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Stage II Retrieval Data Report for Single-Shell Tank 241-C-106

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

CH2MHILL
Hanford Group, Inc.
Richland, Washington

Contractor for the U.S. Department of Energy
Office of River Protection under Contract DE-AC27-99RL14047

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T.L. Sams, CH2M HILL

May 2004

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CH2M HILL Hanford Group, Inc.

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EXECUTIVE SUMMARY

This report was written to satisfy *Hanford Federal Facility Agreement and Consent Order* (HFFACO) (Ecology et al. 1989) Milestones M-45-05H and M-45-05M-T01. This report summarizes the results of the post-retrieval assessment of impacts to human health and the environment for single-shell tank 241-C-106 and includes the characterization data and Waste Management Area C post-retrieval risk assessment results for the residual waste. This report also presents comparative evaluations of waste retrieval technologies that are currently available (i.e., do not require further research and development prior to deployment), and describes and compares retrieval technologies requiring research and development that have potential for future deployment at the Hanford Site tank farms. This report completes the retrieval data report, which includes the Stage I summary (RPP-20110) of the retrieval campaign and residual waste volume determination for single-shell tank 241-C-106.

The pre-retrieval risk assessment applied the selected phase removal methodology for calculating residual inventory, while the post-retrieval risk assessment inventory was based on a post-retrieval sample collected in January 2004. A pre-retrieval risk assessment documented in *Single-Shell Tank System Closure Plan* (RPP-13774 Attachment C-1) calculated the risk of all Waste Management Area C single-shell tank residuals using selected phase removal for calculating residual inventory. The selected phase removal methodology uses the existing (December 2002) best-basis inventory by applying a simple volume ratio adjustment for different phases. The selected phase removal method for calculating residual waste inventory involves making assumptions about which waste phases will remain in the tank following waste retrieval. In this assessment, all liquid phases are considered removed leaving only the inventory associated with the remaining solids.

The post-retrieval risk assessment applied the same methodology documented in RPP-13774, Attachment C-1. For the January 2004 sample, 165 contaminants were evaluated and screened as contaminants of potential concern (Section 3.2.6). Of the 165 contaminants, 42 were used in the risk assessment of which 25 were radionuclides and 17 were nonradionuclides. The incremental lifetime cancer risk (radiological), hazard index, and radiological drinking water dose for the industrial and residential receptors were estimated using peak modeled groundwater concentrations at the Waste Management Area C fenceline from the residual tank waste and are presented in Table ES-1.

For the pre-retrieval risk assessment, the incremental lifetime cancer risk (radiological) for the industrial receptor was estimated as 7.8×10^{-8} for single-shell tank 241-C-106, while the incremental lifetime cancer risk (radiological) for all single-shell tank residuals in Waste Management Area C was 1.0×10^{-6}. Consequently, the pre-retrieval risk for the residual in single-shell tank 241-C-106 is approximately 7.7% or 1/12 of the total cumulative risk for all residuals in the Waste Management Area. For the post-retrieval risk assessment, the selected phase removal inventory was replaced with the inventory calculated from the post-retrieval sample using the nominal volume for the residual waste (370 cubic feet). Replacing the selected phase removal inventory with the post-retrieval sample inventory reduces the risk posed by single-shell tank 241-C-106 from 7.7% to approximately 2.0%.

Table ES-1. Cumulative Incremental Lifetime Cancer Risk, Hazard Index, and Radiological Drinking Water Dose from Peak Groundwater Concentration Related to Residual Waste Volume in Single-Shell Tank 241-C-106.

Metric	Industrial receptor		Year of peak
	Post-retrieval sample inventory	Performance objective[1]	
Industrial receptor radioactive chemicals ILCR	2.0E-08	1.0E-4 to 1.0E-6[1]	5609
Industrial receptor nonradioactive chemicals ILCR	8.9E-10	1.0E-5[2]	5614
Hazard index (unitless)	1.4E-04	1.0[2]	5614
Radiological dose via drinking water (mrem/yr EDE)	5.2E-04 (mrem/yr)	4 mrem/yr[2]	5606
All-pathways dose	2.5E-03 (mrem/yr)	15 mrem/yr[1] or 25 mrem/yr[3]	

Notes:
[1]EPA/540/R-99/006 *Radiation Risk Assessment at CERCLA Sites: Q & A Directive* 9200.4-31P.
[2]RPP-14283, 2004, *Performance Objectives for Tank Farm Closure Risk Assessments*, Rev. 1 CH2M HILL Hanford Group, Inc., Richland, Washington..
[3]DOE Order 435.1, 1997, *Radioactive Waste Management*, U.S. Department of Energy, Washington, D.C.
ILCR = incremental lifetime cancer risk.
EDE = effective dose equivalent.

The three major conclusions from the risk assessment are: (1) risk values presented in this analysis and those contained in RPP-13774 (Attachment C-1) for the entire Waste Management Area are almost the same, (2) the risks estimated for single-shell tank 241-C-106 are a factor of 4 smaller in this analysis than those in RPP-13774 due to the differences between pre-retrieval best-basis inventory and post-retrieval (actual sample) inventory, and (3) of the 42 contaminants of potential concern, technetium-99 and chromium are the primary contaminants that contribute to risk (greater than 99% and 95%, respectively). Based on the current residual inventory, groundwater quality standards would not be exceeded. The conclusions in RPP-13774 are unchanged by the present analysis using residual single-shell tank 241-C-106 waste samples.

This report evaluates available waste retrieval technologies using a three-step process: (1) identify retrieval function requirements, (2) identify retrieval technologies, and (3) identify alternatives that could be deployed in single-shell tank 241-C-106 without further research and development, and compare the relative effectiveness of the available technologies and alternatives against performance objectives. A comparison of the available technologies indicated that no additional retrieval was the preferred alternative.

Waste retrieval technologies that currently are not available for deployment in the Hanford Site tank farms are also presented. The technologies discussed are in various stages of development, some require substantial investment in research and development costs, while others have been deployed elsewhere and would need to be adapted for deployment at the Hanford Site. The technologies discussed in this summary currently are not planned for deployment in support of tank waste retrieval. If one of the technologies was identified for potential use in support of waste retrieval at single-shell tank 241-C-106 or any other tank, the schedule for the initial deployment would range from 3 to 5 years depending on the maturity of the technology.

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LIST OF TERMS

AEAT	AEA Technology Engineering Services
BBI	best-basis inventory
CAD	computer-aided design
CH2M HILL	CH2M HILL Hanford Group, Inc.
COPC	contaminants of potential concern
DOE	U.S. Department of Energy
DST	double-shell tank
DQO	data quality objective
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
gpm	gallons per minute
HI	hazard index
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
HIHTL	hose-in-hose transfer line
HSRAM	*Hanford Site Radiological Assessment Methodology*
ILCR	incremental lifetime cancer risk
ITV	in-tank vehicle
K_d	dispersion coefficient
LDUA	Light Duty Utility Arm
MLDUA	Modified Light Duty Utility Arm
MRS	Mobile Retrieval System
PCB	Polychlorinated Biphenyl
SPR	selected phase removal
SST	single-shell tank
SVOC	semi-volatile organic compound
UCL	upper confidence level
VOC	volatile organic compound
VRS	Vacuum Retrieval System
WTP	Waste Treatment Plant

INVENTORY CALCULATION DEFINITIONS

SPR: **Selected Phase Removal** methodology for calculating the residual inventory in the pre-retrieval risk assessment. This methodology uses the existing (December 2002) best-basis inventory using a simple volume ratio and adjusts for different phases. For example, if the tank had 750 ft^3 of solid material and 250 ft^3 of liquid, and 7.5 kg of a constituent in solid and 1 kg in liquid, then the selected phase removal method would call for all liquids to be completely removed leaving only the inventory associated with the solids remaining. The final residual inventory would be:

$$(360\ ft^3/750\ ft^3) * 7.5\ kg = 3.6\ kg.$$

SVR: **Simple Volume Ratio** methodology for calculating the residual inventory. This methodology uses the existing (December 2002) best-basis inventory and uses a simple volume ratio with no adjustments for different phases. For example, if the tank had 750 ft^3 of solid material and 250 ft^3 of liquid, and 7.5 kg of a constituent in solid and 1 kg in liquid, then the simple volume ratio to calculate the residual inventory would be:

$$(360\ ft^3/1{,}000\ ft^3) * 7.5\ kg + (360\ ft^3/1{,}000\ ft^3) * 1\ kg = 3.06\ kg.$$

Nominal: **Nominal Inventory** methodology was used in the post-retrieval risk assessment and is based on the post-retrieval sample. The nominal inventory for each waste constituent was calculated based on mean concentrations, nominal volume, and mean density (for solids inventory). It is described fully in *Best-Basis Inventory Process Requirements* (RPP-7625).

UCL-Vol: **Inventory Based on the 95% Upper Confidence Level for Volume** using the post-retrieval sample. The inventory of each waste constituent was estimated using the mean concentration, mean density (for solids), and the 95% upper confidence level for volumes. The post-retrieval risk assessment provides sensitivity to this.

UCL-Over: **Overall 95% Upper Confidence Level for Inventory** using the post-retrieval sample. The overall 95% upper confidence level for inventory of each constituent was calculated based on *Statistical Methods for Estimating the Uncertainty in the Best-Basis Inventories* (RPP-6924). The post-retrieval risk assessment provides sensitivity to this estimate.

ILCR: **Incremental Lifetime Cancer Risk** is a risk incidence that represents the increased probability of an individual developing cancer over a lifetime (70 years) from exposure to potential carcinogens (both radiological and chemical).

1.0 INTRODUCTION

This report provides the results of the post-retrieval assessment of impacts to human health and the environment for single-shell tank (SST) 241-C-106 (SST C-106) and includes the characterization data and Waste Management Area (WMA) C post-retrieval risk assessment results for the residual waste. This report completes the retrieval data report, which includes the *Stage I Retrieval Data Report for Single-Shell Tank 241-C-106* (RPP-20110) summary of the retrieval campaign and residual waste volume determination for SST C-106 and satisfies *Hanford Federal Facility Agreement and Consent Order* (HFFACO) (Ecology et al. 1989) Milestones M-45-05H and M-45-05M-T01. RPP-20110 described the retrieval campaign performance and post-retrieval waste volume determination including residual waste volume error calculations. The report further described the performance of both the modified sluicing and the acid dissolution technology used to retrieve the waste remaining, and included data to support completion of retrieval operations. At completion of retrieval operations in December 2003, 2,770 gal or 370 ft^3 remained in the tank which included approximately 11 ft^3 of *liquid* waste and 359 ft^3 of *solid* waste.

The methodology for calculating the final residual inventory of radionuclides and nonradionuclides is presented in inventory characterization (Section 2.0) and the residual waste inventory estimates for the SST C-106 component closure action risk assessment (Appendix A). The post-retrieval SST C-106 risk assessment (Section 3.0) summarizes the expected impacts to human health and the environment due to radioactive and nonradioactive chemicals remaining following completion of retrieval in late December 2003. Documentation of completion of retrieval with current technologies to the extent possible is provided in Section 1.1. The documentation assesses the capability to deploy other waste retrieval technologies (both those in development for deployment at the Hanford Site and technologies under development elsewhere).

1.1 COMPLETION OF WASTE RETRIEVAL USING EXISTING TECHNOLOGIES TO THE LIMIT OF TECHNOLOGY

Two retrieval technologies have been deployed to retrieve waste from SST C-106. The first technology was sluicing, which began in November 1998 and reached the limit of its capability in October 1999. The second technology was the modified sluicing with acid dissolution demonstration under the *Hanford Federal Facility Agreement and Consent Order* (HFFACO) (Ecology et al., 1989), which was deployed in April 2003 and completed in December 2003. Based on the declining performance data of these two technologies, it was determined that these methods would not retrieve the additional waste required to meet the HFFACO criteria of less than 360 ft^3. The basis for this statement is provided in this report.

1.1.1 Sluicing System Retrieval Campaign, 1998-1999

SST C-106 is a 530,000-gal tank that was used to store mixed radioactive waste since 1947. To address a high-heat safety issue, a waste retrieval effort using a sluicing system was initiated in SST C-106 in November 1998 and completed in October 1999 (HNF-5267, *Waste Retrieval Sluicing System Campaign Number 3 Solids Volume Transferred Calculation*). Sluicing operations were conducted using double-shell tank (DST) AY-102 supernatant as a sluicing medium.

The initial wash volume in September 1998 was approximately 230,000 gal of which approximately 197,000 gal was sludge (HNF-EP-0182, *Waste Tank Summary Report for Month Ending September 30, 1998*).

The sluicing effort successfully resolved the SST C-106 high-heat safety issue. The campaign also met the following waste retrieval requirements:

- Retrieve at least 95% (approximately 187,000 gal) of the estimated total sludge of 1.8 m (6 ft) from SST C-106
- Retrieve waste from SST C-106 until the rate of sludge removal is less than 7,500 gal (approximately 7.6 cm [3 in.]) per 12-hour sluice batch and evidence of diminishing retrieval effectiveness is documented for three consecutive batches.

These requirements defined the limit of sluicing retrieval capability for SST C-106. In December 1999, the Washington State Department of Ecology (Ecology) provided the U.S. Department of Energy (DOE) written notification that the waste retrieval criteria requirements had been met for this retrieval campaign (Fitzsimmons 1999, "Completion of Hanford Federal Facility Agreement and Consent Order Interim Milestone M-45-03B").

In July 2000, approximately 44,892 gal (6,001 ft^3) of solid and liquid waste remained (RPP-12547, *Tank 241-C-106 Residual Liquids and Solids Volume Calculation*). In August 2002, the volume of waste in SST C-106 was measured. The estimate of solids remaining in the tank was 9,056 gal (1,211 ft^3), the same as was previously calculated, however, the volume of liquid decreased by approximately 10,000 gal. The August 2002 estimate of waste volume in SST C-106 was 35,986 gal (4,811 ft^3). The liquid reduction was attributed to evaporation.

1.1.2 Modified Sluicing and Acid Dissolution Retrieval Campaign – 2003

To remove the remaining waste in SST C-106, acid dissolution was used to dissolve solids. Oxalic acid, which has been used at the Hanford Site and other DOE sites to decontaminate tanks and equipment, was used to dissolve solids and reduce the waste into smaller particle sizes to enable waste transfer. Modified sluicing describes various performance enhancements over the "past-practice" sluicing techniques that were used to remove the bulk of SST C-106 waste. These enhancements included combinations of pump and nozzle designs to break up the solids and move them to the pump intake. The combination of the acid dissolution and the mechanical break up of waste by a nozzle stream was designed to maximize removal of residual waste during the present retrieval campaign.

The effectiveness of oxalic acid to remove contamination on waste processing equipment at the DOE Savannah River Site facilities is documented in *Waste Tank Heel Chemical Cleaning Summary* (WSRC-TR-2003-00401). Laboratory-scale testing of acid dissolution of SST C-106 waste demonstrated that nearly 70% of the waste solids dissolved in oxalic acid (RPP-17158, *Laboratory Testing of Oxalic Acid Dissolution of Tank 241-C-106 Sludge*).

Several methods of operation were used for the retrieval operation of SST C-106:

- Oxalic acid was added in discrete and accurately measured batches through the mixer-eductor or the pump drop-leg
- Acid was recirculated with the mixer-eductor (for the first four batches of oxalic acid), the acid was removed using the retrieval pump
- Water was continuously added (between 85 and 350 gpm) through one of the two sluicers to mobilize and redistribute, as well as to remove solids, with subsequent or concurrent removal by the retrieval pump.

The oxalic acid dissolution process leached additional waste constituents directly from the sludge and reacted with carbonates in the waste to increase solid waste porosity. The loss of carbonates and the agitation of the waste using the mixer-eductor increased the surface area of solids and therefore the amount of surface sites available for leaching waste constituents during subsequent sluicing and acid dissolution events. The acid dissolution reaction for each acid batch reached steady state after an average of 7 days based on in-tank monitoring indicating that all the available acid reacted completely with the waste. At the completion of the acid reaction, the dissolved wastes were transferred via a pump to DST AN-106.

The modified sluicing technology used a hydraulic process that deployed an articulated high-pressure water head that moved the slurry to the retrieval pump intake. In this campaign, sluicing was initiated after the third acid batch and used after each subsequent oxalic acid batch to remove additional waste. The equipment configuration of the single sluicing nozzle reached the limit of operational effectiveness to retrieve solid waste after the fourth acid dissolution cycle and second sluicing retrieval. The single sluicer nozzle, which was located in riser 3, was no longer effective in moving solids from the far side of the tank to the pump in the middle of the tank. Additionally, sluicing created piles of solids against the tank walls in the location of the tank circumference farthest from the sluicer toward the opposite wall. The motive force of the sluicer nozzle at this configuration was not able to move the remaining waste to the pump intake.

In response to the diminished performance of the single sluicer head, the mixer-eductor was removed and replaced with a second sluicer nozzle. The second nozzle was installed in riser 7 and was used to breakup the remaining waste piles and move the waste to the pump intake. Following this, oxalic acid was added for a sixth time to dissolve the remaining waste.

The residual waste volume represents the quantity remaining after sluicing following the sixth oxalic acid addition and fourth sluicing operation.

Recirculation of the oxalic acid batches to enhance the acid and waste reaction was no longer possible after removing the mixer-eductor following the fifth acid batch. However, good contact between the waste and acid was realized without recirculation because most of the waste had been leveled into a thin layer, allowing the majority of the waste to be submerged in acid.

Table 1-1 contains the material balance of the sluicing operations and indicates the approximate volume of waste that was transferred with each batch. Waste retrieval technology efficiency, based on percent solids in the slurry, was calculated to document the performance of the technology. An observed declining trend of waste removed for each subsequent sluicing operation ranged from 8% for the first operation to 0.3% for the final operation.

Table 1-1. Material Balance Estimates for Sluice Water Additions to Single-Shell Tank 241-C-106.

Sluice operation	Volume of water added (gal)	Volume transferred to DST AN-106 (gal)	Volume increase (gal)	Retrieval efficiency (estimated volume %)
1	56,160	61,033	4,873	8
2	46,472	48,079	1,607	3.3
3	59,228	60,085	857	1.4
4	83,501	83,718	217	0.3

Note:
DST = double-shell tank.

Three performance measures were used to determine that modified sluicing and acid dissolution had reached the limit of technology (RPP-19919, *Campaign Report for the Retrieval of Waste Heel from Tank 241-C-106*). The performance measures are as follows:

1. **Acid Dissolution** - The acid dissolution process was used to dissolve and breakdown the sludge and the solid waste prior to sluicing. The result included increased solution density and a smaller waste particle size which allowed increased waste removal once sluicing commenced. The smaller particle size enabled more waste to be entrained during sluicing and subsequently pumped out of the tank. The estimated 18,000 gal of waste left in the tank prior to retrieval was equivalent to a layer that averaged about 6.5 in. across the bottom of the 75-ft diameter tank. After oxalic acid was added, the waste was soaked to allow the waste digestion process to complete (acid reaction stabilized) and the acid pool was agitated by the mixer-eductor to facilitate the acid-waste reaction. At the completion of the soak period, the retrieval pump was used to remove the solution including entrained waste from the tank.

   The acid dissolution reacted as predicted in the process control plan and the data was recorded for each batch until steady-state pH readings were attained. Oxalic acid was added in six separate batches during the retrieval and the dissolution performance ended in diminished returns for the last two acid batches. In the final batch, the pH of the solution showed a gradual increase during the first 6 days indicating that the acid had reacted with the waste and no increase occurred (steady state) during the rest of the contact period. The average pH over the last 4 days was approximately 0.79, but never reached the expected acid depletion endpoint (a pH of about 1.5), indicating that the exposed waste was fully reacted. This was an indication that all the waste available to dissolve had reacted, that waste remained unreacted, and that the limits of this technology to further dissolve and entrain waste had been reached. The result of waste forms not dissolving in the acid are consistent with the laboratory testing, which documented that up to 30% of the solids would not dissolve in oxalic acid (RPP-17158).

2. **Waste Entrainment** - The waste solids remaining were resistant to further breakdown by acid dissolution or by mechanical breakup by the sluicing stream. This was documented by the diminished mass transfer of solids in the waste slurry pumped from the tank. Therefore, the remaining solids would not likely be entrained in the waste slurry at a rate equal to or higher than the efficiencies documented in the last sluicing batches.

3. **Sluicing Nozzle Efficiency** - The waste that could be mobilized to the pump intake had been moved to within the influence of the pump and retrieved as shown in the post-retrieval video. The performance criteria of the sluicing nozzle included breaking up the solid waste and moving the waste to the pump intake. In this retrieval, when the acid dissolution performance began to diminish, the single sluicing nozzle became ineffective in moving the remaining solid waste to the pump inlet. The mixer-eductor was removed and replaced by a second nozzle which allowed the remaining piles of waste to be moved toward the pump inlet or spread out to facilitate additional exposure of waste surfaces to acid. During the last sluicing, the two nozzles were not able to appreciably move additional waste to the pump inlet as indicated by the diminishing amount of entrained waste recorded.

