units	Inventory (2015)
Am-241	Ci	2.6E+00
Ba-137m*	Ci	5.8E+00
Cs-137	Ci	6.1E+00
I-129	Ci	5.9E-03
Pu-238	Ci	3.8E+01
Pu-239	Ci	8.4E-01
Pu-240	Ci	8.4E-01
Sr-90	Ci	4.1E+02
Tc-99	Ci	4.4E-02
Y-90**	Ci	4.1E+02

*Based on equilibrium relationship with Cs-137
**Based on equilibrium relationship with Sr-90

Table 5.2-2: Tank 12 Cooling Coil Surface Solids Material Chemical Inventory

Constituent	Units	Inventory
Ag	kg	4.6E-01
Al	kg	1.1E+01
B	kg	7.7E-01
Ba	kg	9.0E-02
Cd	kg	4.5E-02
Co	kg	6.2E-02
Cr	kg	1.2E-01
Cu	kg	1.3E-01
Fe	kg	3.7E+00
Hg	kg	4.5E+03
Mn	kg	1.2E+00
Mo	kg	6.4E-01
Ni	kg	2.9E-01
Pb	kg	4.6E+00
Sb	kg	1.5E+00
Sr	kg	4.6E-02
Th	kg	4.1E-01
U	kg	2.5E+00
Zn	kg	6.7E-02
Zr	kg	1.1E-01

5.3 Primary Waste Tank Liquid Residual Material Inventory

The inventory for the liquid in the primary tank was determined using the formulas in Section 3.4 and the input values from Section 4.4. Because each analysis was only performed once, the mean constituent concentrations were used to determine the inventory. For constituents that were not detected, the lowest MDC was used to determine the inventory.

The liquid inventory values for the radionuclide constituents are presented in Table 5.3-1. The radionuclide values are for year 2015 and are not decayed to the anticipated year of HTF closure in 2032. Table 5.3-2 presents inventory values for the chemical constituents.

As stated in Section 3.3.2, the analyte list for the liquid sample was not comprehensive, but focused on the major radiological dose drivers. The total Tank 12 liquid radionuclide inventory of the major dose drivers (Table 5.3-1) is very small at 0.01% of the total tank floor material radionuclide inventory (Table 5.1-1). The inventory contribution from the constituents in the liquid sample not analyzed is expected to be minimal since the contribution of the major dose drivers is so small. Therefore, the Tank 12 liquid residual material inventory of the constituents not analyzed is considered represented in the total Tank 12 floor residual solids material radionuclide inventory.

Table 5.3-1: Tank 12 Liquid Residual Material Radionuclide Inventory

Constituent	Units	Liquid Inventory (2015)
Am-241	Ci	1.7E-01
Ba-137m*	Ci	2.7E+00
Cs-137	Ci	2.9E+00
I-129	Ci	1.2E-04
Pu-238	Ci	1.1E-02
Pu-239	Ci	8.6E-04
Pu-240	Ci	8.6E-04
Sr-90	Ci	6.1E+00
Tc-99	Ci	3.0E-04
Y-90**	Ci	6.1E+00

*Based on equilibrium relationship with Cs-137.
**Based on equilibrium relationship with Sr-90.

Table 5.3-2: Tank 12 Liquid Residual Material Chemical Inventory

Constituent	Units	Liquid Inventory
Ag	kg	5.2E-04
Al	kg	1.5E-02
B	kg	5.8E-03
Ba	kg	2.6E-04
Cd	kg	3.3E-04
Cl	kg	4.0E-01
Co	kg	4.6E-04
Cr	kg	2.2E-03
Cu	kg	9.4E-04
F	kg	1.3E-01
Fe	kg	1.4E-02
Hg	kg	2.9E-01
Mn	kg	1.2E-03
Mo	kg	4.8E-03
Ni	kg	1.4E-03
NO_2	kg	2.6E-01
NO_3	kg	1.5E+00
Pb	kg	3.4E-02
PO_4	kg	1.3E-01
Sb	kg	1.1E-02
SO_4	kg	7.6E-01
Sr	kg	1.5E-04
U	kg	5.0E-01
Zn	kg	2.8E-04
Zr	kg	1.6E-04
Th	kg	1.3E-02

5.4 Tank 12 Final Residual Material Inventory

The Tank 12 final residual radionuclide material inventory to be used for fate and transport modeling is determined by decaying the 2015 radionuclide inventory (presented in Sections 5.1, 5.2, and 5.3) to the year 2032, the assumed year of HTF closure. Tables 5.4-1 and 5.4-2, respectively, present the Tank 12 final residual radionuclide and chemical inventories.

The Tank 12 final radionuclide inventory for the primary tank is the total of the radionuclide inventories for the floor (Table 5.1-1), the cooling coil surface solids material (Table 5.2-1), and the liquid residual material (Table 5.3-1).

The Tank 12 final chemical inventory for the primary tank is the total of the chemical inventories for the floor (Table 5.1-2), the cooling coil surface solids material (Table 5.2-2), and the liquid residual material (Table 5.3-2).