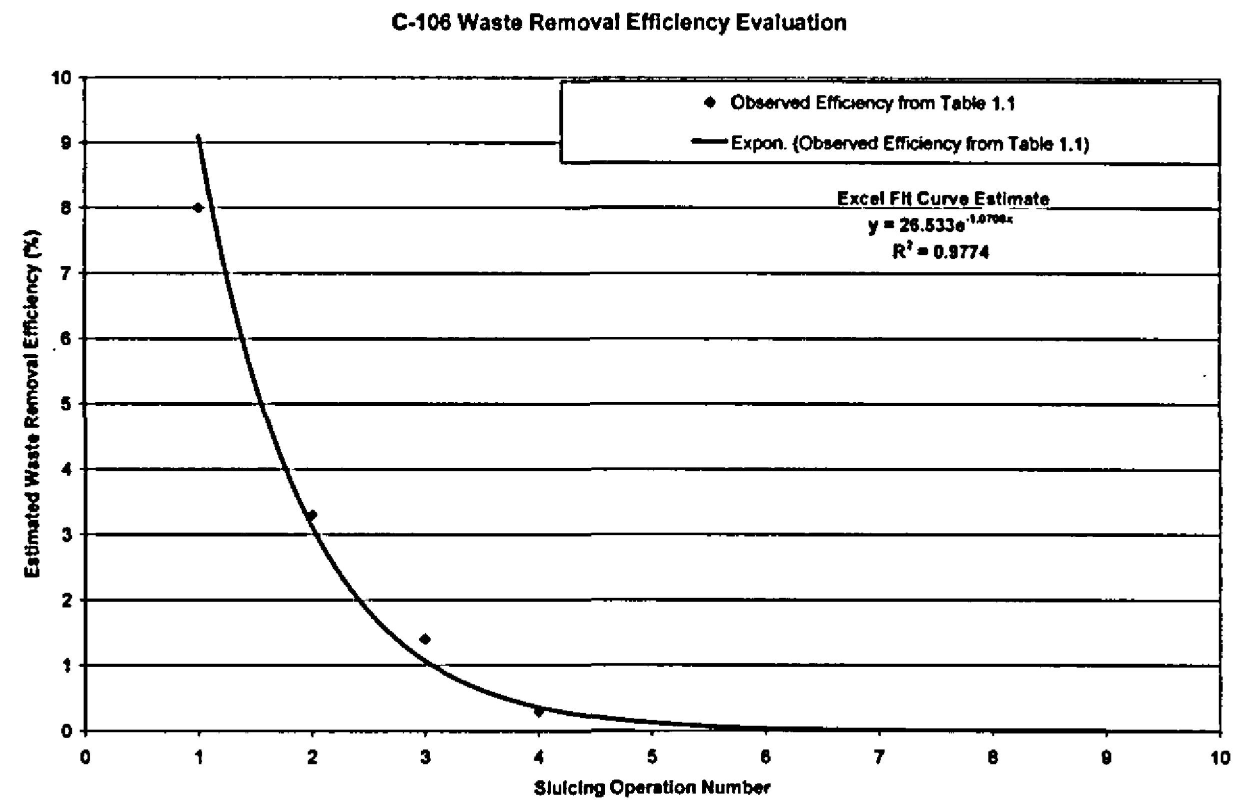
The continued viability of the modified sluicing with acid dissolution technologies to remove waste from SST C-106 was assessed by extrapolation of the performance data provided in RPP-20110. For the purpose of the extrapolation, a 60,000-gal sluicing batch was assumed (Figure 1-1).

The extrapolation method uses an estimated exponential function to describe the continued decrease in waste removal efficiency. The trendline capability of Microsoft Excel[1] was used to estimate a function to describe the changing behavior of the waste retrieval efficiency. Logarithmic, power functions, and exponential line fits were evaluated. The exponential estimation provided the best fit ($R^2 = 0.98$) for the waste retrieval efficiency data presented in Table 1-1. This method estimated a 'worst case' scenario for waste removal based on continued use of modified sluicing with acid dissolution. Using the 'worst case' approach, an additional 335 gal (44.8 ft^3) of waste could be removed from SST C-106. Therefore, this model suggests

[1] Excel is a registered trademark of Microsoft Corporation, Redmond, Washington.

that regardless of the number of additional modified sluicing and acid dissolution operations undertaken, the waste retrieval goal of less than 360 ft^3 would not be reached.

Figure 1-1. Estimated Waste Removal Efficiency for Modified Sluicing with Acid Dissolution.



The actual waste volume reduction and efficiency per sluicing operation realized by continued sluicing would likely be greater than predicted by this estimate, but would require additional water with additional evaporation.

1.1.3 Conclusions

The limits of technology for retrieving waste from SST C-106 have been reached for deployment of the following:

- Sluicing (1998-1999) as concurred with by Ecology in Fitzsimmons (1999)
- Modified sluicing with acid dissolution (2003) based on the technology performance data summarized above and documented in RPP-19919.

The nominal residual waste volume in SST C-106 at the limit of the retrieval technology was calculated to be approximately 370 ft^3. However, at the limit of technology performance for modified sluicing and acid dissolution, approximately 467 ft^3 (3,497 gal) on the 95% upper confidence level (UCL) remained in SST C-106.

1.2 RESIDUAL WASTE CHARACTERISTICS

The SST C-106 post-retrieval risk assessment screened analytes from the post-retrieval sample analysis for contaminants of potential concern (COPC). The screening identified 42 constituents (25 radionuclides and 17 nonradionuclides) as COPCs for evaluation in the risk assessment, including detected and nondetected constituents. The COPC inventory is presented in Section 2.0 and Appendix A using analytical results from pre-retrieval and post-retrieval samples and includes the COPC identification process.

1.2.1 Initial State

The initial state conditions are based on grab samples taken from riser 7 in SST C-106 on April 22, 2003 (RPP-19604, *Analytical Results for Tank 241-C-106 Solid Finger Trap Samples Supporting Pre-Retrieval Closure*). The pre-retrieval inventory of the radionuclide and nonradionuclide contaminants was calculated based on the analyte concentrations in residual solids. The inventory contribution from the residual liquids volume was ignored because the majority of the liquids were transferred during the modified sluicing campaign.

1.2.2 Current Conditions

Following retrieval, a sample of the residual waste was taken. The sample was used to calculate the inventory of nonradionuclides (i.e., hazardous contaminants) and radionuclides. The retrieval sample was analyzed for volatile organic compounds (VOC), semivolatile organic compounds (SVOC), polychlorinated biphenyls (PCB), and inorganics (including metals and conventional parameters) using U.S. Environmental Protection Agency (EPA)-approved methods. The sample analysis was performed in accordance with the analytical strategy specified in *Tank 241-C-106 Component Closure Action Data Quality Objectives* (RPP-13889). The results of the analysis are included in Section 2.0.

Post-retrieval waste volume determinations were conducted following completion of the final retrieval campaign. Using the validated video camera/computer-aided design (CAD) Modeling System methodology provided in *Results of the Video Camera/CAD Modeling System Test* (RPP-18744), the volume of waste remaining was determined to be 370 ft^3 ± 18% uncertainty at the 80% confidence interval and ± 26% uncertainty at the 95% confidence interval (RPP-19866, *Calculation for the Post-Retrieval Waste Volume Determination for Tank 241-C-106*). The progress of the retrieval campaigns culminating in the 370 ft^3 end state volume is presented in Figure 1-2.

The post-retrieval waste volume determination presented in Table 1-2 includes the contribution to the residual waste volume from waste in the tank bottom (liquids and solids), in abandoned in-tank equipment, and on the tank stiffener rings in accordance with the approved data quality objectives (DQO) (RPP-13889).

Figure 1-2. Single-Shell Tank 241-C-106 Waste Volume Reductions.

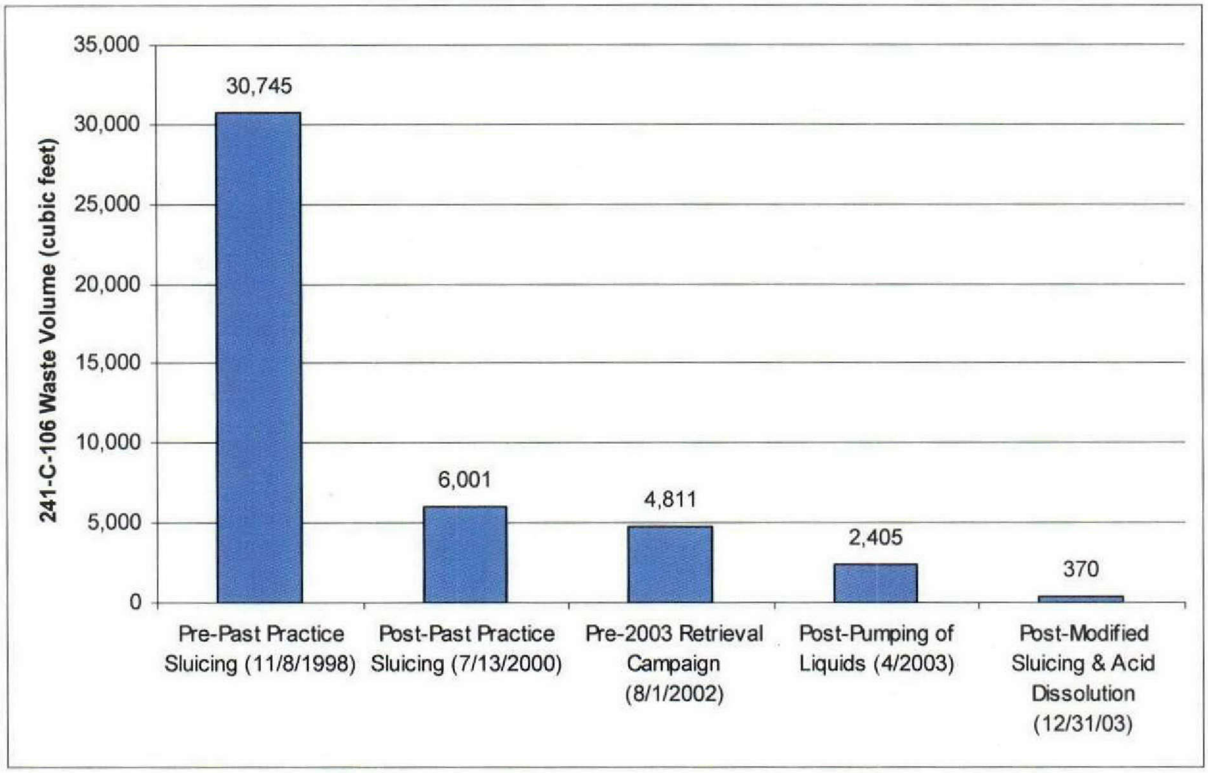


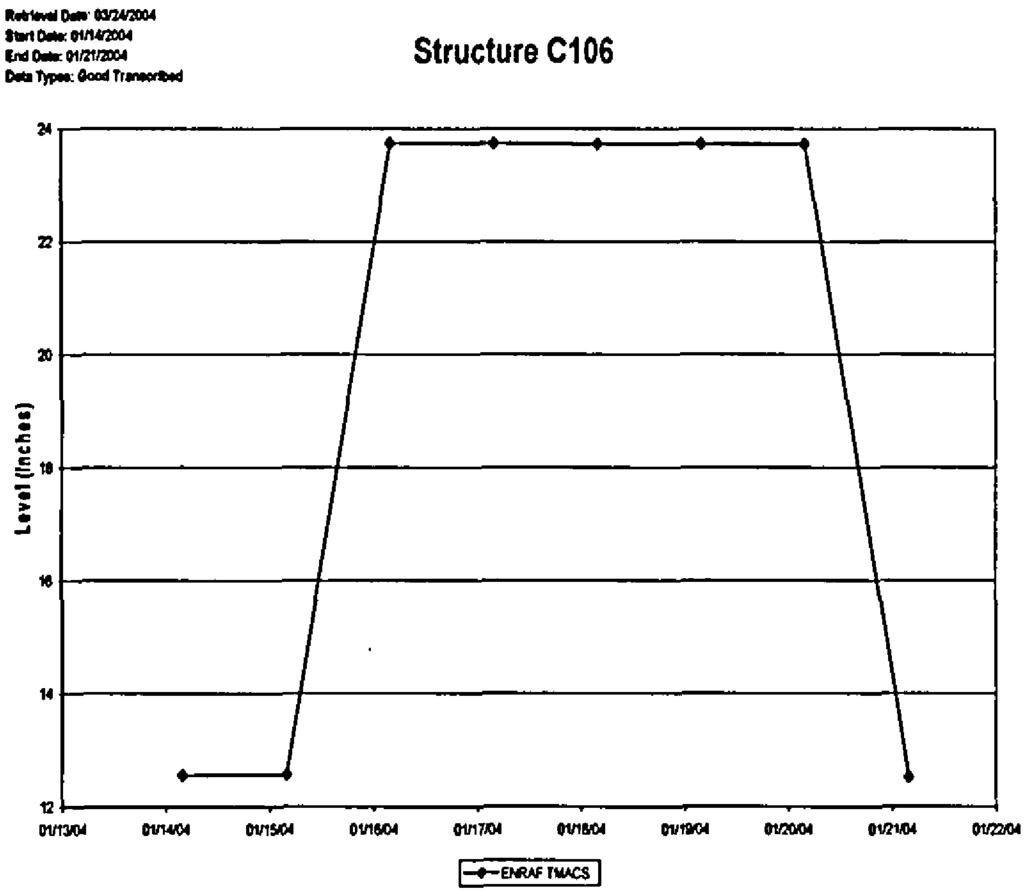
Table 1-2. Single-Shell Tank 241-C-106 Waste Volumes Following Completion of Modified Sluicing and Acid Dissolution.

Waste location	Waste volume (ft^3)	Estimated uncertainty (%)		Estimated uncertainty (ft^3)	
		+	-	+	-
Bottom of tank	336.89	27%	27%	90.96	90.96
Equipment in tank	4.84	0%	25%	0.00	1.21
Stiffener rings	17.30	18%	0%	3.11	0.00
Liquid waste	11.30	27%	27%	3.05	3.05
Total	370.33 [a]	26%	26%	97.12	95.22
Nominal waste ± uncertainty	**370.33± uncertainty**	--	--	**467.45**	**275.11**

Note:
[a] 370 ft^3 is the nominal waste volume remaining after termination of retrieval operations

As documented in RPP-20110, Section 2.4, no leakage occurred during retrieval operations. The waste immersion technique was used to provide a final estimate of the waste remaining in SST C-106 at the completion of the last campaign and to provide measurable evidence that leakage did not occur. At the termination of retrieval operations, a total of 42,000 gal of water was added to immerse all the waste in the tank for a final estimate of residual waste volume. The volume of liquid added was equivalent to the highest liquid level that occurred during retrieval operations and provided an equivalent location and liquid pressure profile to all tank surfaces exposed to liquid during the retrieval campaign. After adding 42,000 gal of liquid to SST C-106, the liquid addition level did not change during the 5 days from January 15, 2004 to January 20, 2004, which is recorded in the Tank Monitoring and Control System operational logs (see Figure 1-3). This was an indication that no leakage occurred during retrieval operations and thus waste volumes released due to leaks were considered to be zero.

Figure 1-3. Single-Shell Tank 241-C-106 Liquid Addition and Measurement Level.



DATE	ENRAF TMACS (tank liquid level in inches)
1/14/2004 4:02	12.56
1/15/2004 4:02	12.57
1/16/2004 4:02	23.74
1/17/2004 4:02	23.74
1/18/2004 4:02	23.73
1/19/2004 4:02	23.73
1/20/2004 4:02	23.73
1/21/2004 4:02	12.53

Notes:
No change in tank liquid level over 5-day period.
TMACS = Tank Monitoring and Control System.

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2.0 CHARACTERIZATION

The inventory used for the pre-retrieval risk assessment (RPP-13774, *Single-Shell Tank System Closure Plan*) was calculated from the best-basis inventory (BBI) using the selected phase removal (SPR) calculation methodology for tank residuals used in the *Environmental Impact Statement for Retrieval, Treatment, and Disposal of Tank Waste and Closure of Single-Shell Tanks at the Hanford Site, Richland, Washington: Inventory and Source Term Data Package*, (DOE/ORP-2003-02).

The methodology for calculating the final residual inventory of nonradionuclides and radionuclides left in SST C-106 is described below and in detail in Appendix A, and provides the inventory data and analytical results as input to the risk assessment presented in Section 3.0. Inventories for chemicals and radionuclides were generated for constituents identified in the DQOs and did not include short-lived daughter products. The waste samples were acquired from the SST C-106 liquid grab samples and solid samples obtained from riser 14 on January 26, 2004, and January 29, 2004, respectively. The samples were analyzed in accordance with RPP-13889. Although short-lived daughter products (^{90}Y-90, ^{137}mBa) account for approximately half the total curies resident in SST C-106, they are immobile and decay to benign products before contributing to risk. Therefore, they were not carried forward into the risk assessment.

Table 2-1 lists the analytes, including daughter products, which combine to total 99.9% of the total tank curies. SST C-106 contained approximately 10.1 million curies prior to the 1998-1999 retrieval campaign. The 1998-1999 retrieval campaign removed approximately 8.2 million curies, leaving approximately 1.77 million curies in the residual waste. The 2003 retrieval campaign removed the bulk of the remaining curies resulting in a total current inventory of approximately 135,000 curies or about 1% of the 1998 inventory. However, it is of interest to note the total curie reduction over the last two retrievals.

Table 2-1. Estimate of Single-Shell Tank 241-C-106 Inventory of Total Curies Before and After the 1998-1999 and the 2003 Waste Retrieval Campaigns.

Analyte	Pre-1998-1999 retrieval campaign total tank inventory (Ci)	Post-1998-1999 retrieval campaign total tank inventory (Ci)	Total removal 1998-1999 campaign	Post-2003 retrieval campaign total tank inventory (Ci)	Total removal 1998-12/2003 campaign
^{90}Sr	4.77E+06	8.46E+05	3.9E+06	6.61E+04	4.7E+06
^{90}Y	4.77E+06	8.46E+05	3.9E+06	6.61E+04	4.7E+06
^{137}Cs	2.67E+05	3.79E+04	2.3E+05	1.45E+03	2.66E+5
^{137}mBa	2.53E+05	3.59E+04	2.17E+05	1.37E+03	2.52E+5
Total curies[a]	1.01E+07	1.77E+06	8.33E+06	1.35E+05	9.97E+6

Note:
[a] Curies contributing to greater than 99% of total inventory.

To determine the SST C-106 inventory, the BBI process was applied to the SST C-106 post-retrieval sample analytical results (RPP-20226, *Analytical Results for Liquid Grab Sampling and Analysis Plan for Tank 241-C-106 Component Closure Action*, and RPP-20264, *Analytical Results for Tank 241-C-106 Solid Clam Shell Samples Supporting Closure Action*) to estimate the residual waste inventory. The nominal inventory for each waste constituent was calculated based on mean concentrations, nominal volume, and mean density (for solids inventory).

The evaluation of the data, using the BBI procedure, involves a data review cycle and calculation of the mean analytical results prior to the inventory calculation. The data was reviewed following the internal procedure "Review and Resolution of TWINS Data" (TFC-ENG-CHEM-D-32). The BBI process is described in *Best-Basis Inventory Process Requirements* (RPP-7625).

A nested analysis of variance (ANOVA) model was fit to the laboratory sample data following the data review. Mean analyte concentrations were estimated using results from ANOVA. Two variance components were estimated and used in the computations. The variance components represent concentration differences between laboratory samples and between analytical replicates.

The model is:

$$Y_{ij} = \mu + L_i + A_{ij},$$
$$i=1,2,...,a; j=1,2,...,n_i;$$

where:

Y_{ij} = concentration from the j^{th} analytical result from the i^{th} riser
μ = the mean
L_i = the effect of the i^{th} laboratory sample
A_{ij} = the analytical error
a = the number of laboratory samples
n_i = the number of analytical results from the i^{th} laboratory sample.

The variable L_i is a random effect, this variable and A_{ij} are assumed to be uncorrelated and normally distributed with means zero and variances $\sigma^2(L)$, and $\sigma^2(A)$, respectively.

The restricted maximum likelihood method was used to estimate the mean concentration and standard deviation of the mean for all analytes that had 50% or more of their reported values greater than the detection limit.

Some analytes had results that were below the detection limit, in these cases, the value of the detection limit was used for nondetected results. For analytes with a majority of results below the detection limit, a simple average is reported.

The inventory calculation, effective as of March 25, 2004, was performed and is documented in the following text. The following information was used in this evaluation:

- SST C-106 sludge concentration means based on laboratory analysis of sludge samples taken on January 29, 2004. The data are reported in RPP-20264.

- SST C-106 liquid concentration means based on laboratory analysis of liquid grab samples taken on January 26, 2004. The data are reported in RPP-20226.

Table 2-2 presents the data selected to derive the inventory for SST C-106.

Table 2-2. Single-Shell Tank 241-C-106 Inventory Source Data.

Waste phase	Applicable concentration data	Associated density (g/mL)	Nominal volume
Supernatant	2004 post-retrieval liquid grab sample analytical results	Not needed for inventory calculations	11.3 ft^3
Sludge1	2004 post-retrieval clam shell sample solids analytical results	1.56	359 ft^3

The supernatant and sludge volume estimates are provided in RPP-19866.

Analytical data from the 2004 clamshell tank solids samples were used to estimate the sludge composition. Analytical data from the 2004 liquid grab samples were used to estimate the supernatant composition. The sample-based inventories were developed in accordance with the BBI creation rules documented in RPP-7625, with the following exceptions:

- The plutonium and curium isotopes were calculated from the $^{239/240}$Pu, ^{241}Am, and $^{243/244}$Cm analytical results, using process knowledge of the isotopic distributions ratios of SST C-106.

- Thorium-228 was not analyzed because the laboratory did not have the appropriate analytical method. Inventory of this radionuclide was estimated from radioactive decay of ^{232}Th and ^{232}U. Based on the decay chain and radioactive half-lives of the daughter products, ^{228}Th activities due to ^{232}Th and ^{232}U decay are approximately equal to the activities of these radionuclides. Thorium-232 was analyzed; ^{232}U activity was estimated from isotopic distribution of total uranium concentration.

Appendix A, presents the detailed calculations and sample-based inventories for the nominal volume remaining in SST C-106. Appendix E provides inventory projections for varying volumes of radionuclides and nonradionuclides as a function of volume.

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3.0 POST-RETRIEVAL SINGLE-SHELL TANK 241-C-106 RISK ASSESSMENT

This risk assessment examines the risk due to the radioactive and nonradioactive chemicals left in SST C-106 following the completion of retrieval in late December 2003. All analytes listed in RPP-20226 and RPP-20264 were evaluated. The samples were analyzed in accordance with the requirements of RPP-13889. Following the evaluation and screening of COPCs, the risk posed by the COPCs is calculated using the same methodology documented in RPP-13774, Attachment C-1. The risk calculated from the post-retrieval sample is then compared against the risk calculated prior to retrieval (RPP-13774).

3.1 RESIDUAL TANK WASTE INVENTORY

Following retrieval, a sample of the residual waste from SST C-106 was taken. The analytical results of the sample were used to calculate the inventory of both nonradionuclides and radionuclides left in SST C-106. Section 2.0 and Appendix A provide the methodology for the calculating the final residual inventory used to perform this risk assessment. The inventory used for the pre-retrieval risk assessment (RPP-13774) was calculated from the BBI using the SPR calculation for tank residuals given in DOE/ORP-2003-02.

The following bullets provide a brief description of how each of the residual inventories were calculated. A complete description of the pre-retrieval inventory is given in DOE/ORP-2003-02. Appendix A contains the complete description of the post-retrieval inventory.

- **Post-Retrieval Sample Residual Inventory:** This method is based on actual sample results and uses the BBI process to determine mean analytical results (Section 2.0). The inventory was then determined using the calculated mean analytical results and the nominal residual volumes (359 ft^3 of solids and 11.3 ft^3 of liquids). This inventory includes all analytes listed in RPP-20226 and RPP-20264. The BBI process is described in RPP-7625.

- **SPR Residual Inventory:** This method is based on modeling. It is calculated by multiplying the existing total tank inventory (from BBI) by a ratio of the final tank volume to the current tank volume. The final inventory was then modified to take into account removal of selected phases of waste (sludge, supernatant, etc.) during retrieval (DOE/ORP-2003-02). Only analytes listed in the BBI were included in this inventory calculation. The assumed volume of the tank residuals is 360 ft^3.

Appendix A gives the residual inventory in SST C-106 for all contaminants analyzed based on the post-retrieval sample collected in January 2004, while Appendix B, Table B-1 provides a listing of the median inventory used in this risk assessment.

Table 3-1 presents the results of the comparison between the two different methods (SPR and post-retrieval sample) for calculating residual inventory for detected values. The residual inventory based on SPR was used in the pre-retrieval WMA C risk assessment presented in

RPP-13774, Attachment C-1. The last column of Table 3-1 provides the ratio obtained by dividing the post-retrieval sample residual inventory by the SPR residual inventory. For the most part, there is agreement between the residual inventory calculated from the SPR method and the inventory calculated from the post-retrieval samples. Based on the geometric average of the ratios of the two inventories, the new laboratory-based estimate of inventories is only 48% of the previous SPR inventory with the ratio of the inventories being within a factor of 3 for 85% of the contaminants in Table 3-1. For the inventory calculated from the post-retrieval sample, all but four analytes were less than the inventory predicted by the SPR. The four analytes that were reported with more inventory than that predicted by the SPR method are ^{233}U, calcium, manganese, and zirconium.

Table 3-1. Comparison Between Post-Retrieval Sample Inventory and Selected Phase Removal for Detected Analytes. (2 sheets)

Class	Primary/ secondary	Constituent	Post-retrieval sample inventory	SPR inventory	Units	Ratio retrieval sample/SPR
Radionuclide	Primary	63Ni	7.30E+01	2.53E+02	Ci	0.29
Radionuclide	Primary	90Sr	6.61E+04	1.25E+05	Ci	0.53
Radionuclide	Primary	99Tc	1.65E-01	4.57E-01	Ci	0.36
Radionuclide	Primary	137Cs	1.45E+03	5.05E+03	Ci	0.29
Radionuclide	Primary	232Th	5.61E-04	1.12E-03	Ci	0.50
Radionuclide	Primary	233U	1.83E-03	3.02E-04	Ci	6.05
Radionuclide	Primary	234U	9.48E-04	5.94E-03	Ci	0.16
Radionuclide	Primary	235U	3.87E-05	2.54E-04	Ci	0.15
Radionuclide	Primary	236U	1.73E-05	1.06E-04	Ci	0.16
Radionuclide	Primary	238U	9.04E-04	6.07E-03	Ci	0.15
Radionuclide	Primary	237Np	5.42E-02	7.36E-02	Ci	0.74
Radionuclide	Primary	239Pu	1.68E+01	3.33E+01	Ci	0.50
Radionuclide	Primary	240Pu	3.58E+00	6.83E+00	Ci	0.52
Radionuclide	Primary	241Pu	3.97E+01	8.16E+01	Ci	0.49
Radionuclide	Primary	241Am	6.53E+01	9.97E+01	Ci	0.65
Inorganic	Primary	Chromium Cr	3.79E+00	2.53E+01	Kg	0.15
Inorganic	Primary	Lead Pb	2.57E+01	6.96E+01	Kg	0.37
Inorganic	Primary	Mercury Hg	1.93E+00	1.95E+00	Kg	0.99
Inorganic	Primary	Nickel Ni	3.02E+01	4.70E+01	Kg	0.64
Inorganic	Secondary	Aluminum Al	3.83E+02	8.11E+02	Kg	0.47
Inorganic	Secondary	Calcium Ca	1.18E+02	3.48E+01	Kg	3.39
Inorganic	Secondary	Iron Fe	2.07E+02	1.35E+03	Kg	0.15

Table 3-1. Comparison Between Post-Retrieval Sample Inventory and Selected Phase Removal for Detected Analytes. (2 sheets)

Class	Primary/ secondary	Constituent	Post-retrieval sample inventory	SPR inventory	Units	Ratio retrieval sample/SPR
Inorganic	Secondary	Lanthanum La	2.45E+00	5.45E+00	Kg	0.45
Inorganic	Secondary	Manganese Mn	5.50E+02	3.36E+02	Kg	1.64
Inorganic	Secondary	Sodium Na	1.89E+02	1.09E+03	Kg	0.17
Inorganic	Secondary	Strontium Sr	1.83E+00	2.88E+00	Kg	0.64
Inorganic	Secondary	Zirconium Zr	2.79E+00	1.17E+00	Kg	2.38

Note:
SPR = selected phase removal.

Uranium-233 is a factor of approximately 35 higher than other isotopes of uranium. The enrichment ^{233}U value relative to the other isotopes of uranium is most likely due to waste generated from a thorium-^{233}U run at the plutonium-uranium extraction plant. Wastes from these runs were primarily disposed to SSTs C-102 and C-104. However, a possible explanation for this would be an undocumented inadvertent transfer of the thorium-^{233}U waste to SST C-106 and could explain the enrichment of ^{233}U relative to the other isotopes of uranium. Calcium, manganese, and zirconium are factors of 3.4, 1.6, and 2.4, respectively, over that predicted by SPR. As discussed later in this report, none of these four contaminants contribute significantly to any of the risk metrics.

3.2 SELECTION OF CONSTITUENTS OF POTENTIAL CONCERN FOR SINGLE-SHELL TANK 241-C-106

The purpose of this section is to select the COPCs for SST C-106. COPCs are defined as those constituents that should be carried forward into the risk assessment process. During the course of the risk assessment, COPCs are evaluated to identify and prioritize those constituents that are estimated to pose an unacceptable risk and are used to support the *Washington Administrative Code* (WAC) 173-303-610(2) closure performance standards for human health and the environment to allow component closure activities to continue.

3.2.1 Data Used in Screening Process

Analytical data (including sludge and supernatant) for SST C-106 were collected and analyzed in accordance with the procedures described in the RPP-13889. All SST C-106 retrieval sample analytical data were evaluated in the COPC screening process. The retrieval samples were analyzed for radionuclides, VOC, SVOC, PCBs and inorganics (including metals and conventional parameters) in accordance with approved 222-S Laboratory procedures based on EPA-approved methods.

Analytical data for the sludge and supernatant sample were converted to inventory as described in Section 3.1; the inventory results are based on the nominal volume estimates. The results were then modeled to estimate groundwater concentrations at the fenceline. For purposes of the COPC screening, all constituents were assumed to have no chemical interaction with soils (i.e., be mobile, having a K_d value of zero) and did not decay (i.e., radiological half-lives were not considered).

3.2.2 Contaminants of Potential Concern Screening Process Approach

Identification of the COPCs used in the risk assessment was through a seven-step screening process. An explanation of each of these steps is provided in the following sections. Figure 3-1 provides an overview of this approach. Only the steps that led to including or excluding a COPC in the risk assessment are shown.

Nondetected values are included in the risk assessment if they pass through the screening process using an inventory calculated at ½ the detection limit per *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual Part A* (EPA/540/1-89/002). A summary of the COPCs identified for the SST C-106 sample is provided in Appendix B, Table B-2.

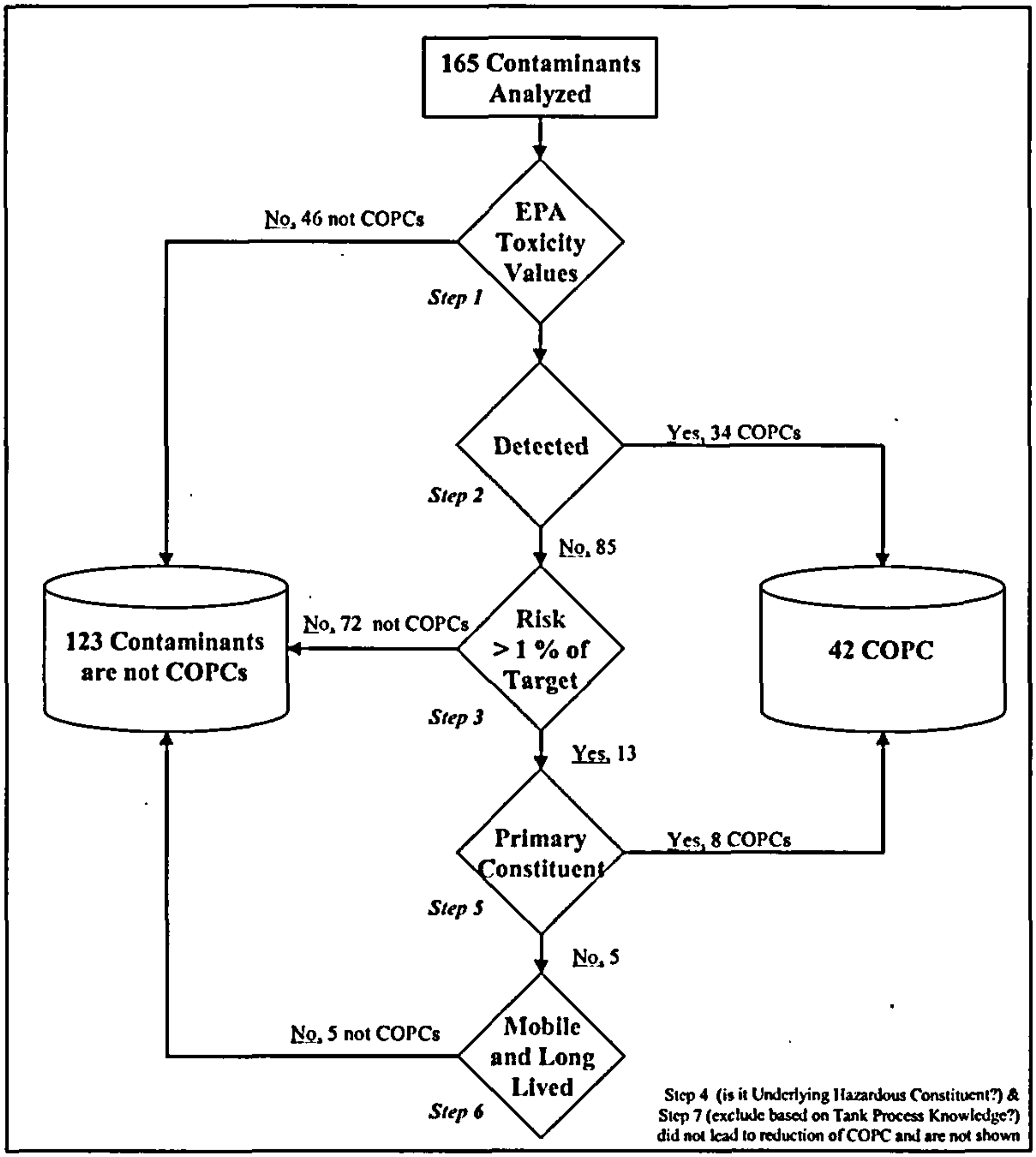
3.2.3 Availability of Toxicity Values

Step 1. Any constituent reported by the laboratory, whether detected or not, was carried forward into the first tier of the selection process. The only criterion in this tier is the availability of a reliable toxicity value. If a toxicity value is available from EPA, then the constituent was carried forward into the second tier of the COPC selection process.

If a constituent does not have a toxicity value from EPA, then the constituent was not carried forward into the risk assessment. EPA sources of toxicity values (cancer slope factors and noncancer reference doses) considered for risk assessment include the following:

- The Health Effects Assessment Summary Tables Radionuclide Table: Radionuclide Carcinogenity – Slope Factors (Federal Guidance Report No. 13 Morbidity Risk Coefficients), provided by the EPA Office of Radiation and Indoor Air (April 16, 2001 update), is a compilation of radionuclide slope factors at www.epa.gov/radiation/heast.html

Figure 3-1. Contaminants of Potential Concern Screening Process.



- The *Integrated Risk Information System* database is available through the EPA National Center for Environmental Assessment in Cincinnati, Ohio. The *Integrated Risk Information System*, prepared and maintained by EPA, is an electronic database containing health risk and EPA regulatory information on specific chemicals (EPA 2004).

- The Health Effects Assessment Summary Tables, provided by the EPA Office of Solid Waste and Emergency Response, is a compilation of toxicity values published in various health effects documents issued by EPA.

- EPA Region IX Preliminary Remediation Goal Table (October 2002) at www.epa.gov/docs/region09/waste/sfund/prg/index.html.

Toxicity values are developed by EPA on an ongoing basis, and they are not available for every constituent analyzed. Exclusion of those constituents without toxicity values may underestimate potential risks within the tank.

3.2.3.1 Chemicals Without Toxicity Values. A total of 165 constituents were reported by the laboratory. Of the 165 constituents, 46 did not have available toxicity values and therefore were excluded from further consideration in the risk assessment, leaving 119 constituents.

3.2.4 Identifying Detected Constituents

Step 2. If a toxicity value was available from a reliable source and the constituent was detected in the SST C-106 sample, then the detected constituent was identified as a COPC and carried forward into the risk assessment. Thirty-four of the 119 constituents with available toxicity values were detected in the SST C-106 sample and carried forward into the risk assessment, which leaves 85 nondetect contaminants.

3.2.5 Evaluating Nondetected Constituents

To determine if the 85 nondetected constituents with toxicity values should be identified as COPCs, additional screening steps were taken. The screening steps assumed that the amount of each nondetected contaminant was at its detection level. The screening steps are:

- Compare ILCR and hazard index (HI) values to risk screening thresholds
- Identify underlying hazardous constituents
- Identify primary constituents (RPP-13889)
- Identify mobile constituents
- Identify process-related constituents.

3.2.5.1 Compare Risk Estimates to Risk Screening Thresholds.

Step 3. The ILCR or HI was calculated for each constituent based on the *Hanford Site Radiological Assessment Methodology* (HSRAM) (DOE/RL-91-45) industrial worker exposure scenario and compared to risk screening thresholds to determine their potential for risk contribution. The HSRAM industrial exposure scenario was selected because the most likely future land use for the tank farm area is considered industrial. If the ILCR for a carcinogenic constituent was less than 1% of the performance objective (1.0×10^{-5}) or 1×10^{-7} or the HI for a noncarcinogenic constituent was less than 1% of the performance objective (1.0) or 0.01, then the constituent was not identified as a COPC and was not carried forward into the risk assessment.

Of the 85 nondetected constituents, 72 constituents were reported with ILCR or HIs less than the identified risk screening thresholds. These 72 constituents were not identified as COPCs and were not carried forward into the next step of the screening process. For the 13 nondetected constituents exceeding the risk screening threshold values, they were all carried forward into the next step of the screening process.

Step 4. If the nondetected constituent was included in the DQO because it is a constituent included in the SST Part A Permit or it is a constituent that was identified as a COPC. If the nondetected constituent was included in the DQO on the basis of being an underlying hazardous constituent, then it was not identified as a COPC. None of the 13 remaining nondetected constituents were identified on the basis of only being an underlying hazardous constituent, therefore the 13 constituents were carried forward into the next step of the screening process. Because this step did not lead to the inclusion or exclusion of a COPC, it is not shown on Figure 3-1. This step may be important in future risk assessments.

3.2.5.2 Identify Primary Constituents.

Step 5. If the nondetected constituent was identified as a primary constituent in the DQO, then it was identified as a COPC. If the nondetected constituent was identified as a secondary constituent, then it was excluded from further consideration in the risk assessment. The term "secondary constituent" is defined in the DQO as being included in the EPA-approved method and is reported as an opportunistic constituent.

Of the 13 remaining nondetected constituents, nine were identified as primary constituents in the DQO and were carried forward into the risk assessment.

3.2.5.3 Identify Mobile, Long-Lived Secondary Constituents.

Step 6. If the nondetected constituent is considered a mobile (K_d < 0.6 ml/g) and long-lived (half life > 100 years) constituent, then it was identified as a COPC. Of the five remaining nondetected constituents (^{94}Nb, ^{106}Ru, ^{125}Sb, ^{134}Cs, ^{226}Ra), two were considered short-lived (^{106}Ru, ^{125}Sb) and three were considered immobile (^{94}Nb, ^{134}Cs, ^{226}Ra); all five were not identified as COPCs and were not carried forward into the next step of the screening process.

3.2.5.4 Identify Process-Related Constituents.

Step 7. If the nondetected constituent is considered to be present in the tank based on process knowledge, then it would be identified as a COPC. However, all nondetected constituents were screened in previous steps, therefore this step was not considered. Because this step did not lead to the inclusion or exclusion of a COPC, it is not shown on Figure 3-1. This step may be important in future risk assessments.

3.2.6 Summary of Contaminants of Potential Concern

A total of 165 constituents were reported by the laboratory and considered in the COPC screening process. Appendix B, Table B-2 provides a complete listing of all analytes and at which step of the screening process an analyte became a COPC or was dropped from further consideration. Of the 165 constituents reported, 42 constituents (25 radionuclides and 17 nonradionuclides) were identified as COPCs and evaluated in the risk assessment. The following constituents were identified as COPCs because they were detected in the SST C-106 sample:

^{63}Ni	^{90}Sr	^{99}Tc	^{137}Cs
^{228}Th	^{230}Th	^{232}Th	^{233}U
^{234}U	^{235}U	^{236}U	^{238}U
^{237}Np	^{240}Pu	^{239}Pu	^{241}Pu
^{241}Am	Aluminum	barium	cadmium
hexavalent chromium	Cobalt	copper	cyanide
iron	Manganese	mercury	nickel
silver	Strontium	zinc	2-butanone
2-propanone	di-n-butylphthalate		

The following nondetected constituents were identified as COPCs because they exceeded the risk screening threshold values and were identified as primary constituents in the DQO:

^{60}Co	^{152}Eu	^{154}Eu	^{155}Eu	^{238}Pu
^{242}Cm	^{243}Cm	^{244}Cm		

3.3 SINGLE-SHELL TANK 241-C-106 RETRIEVAL AND CLOSURE EFFECTS ON SELECTED LONG-TERM RISK METRICS

Projected effects of residual waste retrieval and other component closure activities on selected long-term risk metrics are described in this section. This section addresses changes in long-term human health risk due to changes in the source term after retrieval. The same assumptions, except for the inventory of the residual source term given in RPP-13774 Attachment C-1, apply to this risk assessment. Source term inventories that change in this risk assessment are residual tank waste and hypothetical retrieval leak from SST C-106. For residual tank waste, actual samples from the tank are used to calculate residual inventories. The hypothetical retrieval leak inventories were zeroed out. Results for other tank residuals, ancillary equipment residuals, past ancillary equipment leaks, and past tank leaks do not change. For those results, see RPP-13774, Attachment C-1.

3.3.1 Retrieval Leaks

The risk assessment presented in RPP-13774, Section 4.0, assumed a hypothetical 8,000-gal retrieval leak. No tank leakage occurred during retrieval operations, therefore the risks associated with a retrieval leak are not calculated in this risk assessment and are assumed to be zero (RPP-20110, Section 2.4).

3.3.2 Residual Tank Waste Risk Metrics

The ILCR, HI, and radiological drinking water dose for the industrial and residential receptors are estimated using peak modeled groundwater concentrations from the residual tank waste (Table 3-2).

As shown in Table 3-2, the post-retrieval sample inventory results for industrial ILCR is almost a factor of 4 smaller than that calculated using pre-retrieval inventory (SPR). This is due to the differences between the pre-retrieval inventory (SPR) and post-retrieval sample inventory (Table 3-1). These differences in inventory are also reflected in ILCR-nonrad, HI, and radiological drinking water dose results, which decreased by a factor of approximately 7.0 for each metric.

Table 3-2. Cumulative Incremental Lifetime Cancer Risk, Hazard Index, and Radiological Drinking Water Dose from Peak Groundwater Concentration Related to Residual Waste Volume in Single-Shell Tank 241-C-106.

Metric	Industrial receptor		Residential receptor		Year of peak
	SPR inventory	Post-retrieval sample inventory	SPR inventory	Post-retrieval sample inventory	
Radioactive chemicals ILCR[a] (unitless)	7.8E-08	2.0E-08	1.5E-06	4.8E-7	5609
Nonradioactive chemicals ILCR[a] (unitless)	6.0E-09	8.9E-10	1.3E-08	2.0E-09	5614
Hazard index[b] (unitless)	9.9E-04	1.4E-04	5.5E-03	7.9E-04	5614
Radiological dose via drinking water[c] (mrem/yr EDE)	3.5E-03	5.2E-04	1.0E-02	1.5E-03	5606

Notes:

[a] ILCR target value is < 1.00E-06 to 1.00E-04 for radiological (EPA/540/R-99/006 *Radiation Risk Assessment at CERCLA Sites: Q & A Directive* 9200.4-31P). ILCR target value is < 1.00E-05 for nonradiological (RPP-14283).

[b] Noncarcinogenic Hazard Index is < 1.00 (RPP-14283)

[c] Groundwater dose target values is < 4 mrem/yr (1 L/day ingestion for 250 days for industrial receptor, and 2 L/day for 365 days for residential receptor). (RPP-14283)

EDE = effective dose equivalent
ILCR = incremental lifetime cancer risk
SPR = selected phase removal.

RPP-14283, 2004, *Performance Objectives for Tank Farm Closure Performance Assessments*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

For ILCR-rad, ^{99}Tc is the primary contributor to this metric for radiological contaminants and the reduction in risk between using the SPR inventory and the post-retrieval sample inventory is directly related to the reduction of inventory for this radionuclide and the removal of ^{129}I as a COPC (due to none being found and the nondetect amount being insufficient to trigger further analysis [Section 3.2]). The ^{99}Tc residual inventory calculated by SPR was 0.46 Ci, and for the post-retrieval sample inventory it is 0.165 Ci, a reduction by a factor of approximately 3. For ^{129}I, SPR calculated inventory is 3.7 x 10^{-3} Ci, but it was removed from the post-retrieval risk assessment because it did not pass through the screening process for COPCs. This same pattern is also repeated for radiological drinking water dose, because ^{99}Tc and ^{129}I are the primary contributors to this metric.