Table 5.4-1: Tank 12 Final Radionuclide Residual Material Inventory Decayed to Year 2032

Constituent	Units	Tank 12 Inventory (2032)
Am-241	Ci	1.3E+02
Am-242m	Ci	3.0E-02
Am-243	Ci	1.6E-01
Ba-137m	Ci	5.8E+01
C-14	Ci	<3.2E-03
Cm-243	Ci	<5.1E-02
Cm-244	Ci	<1.1E+00
Cm-245	Ci	3.0E-04
Cs-135	Ci	<6.3E-05
Cs-137	Ci	6.1E+01
I-129	Ci	3.8E-02
Nb-94	Ci	<2.7E-03
Ni-59	Ci	2.0E+00
Ni-63	Ci	1.7E+02
Np-237	Ci	1.6E-01
Pa-231	Ci	1.5E-02
Pu-238	Ci	8.8E+02
Pu-239	Ci	4.3E+01
Pu-240	Ci	1.6E+01
Pu-241	Ci	1.0E+02
Ra-226	Ci	<2.9E-03
Ra-228	Ci	6.1E-03
Sn-126	Ci	1.4E-01
Sr-90	Ci	8.1E+04
Tc-99	Ci	7.2E-02
Th-229	Ci	<1.3E-03
Th-230	Ci	<2.2E-03
Th-232	Ci	6.6E-02
U-232	Ci	2.2E-02
U-233	Ci	<2.0E-01
U-234	Ci	5.5E-02
U-235	Ci	3.4E-04
U-238	Ci	5.9E-03
Y-90	Ci	8.1E+04
Zr-93	Ci	4.0E+00

Table 5.4-2: Tank 12 Final Chemical Residual Material Inventory

Constituent	Units	Tank 12 Inventory
Ag	kg	7.1E+00
Al	kg	6.7E+02
As	kg	1.6E-02
B	kg	9.6E+00
Ba	kg	4.5E+00
Cd	kg	2.6E-01
Cl	kg	1.5E+00
Co	kg	4.8E-01
Cr	kg	4.9E+00
Cu	kg	1.3E+01
F	kg	<3.2E-01
Fe	kg	2.6E+03
Hg	kg	5.9E+03
I	kg	1.9E-01
Mn	kg	1.1E+02
Mo	kg	7.4E-01
Ni	kg	7.4E+01
NO_2	kg	9.1E-01
NO_3	kg	2.5E+00
Pb	kg	7.1E+00
PO_4	kg	<3.2E-01
Sb	kg	<1.5E+00
Se	kg	<1.8E-02
SO_4	kg	8.4E+00
Sr	kg	3.5E+00
Th	kg	6.1E+02
U	kg	1.4E+01
Zn	kg	2.4E+00
Zr	kg	1.1E+01

6.0 REFERENCES

C-ESR-G-00003, Waltz, R.S., *SRS High Level Waste Tank Leaksite Information*, Savannah River Site, Aiken, SC, Rev. 12, August 2015.

G-TTR-H-00008, Chandler, T.L., *Tank 12-Waste Characterization & Sample Analysis Report*, Savannah River Site, Aiken, SC, Rev. 2, October 27, 2014.

M-CLC-H-03256, Grim, G.M., *Tank 12 Internal Component Solid Coating Volume*, Savannah River Site, Aiken, SC, Rev. 0, May 2014.

SRNL-L3100-2014-00245, Oji, L.N., *Bulk Density and Weight Percent Solids for Tank 12H Cooling Coil, Floor, and Mound Samples*, Savannah River Site, Aiken, SC, Rev. 0, October 2014.

SRNL-STI-2014-00263, Shine, E.P., *Statistical Evaluation of Tank 12 Sampling Options*, Savannah River Site, Aiken, SC, Rev. 0, June 2014.

SRNL-STI-2014-00551, Shine, E.P., *Basis for Modifying the Tank 12 Composite Sampling Design*, Savannah River Site, Aiken, SC, Rev. 1, November 2014.

SRNL-STI-2015-00241, Oji, L.N., et al., *Tank 12H Residual Sample Analysis Report*, Savannah River Site, Aiken, SC, Rev. 0, June 2015.

SRR-CWDA-2011-00050, Pavletich, J.P., *Liquid Waste Tank Residuals Sampling and Analysis Program Plan*, Savannah River Site, Aiken, SC, Rev. 2, July 2013.

SRR-CWDA-2014-00052, Dixon, D.B., *Recommended Radionuclide and Chemical Analyte List for Tank 12*, Savannah River Site, Aiken, SC, Rev. 2, August 2014.

SRR-CWDA-2014-00103, Pavletich, J.P., *Tank 12 H Sample Compositing Determination*, Savannah River Site, Aiken, SC, Rev. 0, November 2014.

SRR-CWDA-2015-00084, Shafer, A.R., *Tank 12 Final Characterization Data Quality Assessment*, Savannah River Site, Aiken, SC, Rev. 0, July 2015.

SRR-CWDA-2015-00085, Analytical Laboratories, *Tank 12 Annulus Liquid Sample Report 28-May-2015*, Savannah River Site, Aiken, SC, Rev. 0, June 2015.

SRR-LWE-2012-00226, Grim, G.M., *Tank 12H Sampling Accessibility Evaluation*, Savannah River Site, Aiken, SC, Rev. 0, March 2014.

SRR-LWE-2014-00074, Pavletich, J.P., *Tank 12 Sampling and Analysis Plan*, Savannah River Site, Rev. 1, July 2015.

SRR-LWE-2014-00083, Grim, G.M., *Tank 12 Sample Location Verification Document*, Savannah River Site, Rev. 1, October 2014.

SRR-LWE-2014-00161, Walters, C.D., *Tank 12 Internal Equipment Evaluation*, Savannah River Site, Rev. 0, February 12, 2015.

U-ESR-H-00109, Clark, D.J., *Tank 12 Preliminary Residual Volume Estimate Following BOA Strike 3*, Savannah River Site, Rev. 1, September 4, 2013.

U-ESR-H-00125, Clark, J.L., *Tank 12 Final Volume Determination and Uncertainty Estimate*, Savannah River Site, Rev. 0, October 2014.