For nonradionuclides, chromium is the primary contributor to ILCR-nonrad. The reduction in chromium inventory between the pre-retrieval risk assessment and the post-retrieval risk assessment is the reason for the reduction in ILCR for nonradionuclides.

For the HI metric, the primary contributor to this risk metric is chromium, if all chromium is assumed to be Cr^{+6}, then it contributes to almost 100% of the HI. The difference in the value for this risk metric between inventories calculated by the SPR method and the post-retrieval sample results is the lower inventory of chromium (factor of approximately 6.5 lower), the removal of nitrite, and nitrate as a COPC from the screening process. The total HI for the tank residuals is a factor of approximately 7,000 below the target value of 1.0.

3.3.3 Single-Shell Tank 241-C-106 Effects on Drinking Water Standards

Estimated long-term groundwater quality effects for each residual inventory are compared to the primary drinking water standards (maximum contaminant levels) in Table 3-3. The changes in concentration reflect the change in inventory between SPR and post-retrieval sample.

Table 3-3. Comparison of Groundwater Impacts from Single-Shell Tank 241-C-106 between Selected Phase Removal Inventory and Post-Retrieval Sample Inventory Closure Conditions.

Constituent	SPR inventory	Post-retrieval sample inventory	Drinking water standard (MCL)
Technetium-99	3.9 pCi/L	1.4 pCi/L	900 pCi/L[a]
Chromium (assumes hexavalent chromium)	2.2E-04 mg/L	3.3E-05 mg/L	0.10 mg/L

Notes:

[a] The radionuclide concentration shown is the "C4" concentration, which is the concentration of the individual nuclide in drinking water that would result in an annual dose of 4 mrem/yr using the target organ dose methodology specified by the Washington *State Environmental Policy Act*.

MCL = maximum contaminant level, MCL for chromium is for total chromium, not hexavalent chromium.

SPR = selected phase removal.

3.4 CUMULATIVE EFFECTS OF REPRESENTATIVE COMPONENT SOURCE TERMS

The base case evaluated for SST C-106 includes contribution to risk metrics from residual tank waste after retrieval to 360 ft^3 and an 8,000-gal retrieval leak (RPP-13774, Attachment C-1). Past leak and adjacent ancillary equipment source terms are identified as applicable; however, these source terms are addressed cumulatively at the WMA C risk assessment given in RPP-13774 (Attachment C-1). This section focuses on the changes to the base case risk assessment given in RPP-13774 caused by the inventory calculated from post-retrieval sample.

3.4.1 Radiological Incremental Lifetime Cancer Risk

The cumulative contribution to ILCR-rad for the industrial worker scenario between the different residual inventories is given in Figure 3-2. In this plot the following four curves are shown:

- **WMA C:** SPR Inventory (Green Solid Line, Square Symbols). This is the cumulative WMA C ILCR-rad curve given in RPP-13774, Attachment C-1. The sources included in this curve are given in RPP-13774, Attachment C-1, Table 13. Briefly summarized, this curve includes SPR residual inventory for all C-100 and C-200 series tanks, ancillary equipment leaks, ancillary equipment residuals (i.e., pipeline), and an 8,000-gal retrieval leak from each of the C-100 series tanks. The peak ILCR-rad for this curve is 1.4×10^{-5} and is within the performance objective range (1.0×10^{-4} to 1.0×10^{-6}). The peak ILCR-rad for WMC tank residuals is 1.0×10^{-6} and it occurs in the year 5610. The rise in ILCR-rad after calendar year 11,000 indicates less mobile contaminants such as uranium from hypothetical retrieval leaks and past leaks arriving at the fenceline.

- **WMA C:** Post-Retrieval SST C-106 Sample Inventory (Brown Dash Line, Delta Symbols). For this curve, the inventory calculated from the post-retrieval SST C-106 sample was used for SST C-106 residual inventory. The hypothetical retrieval leak from SST C-106 was removed because no retrieval leak occurred. Except for these changes made for SST C-106, the inputs to the analysis are exactly the same as the previous curve. Although, the previous curve and the current curve overlap, there are some differences. The peak ILCR-rad for this curve is 1.39×10^{-5}. The slightly lower value reflects removing the hypothetical retrieval leak from SST C-106. Additionally, in the year 5000 the curves diverge slightly, this curve had a slightly lower ILCR-rad than the SPR inventory curve. The peak ILCR-rad for WMA C tank residuals using the post-retrieval sample to calculate SST C-106 inventory is 9.7×10^{-7}, or about a 3% reduction in total risk from tank residuals. This reduction is due to the smaller residual inventory of ^{99}Tc, and the removal of ^{129}I as a COPC.

- **SST C-106**: SPR Inventory (Red Dash Dot Line, Circle Symbols). This curve is the same curve given in RPP-13774, Attachment C-1. This is a cumulative curve showing an 8,000-gal retrieval leak from SST C-106 along with the impacts from SST C-106 residuals. The peak value is 1.3×10^{-7} due to the hypothetical 8,000-gal retrieval leak occurring approximately 30 years after closure. The peak for the residuals is 7.8×10^{-8} occurring at year 5610.

- **SST C-106:** Post-Retrieval SST C-106 Sample Inventory (Orange Dash Dot Dot Line, Diamond Symbols). A leak from the tank did not occur during retrieval and therefore, a retrieval leak was not considered (Section 3.3.1). The peak value for this curve 2.0 x 10^{8}, which is almost a fourfold decrease over the risk calculated for the SPR inventory. The decrease in ^{99}Tc inventory and the removal of ^{129}I as a COPC account for the decrease in ILCR-rad. The peak value of 2.0 x 10^{-8} is a factor of 500 below the performance objective of 1.0 x 10^{-5} for this performance metric.

The residential scenario for these four curves is given in Figure 3-3. The same pattern given for the industrial worker receptor (Figure 3-4) is also shown in this figure. However, the order of magnitude in risk for this receptor has increased by approximately a factor of 24 (compare Figure 3-3 with Figure 3-4), which represents greater use of the groundwater by the residential receptor.

Figure 3-2. Comparison of the Selected Phase Removal Inventory and Single-Shell Tank 241-C-106 Post-Retrieval Sample Inventory for both Waste Management Area C and Single-Shell Tank 241-C-106 to Incremental Lifetime Cancer Risk for the Industrial Worker Scenario.

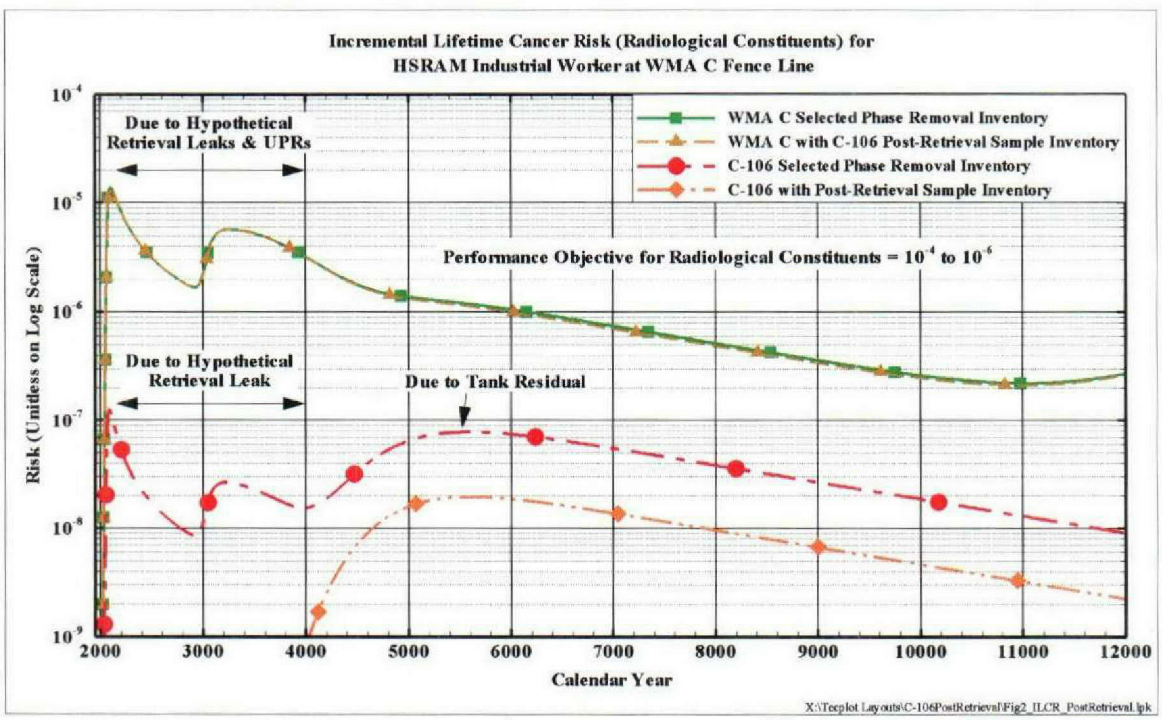
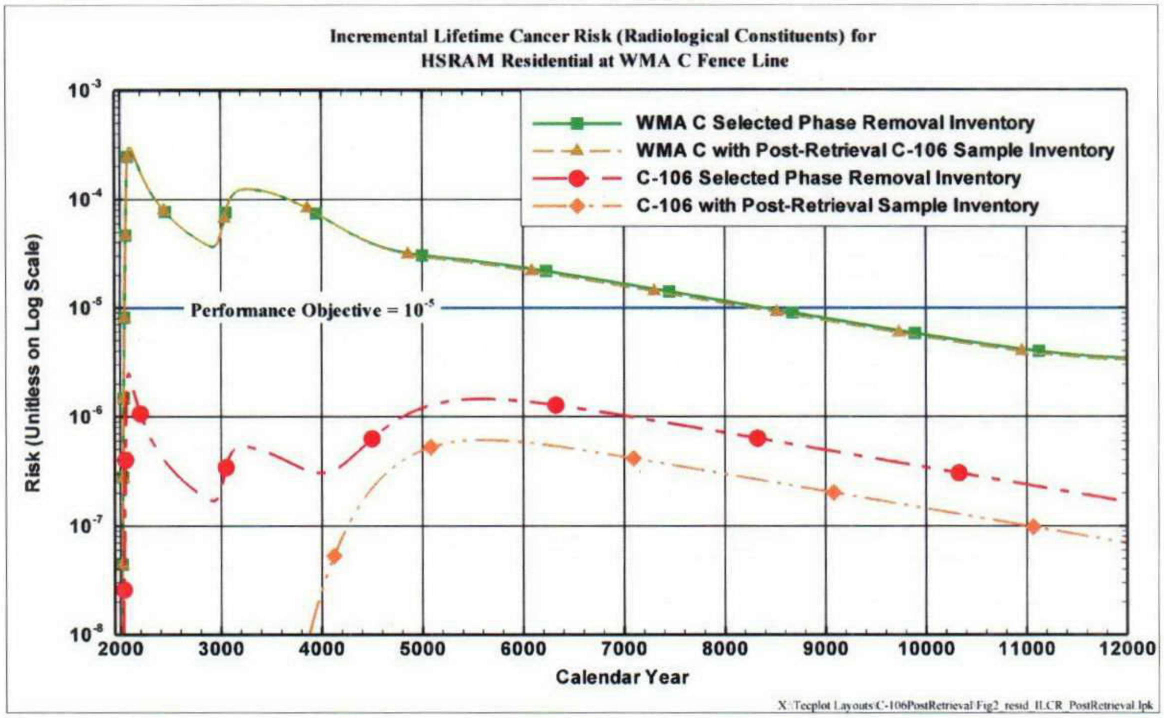


Figure 3-3. Comparison of the Selected Phase Removal Inventory and Single-Shell Tank 241-C-106 Post-Retrieval Sample Inventory for both Waste Management Area C and Single-Shell Tank 241-C-106 to Incremental Lifetime Cancer Risk for the Residential Scenario.



3.4.2 Hazard Index

The cumulative contribution to HI for the industrial worker between the different residual inventories is given in Figure 3-4. In this plot the following four curves are shown:

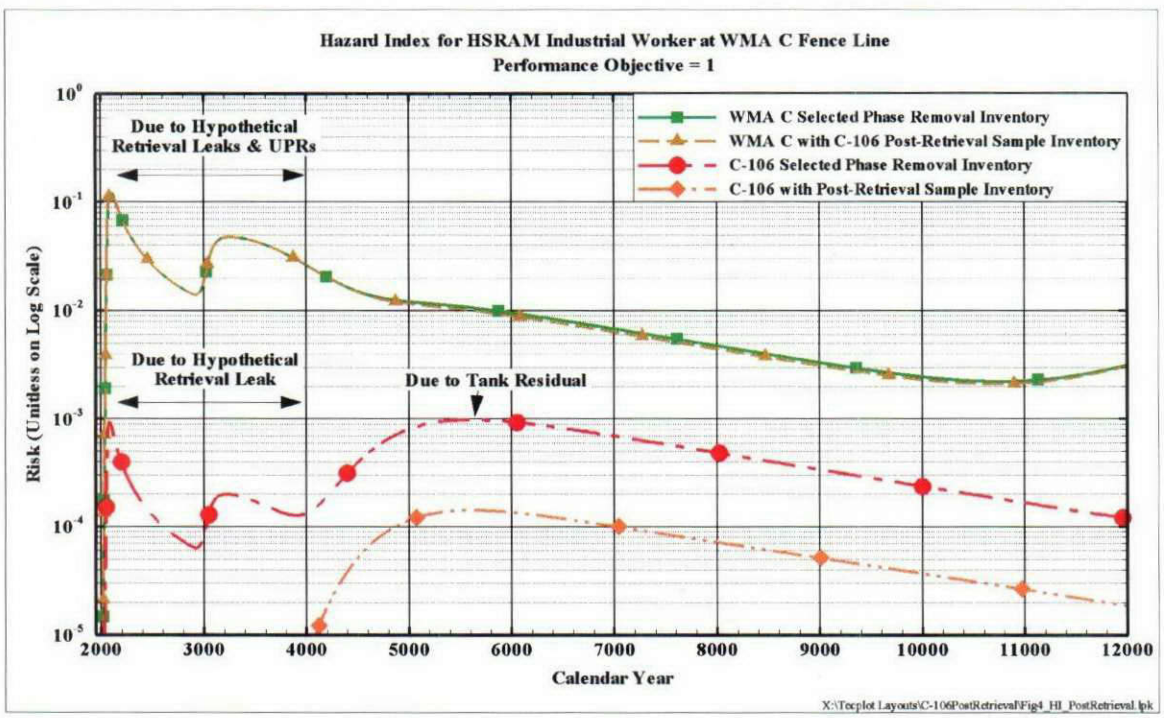
- **WMA C**: SPR Inventory (Green Solid Line, Square Symbols). This is the cumulative WMA C HI base curve. The base curve is described in the first bullet of Section 3.4.1. The peak HI for this curve is 1.25 x 10^{-1} (please note this is slightly higher than what was reported in RPP-13774 [9.7 x 10^{-2}] because of the inclusion of n-Butanol from past unplanned releases). However, it is still below the performance objective of 1.0. The rise in HI at calendar year 11000 indicates less mobile contaminants such as uranium from hypothetical retrieval leaks and past unplanned releases arriving at the fenceline.

- **WMA C:** Post-Retrieval SST C-106 Sample Inventory (Brown Dash Line, Delta Symbols). For this curve, the inventory calculated from the post-retrieval sample was used for SST C-106 residual inventory and the hypothetical retrieval leak from SST C-106 was removed because no retrieval leak occurred. This curve is almost the same as described in the preceding paragraph, but slightly lower due to the removal of the hypothetical retrieval leak from SST C-106 and the lower inventory of constituents that make up the HI. Although, for the most part the previous curve and this one overlap, there are some differences. The peak HI for this curve is 0.123. The slightly lower value reflects removing the hypothetical retrieval leak from SST C-106. Additionally, at about 5,000 years, the curves diverge slightly, this curve has a slightly lower HI than the WMA C SPR inventory curve. This is due to the smaller residual inventory for $Cr+^{6}$ calculated from the SST C-106 post-retrieval sample. The peak HI for tank residuals for this curve is 8.6 x 10^{-3}.

- **SST C-106**: SPR Inventory (Red DashDot Line, Circle Symbols). This curve is the same curve given in RPP-13774, Attachment C-1. This is a cumulative curve showing an 8,000-gal retrieval leak from SST C-106 along with the impacts from SST C-106 residuals. The peak value is 9.9 x 10^{-4} due to the residual waste.

- **SST C-106:** Post-Retrieval SST C-106 Sample Inventory (Orange DashDotDot Line, Diamond Symbols). This curve is for the residual inventory calculated using the post-retrieval sample. A leak did not occur during retrieval. The peak value for this curve 1.4 x 10^{-4}, which is factor of over 7,000 below the performance objective of 1.0. It is also over a sevenfold decrease for the HI calculated for the SPR inventory. The decrease is due to the difference in Cr^{+6} inventories between the post-retrieval sample and SPR inventory; and the dropping of nitrite and nitrate as COPCs (Section 3.2).

Figure 3-4. Comparison of the Selected Phase Removal Inventory and Single-Shell Tank 241-C-106 Post-Retrieval Sample Inventory for both Waste Management Area C and Single-Shell Tank 241-C-106 to Hazard Index for the Industrial Worker Scenario.



3.4.3 Radiological Drinking Water Dose

The cumulative contribution to radiological drinking water dose for the industrial worker between the different residual inventories is given in Figure 3-5. In this plot the following four curves are shown:

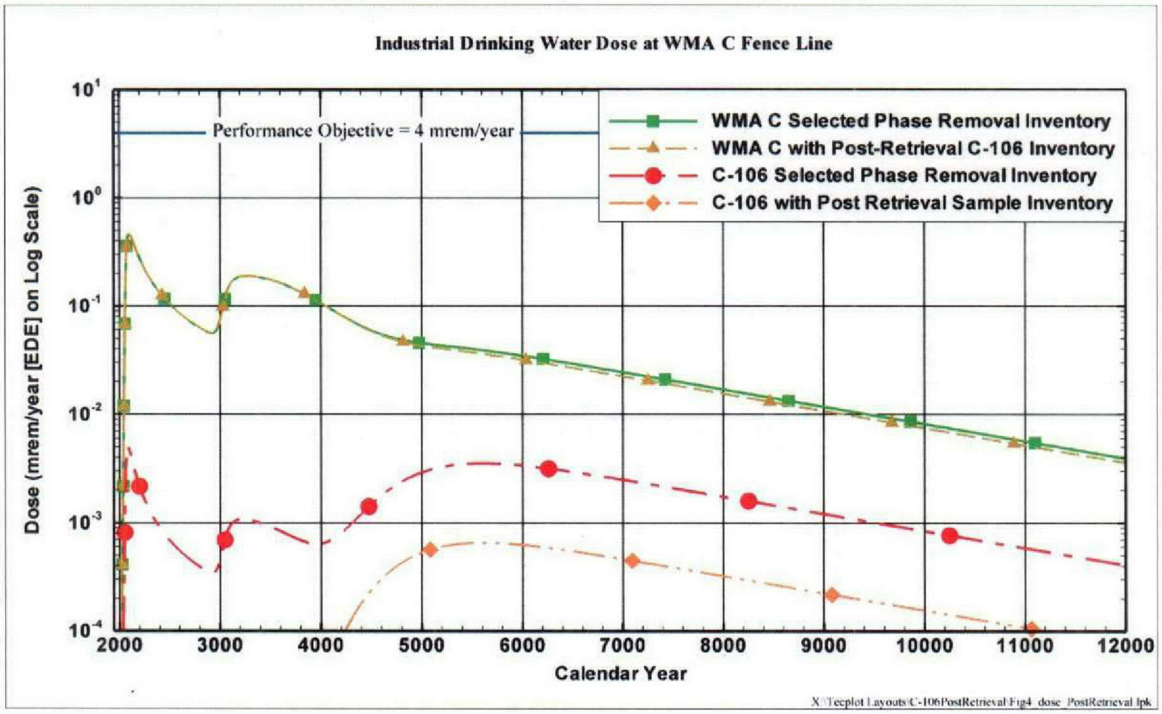
- **WMA C:** SPR Inventory (Green Solid Line, Square Symbols). This is the cumulative WMA C radiological dose base curve. The base curve is described in the first bullet of the Section 3.4.1. The peak radiological dose is for this curve is 4.6 x 10^{-1}, which is below the performance objective of 4.0.

- **WMA C:** Post-Retrieval SST C-106 Sample Inventory (Brown Dash Line, Delta Symbols). For this curve, the inventory calculated from the post-retrieval sample was used for residual inventory and the hypothetical retrieval leak from SST C-106 was removed because no retrieval leak occurred. Except for these changes made for SST C-106, the curve is exactly the same as described in the first bullet of this section. Although for the most part the previous curve and this one overlap, there are some differences. The peak radiological dose for this curve is also 4.5 x 10^{-1}, which indicates the hypothetical 8,000-gal retrieval leak from this tank did not impact this metric because the hypothetical retrieval leak was removed in this curve. Additionally, at about 5,000 years, the SPR and post-retrieval sample curves diverge slightly, with post-retrieval curve having a slightly lower radiological dose than the curve base on the SPR curve. This is due to the smaller residual inventory of ^{99}Tc calculated from the post-retrieval sample.

- **SST C-106:** SPR Inventory (Red DashDot Line, Circle Symbols). This curve is the same curve given in RPP-13774, Attachment C-1. This is a cumulative curve showing an 8,000-gal retrieval leak from SST C-106 along with the impacts from SST C-106 residuals. The peak value is 5.0 x 10^{-3} mrem/yr due to the retrieval leaks considered in the pre-retrieval analysis.

- **SST C-106:** Post-Retrieval SST C-106 Sample Inventory (Orange DashDotDot Line, Diamond Symbols). This curve is for the residual inventory calculated using the post-retrieval sample. Leaks did not occur during retrieval and therefore were not considered. The peak value for this curve is 6.6 x 10^{-4} mrem/yr, which is almost a sevenfold decrease over the radiological dose calculated for the SPR residual inventory. This is due to the smaller residual inventory of ^{99}Tc and ^{129}I, which is no longer a contaminant of concern. This is a factor of almost 6,000 below the performance objective 4 mrem/yr.

Figure 3-5. Comparison of the Selected Phase Removal Inventory and Single-Shell Tank 241-C-106 Archive Sample Inventory for both Waste Management Area C and Single-Shell Tank 241-C-106 to Radiological Drinking Water Dose for the Industrial Worker Scenario.



3.4.4 Results for Individual Contaminants for Post-Retrieval Single-Shell Tank 241-C-106

The results presented in the previous section discussed the impacts to the cumulative totals for WMA C and how the inventory calculated from the post-retrieval sample impacted those cumulative curves. The contaminants from Appendix B, Table B-1 were evaluated in Section 3.2 to determine the COPC. Of the 165 analytes evaluated, 29 radionuclides and 14 nonradionuclides were considered as COPC. Table 3-4 provides the risk for each exposure scenario per radionuclide considered a COPC, while Table 3-5 provides the same information for nonradionuclides. In each of these tables the following columns are provided.

- **Analyte Name** for COPC
- **Inventory** associated with COPC (Appendix B, Table B-2)
- **WMA C Fenceline Concentration** is the modeled (RPP-13774) concentration at the WMA C fenceline. If there is inventory associated with a COPC, the COPC may not have a corresponding concentration at the fenceline. Short-lived radionuclides will decay away before the contaminant can arrive at the WMA C fenceline. Immobile COPCs (i.e., K_d greater 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.

- K_d[2] is the mobility factor used in the groundwater modeling for the analyte. The actual K_d of the COPC is almost always larger than the K_d used in the modeling (i.e., reported ^{90}Sr K_d for Hanford Site sediments is 8 – 15 mg/L, the modeling used 1.0 mg/L). If the K_d is equal to zero, the analyte moves with the groundwater. However, if the K_d is equal to 0.6 mg/L, the contaminant moves at approximately 1/10 the velocity of the groundwater in the aquifer, and even slower in the vadose zone.
- **Half-life** is the half-life of the radionuclide or organic compound in years. All organics were treated with an infinite half-life.
- **HSRAM Exposure Scenarios** for ILCR (radionuclides and nonradionuclides) and HI (nonradionuclides). Use dosimetry factors from *Exposure Scenarios and Unit Dose Factors for Hanford Tank Waste Performance Assessments*, (HNF-SD-WM-TI-707 [Note: this document is in the process of being revised to add more analytes and to address previous comments from Ecology]).
- **All-Pathway Radiological Dose** are provided for the farmer and Native American receptors radionuclides.
- **Drinking Water Dose** for radionuclides using effective dose equivalent.

Evaluation of Tables 3-4 and 3-5 clearly show the major risk driving analytes for radionuclides in this tank is ^{99}Tc (2.0×10^{-8}). For nonradionuclides, chromium, in its hexavalent state, is the primary risk driver, but at an order of magnitude less than ^{99}Tc. Chromium's peak ILCR-nonrad is 8.9×10^{-10}.

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[2] Although during the Notice of Deficiency process for the RPP-13774, it was agreed to evaluate uranium with a lower K_d. However, recent site-specific field and laboratory data indicates lowering the K_d for uranium would not be technically justifiable. The mobility of uranium transport in the 200 Area vadose zone is considered to be retarded in comparison with the movement of water. In contrast, the mobility of ^{99}Tc and nitrate are seen to be the same as that of water. These conclusions are based on numerous laboratory experiments (see for example, the *Geochemical Data Package for the Immobilized Low-Activity Waste Performance Assessment*, PNNL-13037). This retarded movement of uranium compared to ^{99}Tc and water is confirmed by recent preliminary measurements from the B-26 Borehole in the BC Cribs Area (RPP-20303, *Preliminary Data from 216-B-26 Borehole in BC Cribs Area*) where the peak of uranium is found at 22.5 ft below surface, while ^{99}Tc peak is at 101 ft. Recent preliminary results from a borehole drilled near SST C-105 show a similar pattern, uranium peaking at 51 ft (the tank bottom being at about 45 ft) and ^{99}Tc peaking at 146 ft. Thus, laboratory and field experiments confirm that uranium mobility is retarded in vicinity of WMA C.

Table 3-4. Incremental Lifetime Cancer Risk, Radiological Dose, and Drinking Water Dose per Radionuclide Contaminant of Potential Concern using Nominal Post-Retrieval Inventory. (2 Sheets)

Analyte	Inventory (Ci)	WMA C fenceline concentration (pCi/L)	K_d (mL/g)	Half-Life (yr)	HSRAM Incremental cancer risk scenarios (groundwater)						All-pathway radiological dose groundwater (mrem/yr)		Drinking water dose C4E beta/photon (mrem-EDE/yr)	
					Industrial	Residential	Agricultural	Recreational	All pathway farmer	Native American	Farmer	Native American	Residential	Industrial
Cobalt-60	9.00E+00	0	0.1	5.27	0	0	0	0	0	0	0	0	0	0
Nickel-63	7.30E+01	0	1	100.1	0	0	0	0	0	0	0	0	0	0
Strontium-90 + D	6.61E+04	0	1	28.1	0	0	0	0	0	0	0	0	0	0
Technetium-99	1.65E-01	1.43E+00	0	2.1E+05	2.0E-08	4.8E-07	6.7E-07	1.7E-09	1.0E-06	6.9E-06	2.5E-03	6.0E-03	1.5E-03	5.2E-04
Cesium-137 + D	1.45E+03	0	1	30.0	0	0	0	0	0	0	0	0	0	0
Europium-152	3.14E+01	0	1	13.3	0	0	0	0	0	0	0	0	0	0
Europium-154	4.07E+01	0	1	8.59	0	0	0	0	0	0	0	0	0	0
Europium-155	3.90E+01	0	1	4.68	0	0	0	0	0	0	0	0	0	0
Thorium-228 + D	5.75E-04	0	1	1.91	0	0	0	0	0	0	0	0	Not Beta	Not Beta
Thorium-230	8.82E-04	0	1	75380	0	0	0	0	0	0	0	0	Not Beta	Not Beta
Thorium-232	5.61E-04	0	1	1.4E+10	0	0	0	0	0	0	0	0	Not Beta	Not Beta
Uranium-233	1.83E-03	2.26E-07	0.6	1.6E+05	8.5E-14	4.3E-13	4.7E-13	7.0E-15	3.9E-13	1.1E-11	4.7E-08	1.9E-07	Not Beta	Not Beta
Uranium-234	9.48E-04	1.20E-07	0.6	2.5E+05	4.4E-14	2.2E-13	2.4E-13	3.6E-15	2.0E-13	5.5E-12	2.4E-08	9.7E-08	Not Beta	Not Beta
Uranium-235 + D	3.87E-05	4.94E-09	0.6	7.0E+08	2.0E-15	1.2E-14	1.3E-14	1.7E-16	1.0E-14	2.2E-13	9.6E-10	3.8E-09	Not Beta	Not Beta
Uranium-236	1.73E-05	2.22E-09	0.6	2.34E+07	7.8E-16	4.0E-15	4.3E-15	6.5E-17	3.6E-15	9.6E-14	4.3E-10	1.7E-09	Not Beta	Not Beta
Uranium-238 + D	9.04E-04	1.17E-07	0.6	4.5E+09	5.3E-14	2.8E-13	3.1E-13	4.5E-15	2.5E-13	4.9E-12	2.2E-08	8.8E-08	Not Beta	Not Beta
Neptunium-237 + D	5.42E-04	0	1	2.1E+06	0	0	0	0	0	0	0	0	Not Beta	Not Beta

Table 3-4. Incremental Lifetime Cancer Risk, Radiological Dose, and Drinking Water Dose per Radionuclide Contaminant of Potential Concern using Nominal Post-Retrieval Inventory. (2 Sheets)

Analyte	Inventory (Ci)	WMA C fenceline concentration (pCi/L)	K_d (mL/g)	Half-Life (yr)	HSRAM Incremental cancer risk scenarios (groundwater)						All-pathway radiological dose groundwater (mrem/yr)		Drinking water dose C4E beta/photon (mrem-EDE/yr)	
					Industrial	Residential	Agricultural	Recreational	All pathway farmer	Native American	Farmer	Native American	Residential	Industrial
Plutonium-238	1.36E+00	0	1	87.7	0	0	0	0	0	0	0	0	Not Beta	Not Beta
Plutonium-239	1.68E+01	0	1	24110	0	0	0	0	0	0	0	0	Not Beta	Not Beta
Plutonium-240	3.58E+00	0	1	6563	0	0	0	0	0	0	0	0	Not Beta	Not Beta
Plutonium-241 + D	3.97E+01	0	1	14.4	0	0	0	0	0	0	0	0	0	0
Americium-241	6.53E+01	0	1	433	0	0	0	0	0	0	0	0	Not Beta	Not Beta
Curium-242	7.90E-02	0	1	0.446	0	0	0	0	0	0	0	0	Not Beta	Not Beta
Curium-243	1.51E-01	0	1	28.5	0	0	0	0	0	0	0	0	Not Beta	Not Beta
Curium-244	3.63E+00	0	1	18.1	0	0	0	0	0	0	0	0	Not Beta	Not Beta
Maximum					2.0E-08	4.8E-07	6.7E-07	1.7E-09	1.0E-06	6.9E-06	2.5E-03	6.0E-03	1.5E-03	5.2E-04

Notes:

Shaded cells are nondetect and the inventory used in the risk assessment is calculated at ½ the minimum detection limit.

Performance objective for ILCR-Rad = 1.0 E-4 to 1.0 E-6 (EPA/540/R-99/006 *Radiation Risk Assessment at CERCLA Sites: Q & A Directive* 9200.4-31P).

Performance objective for radiological dose = 25 mrem/yr.

Performance objective for drinking water dose 4 mrem/yr.

ILCR = incremental lifetime cancer risk.

WMA = Waste Management Area.

Table 3-5. Incremental Lifetime Cancer Risk and Hazard Index per Nonradionuclide Contaminant of Potential Concern using Nominal Post-Retrieval Inventory. (2 sheets)

Analyte	Inventory (Ci)	WMA C fenceline concentration (mg/L)	K_d (mL/g)	Half-Life (yr)	HSRAM incremental cancer risk scenarios (groundwater)						HSRAM hazard index scenarios (groundwater)					
					Industrial	Residential	Agri-cultural	Recrea-tional	All Pathway Farmer	Native American	Residential	Industrial	Agri-cultural	Recrea-tional	All Pathways Farmer	Native American
Aluminum	4.87E+02	0	1	Infinity	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	0
Barium	2.08E+00	0	1	Infinity	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	0
Cadmium	1.84E+00	0	1	Infinity	0	0	0	0	0	0	0	0	0	0	0	0
Chromium	4.81E+00	4.20E-05	0	Infinity	8.9E-10	2.0E-09	2.0E-09	3.5E-11	3.0E-09	2.5E-06	1.4E-04	7.9E-04	8.2E-04	1.5E-05	3.7E-04	2.7E-02
Cobalt	4.78E-01	2.65E-06	0.1	Infinity	2.7E-11	8.0E-11	8.0E-11	1.5E-12	1.2E-10	3.8E-08	2.7E-06	1.0E-05	1.1E-05	1.7E-07	1.1E-05	6.9E-04
Copper	2.93E+00	0	1	Infinity	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	0
Cyanide	9.93E-02	0	1	Infinity	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	0
Iron	2.66E+02	0	1	Infinity	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	0
Manganese	6.99E+02	0	1	Infinity	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	0
Mercury	2.45E+00	0	1	Infinity	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	0
Nickel	3.85E+01	0	1	Infinity	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	0
Silver	9.98E+00	0	1	Infinity	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	0
Strontium	1.66E+00	0	1	Infinity	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	0
Zinc	2.70E+00	0	1	Infinity	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	0
2-Butanone (MEK)	5.69E-04	4.97E-09	0	Infinity	N/A	N/A	N/A	N/A	N/A	N/A	3.4E-10	1.4E-09	1.4E-09	8.0E-12	1.3E-09	3.4E-09
2-Propanone (Acetone)	1.65E-03	1.44E-08	0	Infinity	N/A	N/A	N/A	N/A	N/A	N/A	1.2E-10	2.9E-09	2.9E-09	1.5E-11	2.5E-09	8.6E-09

Table 3-5. Incremental Lifetime Cancer Risk and Hazard Index per Nonradionuclide Contaminant of Potential Concern using Nominal Post-Retrieval Inventory. (2 sheets)

Analyte	Inventory (Ci)	WMA C fenceline concentration (mg/L)	K_d (mL/g)	Half-Life (yr)	HSRAM incremental cancer risk scenarios (groundwater)						HSRAM hazard index scenarios (groundwater)					
					Industrial	Residential	Agri-cultural	Recrea-tional	All Pathway Farmer	Native American	Residential	Industrial	Agri-cultural	Recrea-tional	All Pathways Farmer	Native American
Di-n-butylphthalate	1.07E-01	1.41E-11	0.6	Infinity	N/A	N/A	N/A	N/A	N/A	N/A	6.6E-14	4.4E-13	4.4E-13	7.1E-15	2.1E-13	6.3E-13
Maximum					8.9E-10	2.0E-09	2.0E-09	3.6E-11	3.0E-09	2.5E-06	1.4E-04	7.9E-04	8.2E-04	1.5E-05	3.7E-04	2.7E-02

Notes:

Performance objective for ILCR = 1E-5 (RPP-14283)

Performance objective for Hazard Index = 1 (RPP-14283)

HSRAM = *Hanford Site Radiological Assessment Methodology* (DOE/RL-91-45).

N/A = not applicable.

RPP-14283, 2004, *Performance Objectives for Tank Farm Closure Performance Assessments*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

3.5 RISK RELATED TO RESIDUAL VOLUME

Figure 3-6 illustrates the reduction of ILCR-rad as a function of SST C-106 residual waste volume. At each level of retrieval below the nominal volume for solids only (of 359 ft^3), the inventory for contaminants in SST C-106 has been reduced linearly. Also included on the figure are results from the inventory calculated using the 95% UCL volume rather than the nominal volume (370 ft^3), 95% UCL for volume, density, and analytes, as well as the pre-retrieval risk represented by the residual inventory calculated from the SPR method. This analysis assumes that no waste will be lost during additional retrievals.

Table 3-6 shows the relative contribution of SST C-106 relative to the total risk of SST residuals at different levels of retrieval. Risk for the total of all WMA C SST residuals was calculated using the SPR inventory given in RPP-13774, Attachment C-1. For that assessment, the ILCR-rad for the industrial receptor was 7.8×10^{-8}, while the ILCR-rad for all of the residuals in WMA C was 1.0×10^{-6}. The percentage of the risk represented by the residual in SST C-106 is approximately 7.8% or 1/12 of the total cumulative risk using the inventory calculated by the SPR. Replacing the SPR inventory, with the inventory calculated from the post-retrieval sample using the nominal volume (370 ft^3) reduces the risk posed by SST C-106 from 7.8% to approximately 2.1%. Replacing the nominal volume with the volume calculated for the 95% UCL will cause the 2.1% contribution from SST C-106 to increase to 2.6%.

Figure 3-6. Change in Incremental Lifetime Cancer Risk for the Industrial Worker for Single-Shell Tank 241-C-106 Residual Waste as a Function of Waste Volume Reduction.

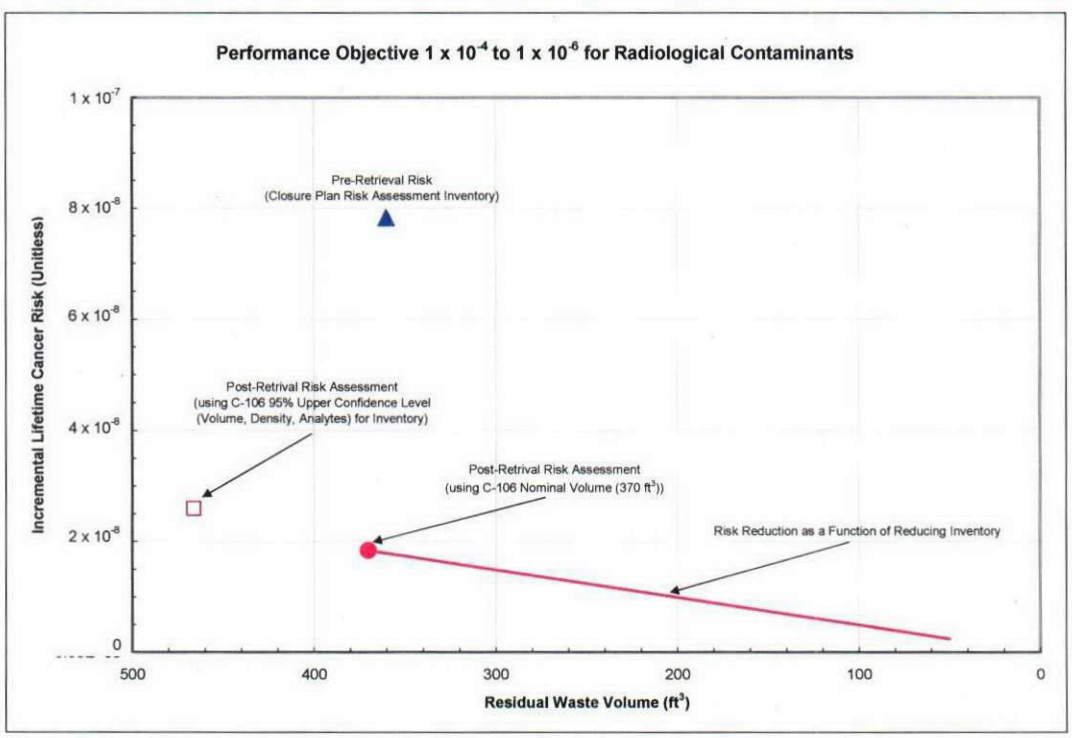


Table 3-6. Relative Contribution of Single-Shell Tank 241-C-106 Residual Waste to Total WMA C Residual Waste to the Industrial Receptor at the WMA C Fenceline at Selected Retrieval Volumes.

Residual inventory (volume)[1]	Total WMA C residual tank waste		SST C-106 residual tank waste		Percentage contribution of SST C-106 to WMA	
	ILCR industrial	All-pathways farmer dose (mrem/yr)	ILCR industrial	All-pathways farmer dose (mrem/yr)	ILCR industrial (%)	All-pathways farmer dose (mrem/yr)
SPR inventory used in pre-retrieval risk assessment (360 ft^3)	1.02E-06	1.97E-01	7.84E-08	2.74E-02	7.72	13.88%
Post-retrieval sample SST C-106 95% UCL overall for inventory of each constituent was calculated based on RPP-6924	9.64E-07	1.73E-01	2.61E-08	3.32E-03	2.71	1.92%
Post-retrieval sample SST C-106 95% UCL volume (466 ft^3 [sludge + liquids])	9.63E-07	1.73E-01	2.48E-08	3.15E-03	2.58	1.82%
Post-retrieval sample SST C-106 Nominal volume (370 ft^3 [sludge + liquids])	9.57E-07	1.73E-01	1.97E-08	2.50E-03	2.05	1.45%
Post-retrieval sample SST C-106 Estimated (300 ft^3 [sludge only])	9.54E-07	1.72E-01	1.64E-08	2.09E-03	1.72	1.21%
Post-retrieval sample SST C-106 Estimated (250 ft^3 [sludge only])	9.51E-07	1.72E-01	1.37E-08	1.74E-03	1.44	1.01%
Post-retrieval sample SST C-106 Estimated (200 ft^3 [sludge only])	9.49E-07	1.71E-01	1.10E-08	1.39E-03	1.16	0.81%
Post-retrieval sample SST C-106 Estimated (150 ft^3 [sludge only])	9.46E-07	1.71E-01	8.22E-09	1.04E-03	0.87	0.61%
Post-retrieval sample SST C-106 Estimated (100 ft^3 [sludge only])	9.43E-07	1.71E-01	5.48E-09	6.96E-04	0.58	0.41%
Post-retrieval sample SST C-106 Estimated (50 ft^3 [sludge only])	9.40E-07	1.70E-01	2.74E-09	3.48E-04	0.29	0.20%

Notes:

[1]See inventory definitions page for a complete description of how each inventory is calculated.

ILCR = incremental lifetime cancer risk.

SPR = selected phase removal.

SST = single-shell tank.

UCL = upper confidence limit.

WMA = Waste Management Area.

RPP-6924, 2000, *Statistical Methods for Estimating the Uncertainty in the Best-Basis Inventories*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

3.6 CONCLUSIONS

The conclusions of this risk assessment are summarized in the following three points:

1. Risk values presented in this analysis and those contained in RPP-13774, Attachment C-1 for the entire WMA are nearly the same.

2. The impacts estimated for SST C-106 are a factor of 4 smaller in this analysis than those in RPP-13774.

3. Of the 42 COPCs analyzed, ^{99}Tc and chromium are the primary contaminants (greater than 99% and 95%, respectively) that drive risk. The conclusions presented in RPP-13774 are unchanged by the present analysis using residual SST C-106 tank waste samples. Based on the current residential inventory, no groundwater quality standards would be exceeded.

4.0 EVALUATION OF POTENTIAL AND FUTURE WASTE RETRIEVAL TECHNOLOGIES

This section describes and presents comparative evaluations of additional waste retrieval technologies that are currently available (i.e., do not require further research and development prior to deployment). It also describes and compares future potential retrieval technologies requiring research and development that have potential for future deployment at the Hanford Site tank farms. The information provided documents that three additional technologies (modified sluicing, Vacuum Retrieval Systems [VRS], and Mobile Retrieval System [MRS]) configured in four alternatives are sufficiently mature to evaluate for potential deployment to retrieve additional waste from SST C-106. Cost, schedule, and performance data are presented, as well as an assessment of technical uncertainties potentially limiting the ability of the technologies to effectively retrieve waste to the HFFACO retrieval criteria. Information is also provided on other potential future technologies that, at this time, are not sufficiently developed and technically mature to support cost, schedule, and performance evaluations.

4.1 AVAILABLE RETRIEVAL TECHNOLOGIES

Evaluation of additional waste retrieval technologies was performed using a three-step process that included:

- Identifying the retrieval functions the technologies would need to perform
- Identifying retrieval technologies/alternatives that could be deployed in SST C-106 without further research and development
- Comparing the relative effectiveness of the additional available technologies/alternatives against performance objectives.

4.1.1 Functions of Retrieval Technologies

Many of the SST retrieval technologies that could be deployed in the near-term could satisfy multiple retrieval functions. Many also have overlapping capabilities. This section describes the retrieval technology functions most relevant to removing additional waste from SST C-106. These functions include:

- **Dissolve Waste** - Waste is dissolved by adding a solvent (e.g., water or acid in Hanford Site tank farms) over time. Once waste is dissolved, the waste solution is pumped out of the SST.
- **Break Up Agglomerated Waste** - Waste is broken up via mechanical energy from a water stream (via nozzle), mixing from a pump, or an in-tank mechanical vehicle. Once agglomerated waste is broken up, facilitate moving or transferring the waste.

- **Mobilize/Move Waste in the Tank** - Waste is mobilized in the tank using water from a water stream (via nozzle) or an in-tank mechanical vehicle. Waste mobilization is attempted to move waste closer to the intake of the transfer system.
- **Transfer Waste Out of Tank** - Waste is captured and transferred out of the tank via a pump. Many types of pumps are available for this function and range from an auger to a vacuum system. These pumps may be operated in batch or continuous modes.
- **Transport Waste From Top of Tank to Receiver Tank System** - Transport of waste from the SST to the receiver tank system can be accomplished by the in-tank pump providing all motive force, or a separate ex-tank booster pump. These pumps may be operated in batch or continuous modes.
- **Minimize Waste Volume** - Waste volume is minimized by using less water for all functions. Less water equates to more efficient use of DST space and places less demand on evaporator and waste transfer facilities.

4.1.2 Additional Available Waste Retrieval Technologies

The waste retrieval technologies that are currently available at the Hanford Site and could be scheduled for deployment in SST C-106 include:

- **Modified Sluicing** – Consists of sluicing system (water supply, nozzles, and controls); a centralized pump; and a transfer system. Modified sluicing has been or is currently being deployed on saltcake tanks (SSTs S-102 and S-112) and sludge tanks (used in SST C-106 and being deployed in SSTs C-103 and C-105).
- **Vacuum Retrieval System (VRS)** – Consists of an articulated vacuum mast, batch vacuum vessel, control system, and a transfer system. VRSs are or will be deployed at C-200, U-200, B-200, and T-200 series tanks.
- **Mobile Retrieval System (MRS)** – The MRS is a combination of the VRS and an in-tank vehicle (ITV). The system is currently slated for deployment on SSTs T-110, T-111, C-101, C-110, and C-111. The MRS is typically identified as the waste retrieval technology for leaking 100-series tanks.
- **Chemical Addition** – The chemical addition system consists of adding chemicals to dissolve and loosen up waste. The chemical addition system was recently deployed on SST C-106.

Table 4-1 shows the available retrieval technologies and describes how well the technologies perform the basic retrieval functions including:

- Dissolving waste
- Breaking up agglomerated waste
- Mobilizing/moving waste in the tank
- Transferring waste out of tank
- Minimizing waste volume.

Table 4-1. Comparison of Technologies and Functions.

Retrieval technology systems	Functions					
	Dissolve waste	**Breakup waste**	**Mobilize/move waste in tank**	**Transport waste out of tank**	**Transport to receiver tank**	**Minimize waste**
Modified Sluicing – Saltcake Tank	Via water addition through spray nozzles or pump drop-leg. Waste dissolution also occurs during soak periods.	Via water nozzles. Not all waste will breakup via water agitation.	Via directed water spray from nozzles. Not all waste can be directed to the pump intake via water spray.	Via in-tank pump. Waste particles must be small enough to pass through pump intake screen.	Via in-tank pump. No booster pump is required.	Waste minimized by using as little water as possible and optimizing conditions such as raw water temperature.
Modified Sluicing – Sludge Tank	N/A	Via water nozzles. Not all waste will breakup via water agitation.	Via water nozzles. Not all waste can be directed to the pump intake via water spray.	Via in-tank pump. Waste particles must be small enough to pass through pump intake screen.	Via in-tank pump. No booster pump is required.	Waste minimized by using as little water as possible. Could be accomplished through recirculation of supernatant.
Vacuum Retrieval	N/A	Waste within vacuum wand operating radius broken up via vacuum wand and scarifying nozzles.	Waste within vacuum wand operating radius is moved/mobilized via the vacuum mast suction and physical manipulation with the vacuum wand.	Waste is removed from the tank via the vacuum wand suction.	Ex-tank vacuum vessel and booster pump.	Waste minimized by using as little water as possible. Could be accomplished through recirculation of supernatant.
Mobile Retrieval	N/A	Waste within vacuum wand operating radius broken up via vacuum wand and scarifying nozzles. Waste located on the floor of the tank can be broken up via the ITV blade or tracks or water cannon.	Vacuum wand and scarifying nozzles in radius of influence, ITV in all floor areas.	Waste is removed from the tank via the vacuum wand suction.	Ex-tank vacuum vessel and booster pump.	Waste minimized by using as little water as possible. Could be accomplished through recirculation of supernatant.
Chemical Addition	Via chemical addition and soaking.	Dissolves waste and potentially softens solids.	N/A. Must be combined with other waste transport technology.	N/A. Must be combined with other waste transport technology.	N/A. Must be combined with other waste transport technology.	Waste minimized by using as little chemical addition as possible.

Notes:

ITV = in-tank vehicle.
N/A = not applicable.

4.1.3 Development of Retrieval Alternatives using Additional Available Technologies

A range of alternatives has been identified to support a comparison of the ability of the technologies to meet performance criteria (e.g., dissolve and breakup waste, mobilize and transfer waste). Alternatives have been identified by combining retrieval technologies as necessary to satisfy all the functions of retrieval. In this section, alternatives are described and costs, schedules, and deployment requirements are identified.

Each of the four alternatives for deployment of additional retrieval technologies discussed in this section pose technical challenges and risks that may inhibit their capability to attain the HFFACO retrieval criteria. Among the areas of technical uncertainty are:

- The MRS and VRS have yet to be demonstrated in Hanford Site SSTs. Retrieval demonstration projects are planned to establish the technical limits for each of these technologies. However, until the demonstrations are complete on comparable tanks (i.e., 100-series tanks) and tank waste (i.e., residual sludge) assurance that either technology could retrieve waste to the HFFACO retrieval criteria remains uncertain.
- Three of the technologies involve deployment of modified sluicing using existing or new equipment (e.g., pumps) under new configurations of risers. The 2003 retrieval campaign involved several mid-campaign optimizations (e.g., reconfiguration of nozzles) of equipment and/or operations that enhanced retrieval effectiveness but failed to complete retrieval of waste to the HFFACO retrieval goal. Further optimizations incorporated into the evaluated alternatives may result in additional waste retrieval; however, the quantity of waste that could be retrieved under the alternatives is uncertain.

While it is the overall goal to define systems that will remove as much of the residuals as possible, the alternatives described below are discussed in the context of a common "minimum volume goal" end state of 200 ft^3 (i.e., removal of 160 ft^3). At the 95% UCL of residual waste remaining in a tank, 467 ft^3 of solids are present in the tank and the alternative retrieval technology selected must retrieve an additional 107 ft^3 of waste from the tank to reach the 360 ft^3 residual waste volume requirement. To ensure the residual waste volume in the tank is less than or equal to the 360 ft^3 requirement, the removal volume goal was conservatively set at 160 ft^3 based on the volume estimation uncertainty associated with the residual waste volume determination and the additional uncertainties associated with the waste retrieval technology performance. Each of the alternatives potentially could attain the minimum volume goal and more; however, there are differences in costs, schedule, water usage, and impacts to the DSTs and the evaporator, as well as ease of implementation and technical risk. These differences are compared in Section 4.2 and evaluated to these criteria.

It is assumed that the appropriate assessments (e.g., criticality, waste compatibility, infrastructure impacts, and sequence impacts) would be performed for each alternative prior to design and implementation of a given alternative. These assessments are not part of this discussion.

The cost estimate and water usage for each alternative are documented in Appendix C and Appendix D, respectively.

4.1.3.1 Alternative A – Raw Water Modified Sluicing (Current Equipment). For Alternative A, the current SST C-106 modified sluicing system would be restarted and operated to remove tank waste until the minimum goal is satisfied. It is anticipated that the volume of raw water required to attain the minimum volume goal is 1,870,000 gal (Appendix D). Restarting the SST C-106 modified sluicing system would include the following steps:

- Complete C-200 series tank waste retrievals. Equipment and resources required to retrieve additional waste from SST C-106 are not available until completion or interruption of C-200 series tank waste retrievals.
- Re-connect the hose-in-hose transfer line (HIHTL) from SST C-200 series tanks to the SST C-106 system.
- Re-install and/or reconnect any SST C-106 equipment that has been decommissioned.
- Operate sluicers and pump until minimum volume goal or lower has been achieved.
- Evaluate volume remaining.
- Collect samples and characterize.
- Decommission equipment.

The use of oxalic acid or a substitute chemical such as nitric acid or a chemical solution such as oxalic acid and nitric acid combined is not expected to be more effective than sluicing. Oxalic acid was added in six separate batches during the retrieval in 2003. Diminishing returns were achieved with the last two acid batches. In the last batch, the pH after 8 days was about 0.79, and the reading did not increase over the last 4 days. Fully depleted oxalic acid is expected to reach a pH of 1.5. The lower pH indicates that all of the reactive solids had reacted. These results confirm laboratory testing that showed that about 30% of the solids would not dissolve in oxalic acid. Because the solids in the tank have been exposed to multiple batches of oxalic acid, additional dissolution of the solids would be minimal.

Use of an alternative acid or mixture of acids is not expected to be effective based on the laboratory work (RPP-17158). The laboratory tests at the Savannah River Site and Hanford Site showed the oxalic acid was generally as effective as any other acid for dissolving the sludges in the storage tanks. The use of nitric acid was only slightly more effective than oxalic acid for these sludges. Nitric acid was rejected for use because of the marginal dissolution improvement and the measurable oxidation of tank surfaces. At this time nitric acid is not considered suitable for tank waste retrieval.

Even if oxalic acid is used and dissolved 5% to 10% of the tank solids (between 150 and 300 gal), sluicing would need to be deployed to remove the remaining amount of solids. Additionally, sodium hydroxide would need to be added to DST AN-106 to neutralize the addition of oxalic acid. The combination of the oxalic acid solution (about 30,000 gal), sluicing water, and sodium hydroxide is expected to be equivalent to or greater than the volume of water if only sluicing is used (Alternative A). Finally, when neutralized in DST AN-106, the oxalic acid precipitates as sodium oxalate solids. Thus, the volume of solids in the DSTs would increase. For these reasons, chemical addition/modified sluicing is not evaluated further.

The estimated implementation cost for Alternative A is approximately $1.9 million and adding $3.7 million in evaporator costs results in a total retrieval and storage cost of $5.7 million (Appendix C). Due to the high volume of water required for this alternative, the anticipated duration of retrieval from start to finish is approximately 12 months.

4.1.3.2 Alternative B – New Modified Sluicing with New Slurry Pump. Alternative B consists of the design, procurement, construction, startup, and operation of an entirely new modified sluicing system specifically designed for the sludge residuals in SST C-106. This alternative would support the use of recycled DST supernatant as the sluicing medium minimizing total liquid volumes. However, use of DST supernatant could introduce new waste to the tank and thus may require flushing with raw water in later stages of the retrieval campaign. The system would include new pumps and sluice nozzles installed in new risers designed to take the residual volume from current levels to below the minimum volume goal. The new slurry pump may be a progressive cavity, or other type capable of pumping solids. The existing transfer route to the AN tank farm would be used once the C-200 series tank waste retrievals are completed. It is anticipated that the volume of additional raw water required to attain the minimum volume goal is 90,000 gal. Implementing the Alternative B system would include the following steps:

- Complete C-200 series tank waste retrievals. Equipment and resources required to retrieve additional waste from SST C-106 are not available until completion or interruption of C-200 series tank waste retrievals.
- Re-connect the HIHTL from C-200 series tanks to SST C-106 system.
- Replace existing pump with new pump (assume progressive cavity with "fluidizer head").
- Construct two new risers and install two new sluicer nozzles.
- Re-install and/or reconnect any SST C-106 equipment that has been decommissioned.
- Operate system until minimum volume goal or lower has been achieved.
- Evaluate volume remaining.
- Collect samples and characterize.
- Decommission equipment.

The estimated implementation cost for Alternative B is approximately $5.7 million and adding $180,000 in evaporator costs results in a total retrieval and storage cost of $5.88 million. The anticipated schedule duration from start to finish is 12 months.

4.1.3.3 Alternative C – Modified Sluicing Followed by New Vacuum Retrieval System. Alternative C is based on the use of modified sluicing to cleanup the tank bottom and remove as much as is possible in a short period of time (with minimal water). Two new risers would then be installed near or above the areas where waste solids and fines are located. Vacuum system masts would be installed in the new risers to retrieve as much of the waste solids and fines that would fall within the approximately 20-ft vacuum mast radius. This would be a batch process where waste would be vacuumed into the batch vessel followed by water addition and slurry of the waste to the AN tank farm via the existing SST C-106 HIHTL.

The work consists of the design, procurement, construction, startup, and operation of the existing modified sluicing system and an entirely new VRS specifically designed for the sludge residuals in SST C-106. The current VRS design for B-200 series tanks would be used as a starting point. The Alternative C system would be operated to remove tank waste until the minimum volume goal or lower is attained. It is anticipated that the volume of additional raw water required to attain the minimum volume goal is 225,000 gal. Implementing the Alternative C system would include the following steps:

- Complete C-200 series tank waste retrievals. Equipment and resources required to retrieve additional waste from SST C-106 are not available until completion or interruption of C-200 series tank waste retrievals.
- Re-connect the HIHTL from the C-200 series tanks to the SST C-106 system.
- Re-install and/or reconnect any SST C-106 equipment that has been decommissioned.
- Operate the modified sluicing system to cleanup the tank bottom.
- Install two new risers above or near the waste solids and fines (accounting for the vacuum mast 20 ft radius).
- Install two vacuum masts.
- Operate the VRS until minimum volume goal or lower has been achieved.
- Evaluate volume remaining.
- Collect samples and characterize.
- Decommission equipment.

The estimated implementation cost for Alternative C is approximately $10.2 million and an additional $450,000 in evaporator costs, resulting in a total retrieval and storage cost of $10.6 million. The anticipated duration for retrieval from start to finish is 16 months.

4.1.3.4 Alternative D – Mobile Retrieval System. The MRS consists of a VRS in combination with an ITV. Alternative D consists of the design, procurement, construction, startup, and operation of a new MRS specifically designed for the sludge residuals in SST C-106. The existing transfer route to the AN tank farm would be used once the C-200 series tank retrievals are completed. The MRS would be operated to remove tank waste until the minimum goal or lower is satisfied. The MRS generates water from the vacuum system and requires significant water to transfer wastes to the AN tank farm. It is anticipated that the volume of additional raw water required to attain the minimum volume goal is 175,000 gal. Retrieving SST C-106 with the MRS would include the following steps:

- Complete C-200 series tank waste retrievals. Equipment and resources required to retrieve additional waste from SST C-106 are not available until completion or interruption of C-200 series tank waste retrievals.
- Re-connect the HIHTL from C-200 series tanks to the SST C-106 system.
- Install new ITV riser.
- Install the new ITV.
- Remove the Gorman-Rupp[3] pump from riser 13.
- Install vacuum system.
- Operate MRS until minimum volume goal or lower has been achieved.
- Evaluate volume remaining.
- Collect samples and characterize.
- Decommission equipment.

The estimated implementation cost for Alternative D is approximately $13.1 million and an additional $350,000 in evaporator costs resulting in a total retrieval and storage cost of $13.5 million. The anticipated duration of retrieval from start to finish is 18 months.

4.2 COMPARATIVE EVALUATION OF AVAILABLE RETRIEVAL ALTERNATIVES

The four alternatives identified in Section 4.1.3 were comparatively evaluated using three methods. The first method compared how well the waste retrieval alternatives satisfied the retrieval functions identified in Section 4.1.1. The functions compared included: dissolving, breaking up, mobilizing, transferring, and minimizing waste. Table 4-2 presents the results of this comparison.

The second method used to compare the alternatives was a comparison of the costs (retrieval implementation as well as evaporator costs for supporting efficient DST storage of the retrieved waste), schedules (start to finish for the retrieval function only), impacts on near-term DST

[3] Gorman-Rupp Company, Mansfield, Ohio.

storage (storage required to support retrieval and prior to evaporation), and the estimated total cost per cubic foot of waste retrieved to meet a minimum target level of waste retrieval that would ensure attaining the HFFACO retrieval criteria, given measurement and retrieval technology performance uncertainties. For this evaluation, comparable information was presented for the 2003 retrieval campaign. Table 4-3 summarizes the results of this comparison.

Table 4-2. Comparison of Retrieval Alternatives vs. Basic Retrieval Functions. (2 sheets)

Alt.	Retrieval alternatives	Functions					
		Dissolve waste	Breakup waste	Mobilize/move waste in tank	Transport waste out of tank	Transport waste to receiver tank	Minimize waste
A	Raw Water Modified Sluicing (Current Equipment)	N/A	Not very efficient at breaking up remaining agglomerated wastes in SST C-106.	Not very efficient at moving waste in SST C-106 due to location of sluice nozzle with respect to solids residuals. Also, "320" sluicer flow rate makes solids movement difficult due to rapid rise of liquid level in tank (high flow rate).	Satisfactory as long as waste can be moved to the intake of the pump.	Satisfactory.	Not very effective due to the high volume of required raw water to meet objectives. (1,870,000 gal)
B	New Modified Sluicing with New Slurry Pump	N/A	More effective at breaking up waste due to the proximity of the new risers and sluicers to the remaining waste areas.	More effective at moving waste due to the proximity of the new risers and sluicers to the remaining waste areas.	Satisfactory as long as waste can be moved to the intake of the pump.	Satisfactory.	Best of all alternatives at minimizing waste. Minimal raw water usage due to use of recirculated supernatant. May require addition of raw water to remove supernatant. (90,000 gal)
C	Modified Sluicing Followed by New Vacuum Retrieval System	N/A	More effective at breaking up waste due to the location of the new risers and vacuum masts directly over the waste areas.	Very effective at moving waste within the working area of vacuum mast. Not effective at moving waste outside this radius.	Satisfactory.	Satisfactory, however water must be added in the batch vessel to adjust the slurry for pumping to the DST system.	Moderately effective, however high volumes of water are needed to slurry the waste to the DST system. (225,000 gal)

Table 4-2. Comparison of Retrieval Alternatives vs. Basic Retrieval Functions. (2 sheets)

Alt.	Retrieval alternatives	Functions					
		Dissolve waste	Breakup waste	Mobilize/move waste in tank	Transport waste out of tank	Transport waste to receiver tank	Minimize waste
D	Mobile Retrieval System	N/A	Most effective at breaking up waste due to the combination of the tracked vehicle with a blade and the vacuum mast and scarifying nozzles.	Very effective at moving waste in all parts of the tank.	Satisfactory.	Satisfactory, however water must be added in the batch vessel to adjust the slurry for pumping to the DST system.	Moderately effective, however high volumes of water are needed to slurry the waste to the DST system. (175,000 gal)

Notes:

DST = double-shell tank.
N/A = not applicable.
SST = single-shell tank.

Table 4-3. Summary Comparison of Single-Shell Tank C-106 Retrieval Alternatives. (2 sheets)

Retrieval alternatives	Retrieval system cost	Increase in evaporator costs[a]	RPP retrieval and storage life-cycle costs	Actual or estimated volume of waste removed (ft^3)[b]	Cost per unit volume removed (retrieval and storage) ($/$ft^3$)	Near-term DST storage impact (gal)[c]	Duration start to finish (months)
2003 Liquid Pumping/ Modified Sluicing and Acid Dissolution	$21,419,600	$1,000,000	$22,419,600	4,340	$5,170	500,000	9
A - Raw Water Modified Sluicing (Current Equipment)	$1,925,950	$3,740,000	$5,665,950	160	$35,412	1,870,000	12
B - New Modified Sluicing with New Slurry Pump	$5,668,735	$180,000	$5,848,735	160	$36,555	90,000	12

Table 4-3. Summary Comparison of Single-Shell Tank C-106 Retrieval Alternatives. (2 sheets)

Retrieval alternatives	Retrieval system cost	Increase in evaporator costs[a]	RPP retrieval and storage life-cycle costs	Actual or estimated volume of waste removed (ft^3)[b]	Cost per unit volume removed (retrieval and storage) ($/$ft^3$)	Near-term DST storage impact (gal)[c]	Duration start to finish (months)
C - Modified Sluicing Followed by New Vacuum Retrieval System	$10,171,593	$450,000	$10,621,593	160	$66,385	225,000	16
D - Mobile Retrieval System	$13,131,774	$350,000	$13,481,774	160	$84,261	175,000	18

Notes:

[a] Based on DOE/ORP-11242, system plan projects processing 28 million gal (FY 2004-FY 2011) and baseline for same period assigns $51 million for evaporator operations. $51/28 gal = ~$2.00/gal.

[b] For the additional retrieval alternatives waste removal was assumed at 160 ft^3.

[c] DST storage required during and following retrieval and prior to evaporation.

DST = double-shell tank.
RPP = River Protection Project.

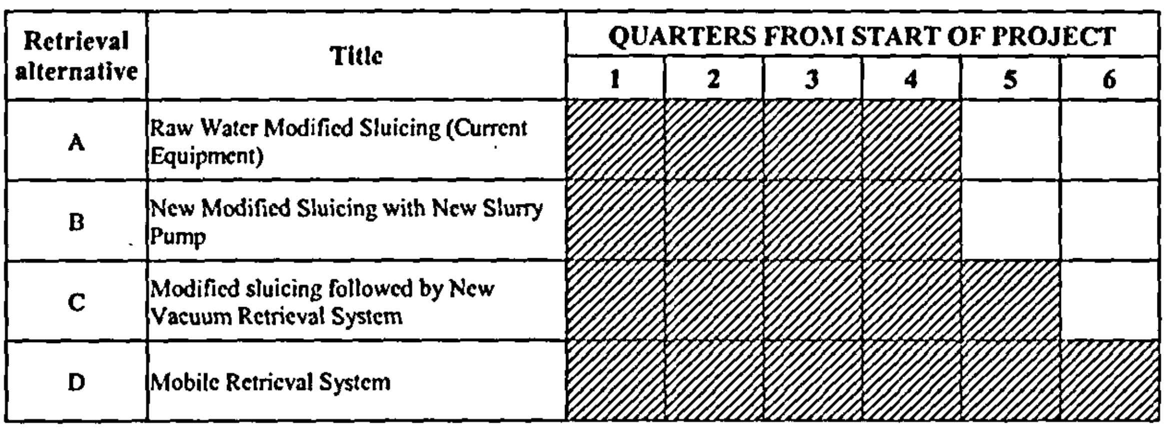
DOE/ORP-11242, 2003, *River Protection Project System Plan*, Rev. 2, U.S. Department of Energy, Office of River Protection, Richland, Washington.

The final method used to compare the alternatives was a value engineering process which is summarized below with supporting information presented in Appendix F.

- **Cost** - Costs include the up-front design, procurement, construction, and operation costs as well as the costs from additional volume to the evaporator. The costs are summarized in Table 4-3 and provided in detail in Appendix C. The costs ranged from $5.7 million for Alternative A to $13.5 million for Alternative D. The cost is a conservative estimate of the potential costs associated with each alternative. Costs not included in the estimate include costs associated with decontamination and decommissioning and/or disposal of equipment used under each alternative and the cost of treatment and disposal of the retrieved waste.

- **Schedule** - Figure 4-1 shows the schedules for each alternative. Alternatives A and B could be completed in the shortest amount of time, 12 months. Alternative D would require the most time due to the complexity of installing new risers and the ITV. This is approximately the same time frame for the SSTs T-110 and T-111 waste retrievals (MRS deployments). The first deployment of MRS will go through more rigorous readiness and startup activities which will take more time.

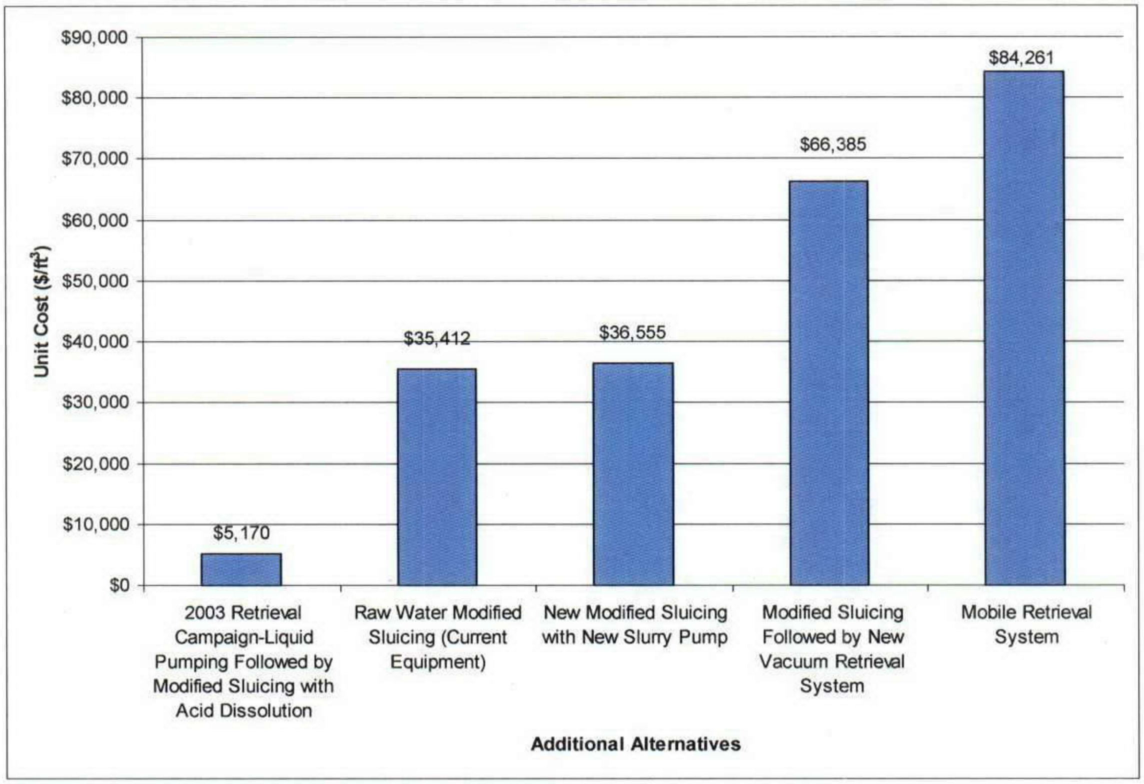
Figure 4-1. Single-Shell Tank 241-C-106 Retrieval Alternative Schedule Comparison.



Note: Schedule duration is for retrieval activities. Characterization and assessment durations not included.

- **Cost Per Cubic Foot of Waste Volume Removed During Retrieval by Alternative** – Table 4-3 presents the RPP retrieval and storage total costs by alternative presented as well as the targeted volume of waste removal estimated for the additional retrieval technology alternatives. The table also presents comparable data for the 2003 retrieval campaign, including the costs and volume of waste removed associated with liquid pumping and deployment of modified sluicing and acid dissolution. Based on the data in Table 4-3, Figure 4-2 illustrates the comparison of the cost per cubic foot of waste removed for the alternatives evaluated in this document as well as the 2003 retrieval campaign. The 2003 retrieval campaign costs approximately $5,170/ft^3 of waste retrieved from SST C-106. The cost per cubic foot of waste retrieved for the four additional evaluated alternatives would range from $35,000/ft^3 to $84,000/ft^3. These costs per unit of waste removed are a factor of 100 to 280 times greater than experienced for the 2003 retrieval campaign.

Figure 4-2. Comparison of the Cost per Cubic Foot of Waste Retrieval between the 2003 Retrieval Campaign and the Additional Retrieval Technology Alternatives.



In addition to comparing the alternatives to satisfy identified retrieval functions and the relative costs and schedule to implement, a relative comparison of the alternatives was completed using value engineering tools including paired comparison analysis and a rated criteria analysis (Appendix F). For the purpose of the comparisons, the four alternatives identified above and a no-action alternative were considered. The no-action alternative assumed no further waste retrieval activities were initiated for SST C-106.

Paired comparison analysis is particularly beneficial in establishing priorities when there are conflicting demands (e.g., cost versus schedule) on limited resources. The paired comparison analysis aided in establishing the relative importance of the following evaluation criteria:

- **Cost of the Alternative.** This criterion includes all life-cycle facets of the alternative. A higher value means the total cost for installing, operating, and demobilizing the particular technology is less than other technologies that are being considered. A higher value also means that the total estimated cost contains a higher level of confidence for completing within the indicated estimate at completion.

- **Schedule for the Alternative.** This criterion includes all life-cycle facets of the alternative. A higher value means the total duration for installing, operating, and demobilizing the particular technology is shorter than other technologies that are being considered and that the schedule contains a higher level of confidence for achieving the scheduled end date.

- **Risk to Workers for the Alternative.** This criterion includes ALARA considerations for both industrial (structural, chemical, electrical, etc.) and radiological safety and health. A higher value means lower risk to the worker for implementing that particular technology.

- **Ease of Implementation for the Alternative.** This criterion refers to the level of difficulty that each alternative may include when installing, operating, and demobilizing equipment, instruments, etc. It also includes the level of project and technical risk associated with implementation. A higher value means comparatively less difficulty for implementing and less risk for that particular alternative.

- **The Risks to the Public or Non-Occupational Personnel for the Alternative.** Usually this criterion includes near-term or long-term releases to the air or surrounding soils that account for the potential risk to the environment. A higher value means comparatively lower risk to the public for that particular alternative.

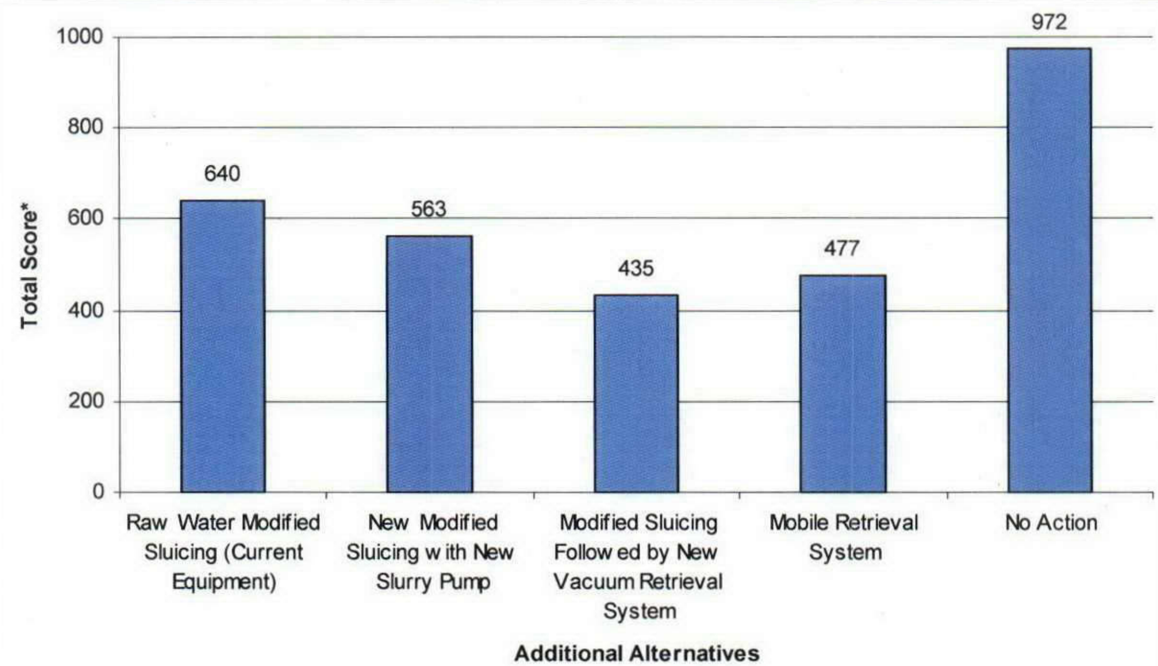
- **Impacts of each Alternative to the RPP Mission.** This criterion assesses the potential for each alternative to divert or delay other activities or programs that would otherwise be completed. A higher value means comparatively lower impacts for that particular alternative.

Appendix F contains the results of the paired comparison analysis.

The comparison established that of the above listed six criteria, minimizing risk to workers and risk to human health and the environment were the dominant criteria (53 and 28, respectively, out of a total potential base score of 100). The remaining four criteria were scored between 2 and 7 out of a total potential base score of 100. Using the weighed evaluation criteria, the subject matter experts then used an independent scoring process to complete a rated criteria analysis (based on the Kepner-Tregoe method described in the *New Rational Manager*) of the four retrieval alternatives and a no-action case. Each alternative was ranked on a scale of 1 to 10 for each of the six criteria (10 representing the highest score and 1 the lowest). The basis for the assignment of the ranked score for each alternative by each criterion is provided in Appendix F. After each alternative was ranked against each of the criteria the rank score was then multiplied by the weighing assigned to the criteria under the paired comparison and the scores were tallied to derive a relative ranking of the alternatives. The ranking and weighing is only directly pertinent to decisions on SST C-106 waste retrieval.

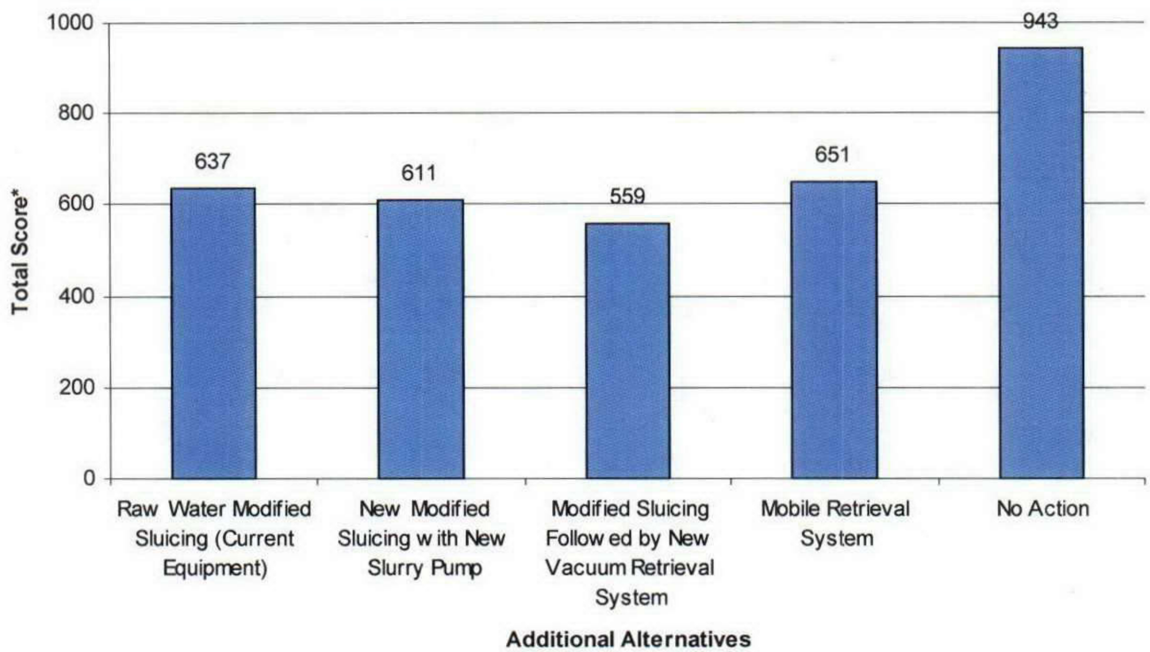
Figure 4-3 represents the results of the two-step analysis. The analysis determined that the highest ranked alternative based on the six evaluation criteria would be to take no further action for SST C-106 waste retrieval. This result was largely driven by the relatively higher risk to workers of all of the other alternatives compared to no action and the relatively minimal levels of human health and environmental risk reduction for Alternatives A through D compared to no action. To test the sensitivity of the analysis to a change in the relative weighting of the dominant criteria (worker risk and human health and environmental risk) the weighting of these criteria were reversed (53 for human health and environment and 28 for worker risk). Figure 4-4 illustrates the overall relative ranking of the alternatives remained unchanged. Taking no further action remained the highest ranked alternative. However, Alternative D replaced Alternative A as the second ranked alternative. Other than changing the comparative ranking of the four retrieval alternatives the other major difference between the results documented in Figures 4-3 and 4-4 were that differences in total scopes between all of the retrieval alternatives was significantly diminished.

Figure 4-3. Relative Comparison of Single-Shell Tank C-106 Additional Retrieval Alternatives.



*The total score for each alternative reflects a composite of the comparative ranking and w eighted scoring of the six criteria. A higher score reflects a comparatively better ranking against the criteria and provides a relative understanding of the alternatives compared to each other.

Figure 4-4. Sensitively Case Results for the Comparison of Single-Shell Tank C-106 Retrieval Alternatives.



*The total score for each alternative reflects a composite of the comparative ranking and w eighted scoring of the six criteria. A higher score reflects a comparatively better ranking against the criteria and provides a relative understanding of the alternatives compared to each other.

4.3 POTENTIAL FUTURE RETRIEVAL TECHNOLOGIES

This section describes waste retrieval technologies that are not currently available for deployment in the Hanford Site tank farms. The technologies discussed in this section were identified, in part, based on their assumed potential to remove some or all of the residual waste in SST C-106. Removal of all waste or a significant portion of the waste may require deployment of multiple technologies. The technologies discussed below are at varying stages of technology development with some requiring substantial investment in research and development while others have been deployed elsewhere and would need to be adapted for deployment at the Hanford Site. None of the technologies discussed in this section are currently planned for deployment in support of tank waste retrieval. If one of the technologies were identified for potential use in support of waste retrieval at SST C-106 or any other tank, the schedule for the initial deployment would range from 3 to 5 years depending on the maturity of the technology. Activities that would need to be completed would include engineering, procurement, testing, and construction.

4.3.1 AEA Technology Power Fluidics™

CH2M HILL Hanford Group, Inc. (CH2M HILL) and its predecessor Tank Farm Contractors have been working with AEA Technology Engineering Services (AEAT) over the last several years to evaluate the power fluidic concept for sampling, mixing and pumping tank waste at the Hanford Site. A technology search and evaluation of potential technologies applicable for retrieval of saltcake waste from the Hanford Site SSTs recommended the fluidic mixing and pumping systems, such as developed by AEAT, be considered to demonstrate dissolution retrieval of saltcake waste. It was noted in this evaluation that the fluidic mixing/pumping technology is not only capable of supporting recovery of soluble salt wastes, but is also suited for mobilization and retrieval of insoluble solids (e.g., sludge waste).

Subsequently an evaluation was carried out of the fluidic mixing and pumping for application in the Hanford Site SST Retrieval Program. This evaluation recognized that the AEAT Power Fluidics[4] system had potential application in the retrieval of both soluble and insoluble SST waste. It recommended a deployment configuration in SST S-102 consisting of two pulse-jet mixers and three reverse flow diverter pumps. The configuration was based on a desired constant pumping recovery rate, limited riser availability, riser sizes and location, minimization of unmixed zones/areas, liquid waste minimization, and potential capability to reach the tank closure cleanliness goal of less than 360 ft^3 of residual waste. The technical investigation and evaluation recommended that the system should be mocked up full scale and tested to determine the effective range and cleaning capabilities prior to construction activities at the tank farm. It identified that there was considerable uncertainty whether the system could achieve the cleanliness goal. When the schedule for SST S-102 retrieval was accelerated, it was obvious that the AEAT Power Fluidics system was not yet mature enough to be pursued for field deployment to support the FY 2004 retrieval schedule. The DOE-HQ Office of Science and Technology EM-50, now Cleanup Technologies (EM-21) continued to fund the development and testing of the full scale mockup. In FY 2003, AEAT completed the third phase of development of the AEAT fluidic mixing system for SST waste retrieval. In response to the CH2M HILL's scope of work for design, fabrication and cold testing of a prototype AEAT full scale SST fluidic retrieval system, AEAT designed, fabricated and delivered a full-size prototype retrieval system for testing. That testing was carried out by an AEAT team at the Hanford Site Cold Test Facility in October and November 2003. The tests on the full-size prototype system demonstrated operation of the Power Fluidics for breaking up/dissolving/mobilizing a saltcake stimulant and mobilizing and pumping sludge. The central module was deployed through a 36-in. diameter simulated riser at the Cold Test Facility, and the outboard nozzles capable of full pan and tilt were deployed through simulated 4-in. diameter risers.

The AEAT test report provides an overview of the fluidic equipment, the test simulants, test program, test results, and conclusions and recommendations. The concept and operation of a charge vessel system with multiple wash nozzles was clearly demonstrated. However, the test

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[4] Power Fluidics is a trademark of AEA Technology Engineering Services, Pittsburgh, Pennsylvania.

objectives were not fully demonstrated: (1) the minimum reverse flow diverter (i.e., pump) intake distance from the floor was not determined and (2) the minimum effective cleaning radius (where sludge or solids could no longer be mobilized) was not determined. It was not fully demonstrated that the system was able to effectively mobilize and transfer solids (salt or sludge). Additional testing would be needed to determine the minimum residual volume of a particular kind of waste that could be expected to remain ("limits of technology"). The technical approach for getting waste moved to the vicinity of the pump was with the three out-board sluicing nozzles, similar to the two nozzle approach employed in the latter stages of SST C-106 retrieval. Outside of the tank equipment was not configured for field deployment. Any further testing would need to be done with the final configuration intended for deployment in the tank farms.

Another application of this technology in conjunction with sludge retrieval would be to operate the unit as a sludge mixer to suspend solids. The waste would then be retrieved by pumping using the same equipment operating in the mode of the unit as tested at the Cold Test Facility when pumping sludge. Alternately, the mixer could be used in conjunction with a retrieval pump, such as used in SST C-106, or as used at Oak Ridge in the Bethel Valley Evaporator Service Tanks or in the testing done with the Russian pulsating mixer pump described below.

AEAT also provided fluidic pulse jet mixers for use in the five 50,000-gal Bethel Valley Evaporator Service Tanks. They also provided a unit for use in a 55,000-gal horizontal tank at Oak Ridge with a capital cost reported at $550K (DOE/EM-0622, Innovative Technology Summary Report *Russian Pulsating Mixer Pump*).

4.3.2 Russian Pulsatile Mixer Pumps/Fluidic Retrieval Systems

CH2M HILL worked with the Russian Integrated Mining and Chemical Combine organization at Zheleznogorsk in conjunction with the American Russian Environmental Services Inc., over the last several years to evaluate their fluidic concept for mixing and pumping tank waste at the Hanford Site. The system is generally similar to the AEAT system, but has design details different for the pump mechanism and nozzles. While the AEAT has no moving parts in the pump, the Russian unit employs a simple check valve mechanism. Both systems use two distinct cycles, fill and discharge, to perform mixing action. More detailed technical descriptions of the Russian pulsatile mixer pump, the testing program which also involved Battelle Pacific Northwest Division, and initial results of the deployment in one of the Gunite and Associated Tanks at Oak Ridge National Laboratory to mobilize settled solids are provided in *Russian Pulsating Mixer Pump Deployment in the Gunite and Associated Tanks at ORNL* (Hatchell et al. 2001). The design and fabrication of the pulsatile mixer pump occurred in a Russian facility that does not work to U.S. standards, so full compliance with U.S. standards was not achieved. The alliance with American Russian Environmental Services Inc., is intended to allow fabrication in the United States to U.S. standards in the future. The pump was capable of being deployed through a 22.5-in. diameter opening.

The Russian pulsating mixer pump, a reciprocating, air-operated mixer was deployed in January 2001 at the Oak Ridge Site in Tank TH-4 to mobilize a 2.5-in. layer of sludge; the waste was pumped out using an air-powered, double-diaphragm pump and left a residual heel 4 in.

deep (1,100 gal) near the outer walls of the 20-ft diameter tank with 6.5-ft vertical sidewalls and a 14,000 gal capacity. The cleaning radius was 6 to 8 ft. The pumping operation took place over a 3-day period with actual operation time for the mixer pump of 25 hours. The capital cost of the Russian pulsating mixer pump installed at Oak Ridge was $175K. There was no apparent advantage in capital cost, installation, or pump disposal cost provided by the Russian unit compared to Savannah River Site and Hanford Site costs. It may have a lower operating cost, and therefore a lower long-term replacement cost. The same report stated that testing of the Russian mixer in a larger-diameter tank needed to be done (DOE/EM-0622).

A third generation pulsating mixer/sluicer with a dual nozzle design was developed and has been tested with nonradioactive simulants in 2001 and 2002. A fourth generation dual nozzle pulsating mixer/sluicer underwent cold testing has been developed for use at the Mining and Chemical Combine nuclear facility in Zhelznogorsk, Russia, to retrieve radioactive sludge from the bottom of their 12-m diameter by 30-m high nuclear waste tanks. The large-scale simulant tests of the concept for retrieving tank waste at the Hanford Site have been observed in Russia by Hanford Site staff in 2002. This unit can be deployed through a 12-in. diameter riser, and is designed to operate with a minimum amount of liquid (15 cm is expected to be feasible) (Gibbons et al. 2002). This year (2004), the Russians are in the process of retrieving one of their large waste tanks using this technology. CH2M HILL has requested that DOE-HQ EM-21 fund this technology to provide a lessons-learned report following completion of that retrieval. That request is under consideration.

4.3.3 Small Mobile Retrieval Vehicles

- **Remotely Operated Vehicle Systems at Oak Ridge** - In the 1996-1998 time frame the team at Oak Ridge National Laboratory deployed a series of hydraulically powered, remotely operated vehicles. The first two were known as Houdini[5] vehicles supplied by RedZone Robotics, Inc. Improvements were targeted at two main areas: reliability and maintainability. The main redesign focused on improving the ergonomics on the tether management and deployment system and modifying many of the electrical and plumbing features of the vehicle. The frame was a 4 ft by 5 ft parallelogram style frame, folding to enable it to deploy through a 24-in. tank riser. It operated over 80 hours, over several weeks, and took five samples. There were many hardware failures requiring repair or replacement. It was used later in other tanks in conjunction with a wall-washing tool (the linear scarifying end-effector), the confined sluicing end-effector, and the Modified Light Duty Utility Arm[6] (MLDUA). Many lessons learned are documented (ORNL/TM-2001/142/V1, *The Gunite and Associated Tanks Remediation Project Tank Waste Retrieval Performance and Lessons Learned* and Vesco et al. 2001, *Lessons Learned and*

[5] Houdini is a trademark of RedZone Robotics, Inc., Pittsburgh, Pennsylvania.

[6] Modified Light Duty Utility Arm is a trademark of SPAR Aerospace, Ltd.

Final Report for Houdini® Vehicle Remote Operations at Oak Ridge National Laboratory).

- **Scarab III**[7] - Many features of these vehicles can be found in the unit currently developed at the Hanford Site for use in SSTs. The Scarab III vehicles four rubber-treaded wheels for traction on slick surfaces and four metal wheels for biting into thin layers of waste. The Scarab can climb over 8-in. obstacles and has a manipulator arm to grasp the sample collection device and maneuver it to collect the sample. The manipulator gripper end-effector had a payload limit of 5 lb. It requires an 18-in. diameter access. There were three on-board cameras for viewing deployment, retrieval, and driving operations. The unit was operated a total of about 8 hours over 3 days and retrieved nine samples from material varying in consistency from "...red clay to crusty concrete to chocolate ice cream..."(DOE/EM-0587, Innovative Technology Summary Report *Remotely Operated Vehicle (ROV) System for Horizontal Tanks*)

- **TMR Associates VAC TRAX**[8] - The VAC TRAX is a remote-operated rotating high-pressure water jetting tool that directs ultra high-pressure water to remove material coverings from a variety of surfaces; for example contaminated paint from concrete walls and floors. At higher pressures the VAC TRAX is capable of light scabbling or deep scarification of concrete surfaces. The VAC TRAX is fully encapsulated with the water and debris vacuumed from the manifold of the VAC TRAX through a flexible vacuum hose (TMR Associates, 2004, website: http://tmrassociates.org/vac_trax.htm). This unit was used at Rocky Flats for cleaning floors, walls, and ceilings of a heavily plutonium-contaminated hot cell. With a different end-effector it was used for taking a core of the concrete floor of the hot cell to determine the depth of plutonium contamination. Numatec Hanford, working with Fluor Hanford in FY 2003, employed TMR Associates to bring their equipment and crew to decontaminate the 222-S Laboratory as preparation for dismantling the building. The system supplies water up to 36,000 psi through a rotating manifold containing orifices to produce a concentrated stream. The vacuum is applied to the VAC TRAX shroud sufficient to hold the weight of the machine. Very little volume is on the surface at any time, the unit seems to be moving with no water visible around the limited area of the shroud (e.g., 9-in. diameter cleaning path).

4.3.4 Tank Wall Washing at West Valley Demonstration Project

During the early stage of waste retrieval at the West Valley Demonstration Project the retrieval process was very efficient. As the removal of the contents moved from bulk removal to heel and

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[7] Scarab III is a trademark of R.O.V. Technologies, Inc., Vernon, Vermont.

[8] VAC TRAX is a registered trademark of TMR Associates, Rutherford, New Jersey.

residue retrieval, the number of transfers and associated time per transfer climbed steadily. (Hamel and Damerow 2001, *Completing HLW Vitrification at the WVDP; The Approach to Final Retrieval, Flushing, and Characterization*). Tethered robotics were evaluated, but not used for retrieval of the waste or characterization because of the many obstructions in the tank. Riser-mounted arms and positioning systems were developed to provide the capability to wash residues from the tanks' internal surfaces. Oxalic acid or mixed organic acids were not used because of concerns with the carbon steel tank integrity.

4.3.5 Dry Ice Blasting

Decontaminating surfaces using dry ice blasting is a relatively new cleaning process using solid CO_2 pellets. The pellets sublimate (convert directly from a solid blast pellet to a vapor) leaving no residue. This is envisioned as a sand-less sandblasting approach to dislodge hard to remove residue from the tank surfaces. The dry ice is accelerated by compressed air and requires between 80 to 100 psi and 120 to 150 cfm (Lapointe 2004, *Sand-less Sandblasting*). The EPA, on their fact sheet for alternatives to trichloroethane, identified dry ice blasting with solid pellets as a desirable alternate for cleaning metal surfaces (EPA 2000, *Technical Fact Sheet for 1,1,1-Trichloroethane (TCA) Hazards and Alternatives*).

4.3.6 Modified Light-Duty Utility Arm at Oak Ridge

Concise reviews are available describing the MLDUA, a custom long-reach manipulator system developed, designed, and built by SPAR Aerospace, Ltd., the same organization that provided the long-reach manipulator system used on the NASA Space Shuttle program (Glassell et al. 2001, *System Review of the Modified Light Duty Utility Arm after the Completion of the Nuclear Waste Removal from Seven Underground Storage Tanks at Oak Ridge National Laboratory*; DOE/EM-0406, Innovative Technology Summary Report *Light Duty Utility Arm*). The earlier version of the arm, the Light Duty Utility Arm (LDUA) had a horizontal reach of 13.5 ft, a vertical reach of 50 ft below grade, and a payload of 50 lb. The MLDUA had the same vertical reach, a slightly larger horizontal reach of 15 ft and, most importantly, an increased payload of 200 lb. The LDUA was used at Idaho National Engineering and Environmental Laboratory for gathering samples of waste heel materials in their smaller tanks. The MLDUA was used at Oak Ridge for the cleanup of seven underground tanks, either 25 ft or 50 ft in diameter. The MLDUA performed the following operations in support of the underground tank waste cleanup operations:

- Grasping the sluicer to allow deployment of the hose management arm into the tanks
- Holding and maneuvering the sluicer to remove tank waste and waste material
- Tank wall radiation surveys
- Tank wall material sample collection
- Tank wall cleaning operations with high-pressure water jets
- Vertical pipe cutting operations
- Pipe plugging operations
- Support for tank wall coring operations.

However, the MLDUA had some problems. Many lessons were learned in both manipulator operations within the tank and manipulator design. These lessons have not been incorporated into any subsequent versions to date.

4.4 CONCLUSIONS

The comparative evaluations of waste retrieval technologies which are currently available for deployment in support of additional waste retrieval from SST C-106 establish that:

- All the alternatives are potentially capable of attaining additional retrieval of residual waste remaining in the tank. However, the paired comparison analysis evaluated the dynamics and the trade-offs between competing goals of protecting the environment, worker safety, cost, schedule, ease of implementation and confidence in technical success, and the impacts to DST space and other opportunity costs that would affect the long-term mission to clean up the site. The two top priorities were worker safety and protecting the environment and in either case the highest ranked alternative was to conduct no further retrieval of residual waste from SST C-106.

- The schedule for deployment and completion of waste retrieval for the alternatives range from 12 months (Alternative A) to 18 months (Alternative D). The estimated schedules do not include durations or the schedule associated with decontamination and decommissioning and/or disposal of equipment used under each alternative.

- The cost of the alternatives range from \$5.7 to \$13.5 million. Generally, those alternatives relying on current equipment and with the least likelihood of success would cost less with estimates ranging from \$5.7 to \$5.9 million. Alternatives using new equipment and with a greater likelihood of success would cost more with estimates ranging from \$10.6 to \$13.5 million. The estimated costs do not include costs associated with decontamination and decommissioning and/or disposal of equipment used under each alternative or the cost of treatment and disposal of retrieved waste.

- The 2003 retrieval campaign costs approximately \$5,170/ft^3 of waste retrieved from SST C-106. The cost per cubic foot of waste retrieved for the four additional evaluated alternatives would range from \$35,000/ft^3 to \$84,000ft^3 or a factor of 100 to 280 times greater than experienced for the 2003 retrieval campaign.

- Deployment of a new retrieval technology resulting in a reduction in residual waste volume from the current estimate of 467 ft^3 (sludge and liquids) to the HFFACO criteria of 360 ft^3 would result in a nominal reduction in the ILCR under the industrial worker scenario from an ILCR of 2.48×10^{-8} to 1.97×10^{-8}. The risk contribution of the residual waste in SST C-106 to the cumulative risk of WMA C would be reduced from approximately 2.58% of the total risk to 2.05%. Deployment of a new waste retrieval technology that would reduce the volume of residual waste to 200 ft^3 (a 56% reduction in total volume) would result in an insignificant reduction in the human health risks associated with SST C-106 residual waste or the overall human health risks associated with WMA C (see Section 3.3).

Significant uncertainty exits regarding the effectiveness of evolving technology discussed in Section 4.3 to remove the residual waste to HFFACO retrieval criteria. The potential technologies identified are at varying stages of development with some requiring substantial investment in research and development while others have been deployed elsewhere and would need to be adapted for deployment at the Hanford Site. None of the technologies are currently planned for deployment in support of tank waste retrieval.

If one of the technologies were identified for potential use in support of waste retrieval at SST C-106 or any other tank, the schedule for the initial deployment would range from 3 to 5 years depending on the maturity of the technology (TWR-4454, *Alternatives Generation and Analysis C-104 Single-Shell Tanks Waste Feed Delivery*). Activities that would need to be completed include engineering, procurement, testing, and construction. Without further evaluation it is not possible to estimate the cost for research and development of the potential waste retrieval technologies or to determine if a single or combination of technologies would be required to attain the retrieval criteria.

5.0 REFERENCES

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APPENDIX A

SINGLE-SHELL TANK 241-C-106 RESIDUAL WASTE INVENTORY ESTIMATES FOR TANK COMPONENT CLOSURE ACTION RISK ASSESSMENT

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RPP-20699
Revision 0

TANK 241-C-106 RESIDUAL WASTE INVENTORY ESTIMATES FOR TANK COMPONENT CLOSURE ACTION RISK ASSESSMENT

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ANOVA	Analysis of variance
BBI	Best-basis inventory
Ci	Curies
ft^3	Cubic feet
g/mL	Grams per milliliter
Kg	Kilogram
UCL	Upper confidence level

TANK 241-C-106 RESIDUAL WASTE INVENTORY ESTIMATES FOR TANK COMPONENT CLOSURE ACTION RISK ASSESSMENT

1.0 INTRODUCTION

In fiscal years 2003 and 2004, most of the waste in tank 241-C-106 was retrieved to the double-shell tank (DST) system, leaving behind a small amount of residual liquid and sludge. Inventories of constituents-of-concern in the residual waste are needed to support component closure activities for the tank. The inventories were computed from residual waste characterization data and residual liquid and sludge volume estimates. Waste characterization requirements are identified and technical basis provided in RPP-13889, *Tank 241-C-106 Component Closure Action Data Quality Objectives*. Direction for sampling and laboratory analysis to implement the data quality objectives is provided in RPP-18375, *Liquid Grab Sampling and Analysis Plan for Tank 241-C-106 Component Closure Action* and RPP-18376, *Solids Grab Sampling and Analysis Plan for Tank 241-C-106 Component Closure Action*.

Analytical results of liquid and sludge samples are reported in RPP-20226, *Analytical Results for Liquid Grab Sampling and Analysis Plan for Tank 241-C-106 Component Closure Action* and RPP-20264, *Analytical Results for Tank 241-C-106 Solid Clamshell Samples Supporting Closure Action*, respectively. Volumes of the residual liquid and sludge in the tank are estimated in RPP-19866, *Calculation for the Post-Retrieval Waste Volume Determination for Tank 241-C-106*. Data and information in these reports were used to compute the inventories of constituents-of-concern in the residual liquid and sludge. Specifically, the inventories will be used in risk assessment calculations in support of the tank component closure actions.

2.0 CALCULATION OF RESIDUAL WASTE INVENTORIES

The residual liquid and sludge waste inventories were computed by following the best-basis inventory process as described in RPP-7625, *Best Basis Inventory Process Requirements*. A review of the analytical data was conducted to evaluate suitability of the data for inventory computation. The data review followed the internal procedure TFC-ENG-CHEM-D-32, "Review and Resolution of TWINS Data." At the request of Tank Closure Planning, inventories were computed for three cases: Case 1 - Nominal Inventories, Case 2 – Inventories Based on the 95% Upper Confidence Level (UCL) for Volume, and Case 3 - Overall 95% Upper Confidence Levels. Inventories of constituents-of-concern for the three cases were computed as discussed the following sections.

2.1 CASE 1 - NOMINAL INVENTORIES

The nominal inventory for each liquid waste constituent-of-concern was computed by multiplying the mean concentration and the nominal liquid volume (i.e., inventory = concentration x volume). Sludge concentration data were reported on per unit weight basis; therefore, a mean density was used to convert the units of sludge concentration data to per unit volume basis. The nominal inventory of each sludge constituent was calculated by multiplying the mean concentration, mean density, and nominal sludge volume (i.e., inventory = concentration x density x volume). Table 2-1 represents the data used to compute the nominal inventory for tank 241-C-106.

Table 2-1. Information Used in Computation of the Nominal Inventories

Waste Phase	Applicable Concentration Data	Associated Density (g/mL)	Nominal Volume
Supernatant	Mean concentrations based on the 2004 post-retrieval liquid analytical results	Not needed for inventory calculations	11.3 ft^3
Sludge	Mean concentrations based on the 2004 post-retrieval sludge analytical results	Mean density of post-retrieval sludge (1.56)	359 ft^3

Analytical data reported in RPP-20226 and RPP-20264 were used to calculate the mean concentrations for the supernatant and sludge. A nested analysis of variance (ANOVA) model was fit to the laboratory sample data following the data review. Mean concentrations were computed using results from the ANOVA. Two variance components were estimated and used in the computations. The variance components represent concentration differences between laboratory samples and between analytical replicates.

The model is:

$$Y_{ij} = \mu + L_i + A_{ij},$$

$$i=1,2,...,a;\ j=1,2,...,n_i;$$

where

- Y_{ij} = concentration from the j^{th} analytical result from the i^{th} riser,
- μ = the mean,
- L_i = the effect of the i^{th} laboratory sample,
- A_{ij} = the analytical error,
- a = the number of laboratory samples, and
- n_i = the number of analytical results from the i^{th} laboratory sample.

The variable L_i is a random effect. This variable and A_{ij} are assumed to be uncorrelated and normally distributed with means zero and variances $\sigma^2(L)$, and $\sigma^2(A)$, respectively.

The restricted maximum likelihood method (REML) was used to estimate the mean concentration and standard deviation of the mean for all constituents that had 50 percent or more of their reported values greater than the detection limit.

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 was calculated. Mean concentrations and relative standard deviations for liquid and sludge constituents-of-concern are provided in Appendix A. Note that in accordance with best-basis inventory (BBI) protocol, the relative standard deviations for non-detected constituents are assumed to be 1.

Based on the mean concentrations and density calculated as discussed above and volume estimates in RPP-19866, liquid and sludge inventories were determined using S-Plus and EXCEL spreadsheets. The spreadsheets for sludge and supernatant inventories were verified according to the internal procedure TFC-ENG-CHEM-D-33, "Spreadsheet Verification" and documented in spreadsheet verification forms SVF-192 and SVF-193, respectively.

The inventories were computed in accordance with the BBI creation rules documented in RPP-7625, *Best-Basis Inventory Process Requirements*, with the following exceptions:

- Inventories were generated only for constituents identified in the data quality objectives (RPP-13889). Inventories for BBI analytes that are not included in the data quality objectives were not computed.

- Inventories of radionuclides were calculated using as-reported concentrations (All analyses were performed in January and February 2004). That is they were not decay-corrected to January 1, 2001.

- The plutonium and curium isotopes were calculated from the $^{239/240}$Pu, ^{241}Am, and $^{243/244}$Cm analytical results, using process knowledge of the isotopic distributions ratios of tank 241-C-106.

- Thorium 228 was not analyzed because the laboratory did not have the appropriate analytical method. Inventory of this radionuclide was estimated from radioactive decay of ^{232}Th and ^{232}U. Based on the decay chain and radioactive half-lives of the daughter products, ^{228}Th activities due to ^{232}Th and ^{232}U decay are approximately equal to the activities of these radionuclides. Thorium-232 was analyzed; ^{232}U activity was estimated from isotopic distribution of total uranium concentration.

- Hexachloroethane and 1,2,4-trichlorobenzene were analyzed by both volatile organic analysis and semi-volatile organic analysis methods. These constituents were not detected in the waste samples. Volatile organic analysis is much more sensitive for these compounds than semi-volatile organic analysis. Therefore, only volatile organic analysis results were used in the inventory estimates.

- Inventories of radionuclides analyzed by inductively coupled plasma/mass spectrometry were not converted to curies.
- Inventories calculated based on detection limits are not specifically identified.

Table 2-2 provides the nominal inventories of constituents-of-concerns in the tank 241-C-106 residual liquid and sludge.

Table 2-2. Liquid and Sludge Inventories -Nominal Case

Constituent	Inventory Unit	Liquid Inventory	Sludge Inventory
1,1,1-Trichloroethane	Kg	1.92E-07	1.15E-04
1,1,2,2-Tetrachloroethane	Kg	2.75E-07	8.42E-05
1,1,2-Trichloro-1,2,2-trifluoroethane	Kg	5.44E-07	1.29E-04
1,1,2-Trichloroethane	Kg	1.73E-07	8.42E-05
1,1-Dichloroethene	Kg	3.49E-07	1.36E-04
1,2,4-Trichlorobenzene	Kg	4.16E-07	1.29E-04
1,2-Dichlorobenzene	Kg	3.84E-05	2.15E-02
1,2-Dichloroethane	Kg	1.73E-07	8.32E-05
1,4-Dichlorobenzene	Kg	3.20E-05	2.07E-02
1-Butanol	Kg	1.86E-04	2.15E-02
2,4,5-Trichlorophenol	Kg	9.60E-05	1.10E-02
2,4,6-Trichlorophenol	Kg	9.28E-05	1.16E-02
2,4-Dinitrotoluene	Kg	4.16E-05	1.50E-02
2,6-Bis(1,1-dimethylethyl)-4-methylphenol	Kg	5.44E-05	1.45E-02
2-Butanone	Kg	6.12E-06	4.42E-04
2-Chlorophenol	Kg	8.64E-05	2.07E-02
2-Ethoxyethanol	Kg	4.16E-05	1.13E-02
2-Methylphenol	Kg	8.96E-05	4.05E-02
2-Nitrophenol	Kg	8.32E-05	2.46E-02
2-Nitropropane	Kg	6.72E-07	2.01E-04
4-Chloro-3-methylphenol	Kg	1.02E-04	7.55E-03
4-Nitrophenol	Kg	9.92E-05	1.13E-02
Acenaphthene	Kg	5.12E-05	2.38E-02
Acetate	Kg	1.48E-02	3.53E+01
Acetone	Kg	2.34E-05	1.28E-03
Actinium-228	Ci	3.68E-05	7.78E+01
Aluminum	Kg	3.00E-02	3.83E+02
Americium-241	Ci	1.34E-06	6.53E+01
Ammonium Ion by IC	Kg	3.15E-03	9.66E-01
Antimony	Kg	2.18E-04	1.19E+00
Antimony-125	Ci	2.07E-04	6.34E+01
Arsenic	Kg	2.90E-04	2.89E+00
Barium	Kg	1.15E-05	1.64E+00

Table 2-2. Liquid and Sludge Inventories -Nominal Case

Constituent	Inventory Unit	Liquid Inventory	Sludge Inventory
Benzene	Kg	2.94E-07	8.05E-05
Beryllium	Kg	8.96E-06	5.66E-02
Bismuth	Kg	5.50E-04	2.94E+00
Boron	Kg	2.16E-04	1.19E+00
Bromide	Kg	1.86E-02	4.45E+01
Butylbenzylphthalate	Kg	2.59E-05	4.21E-03
Cadmium	Kg	3.07E-05	1.44E+00
Calcium	Kg	1.10E-04	1.18E+02
Carbon disulfide	Kg	3.07E-07	1.19E-04
Carbon tetrachloride	Kg	2.82E-07	1.52E-04
Carbon-14	Ci	9.62E-07	8.24E-03
Cerium	Kg	2.82E-04	5.71E+00
Cerium/Praseodymium-144	Ci	3.89E-04	2.76E+02
Cesium-134	Ci	3.19E-05	1.74E+01
Cesium-137	Ci	1.39E-01	1.45E+03
Chloride	Kg	5.63E-03	6.14E+00
Chlorobenzene	Kg	1.73E-07	9.96E-05
Chloroform	Kg	2.11E-07	1.22E-04
Chromium	Kg	2.56E-05	3.79E+00
Cobalt	Kg	6.27E-05	3.76E-01
Cobalt-60	Ci	8.24E-06	1.80E+01
Copper	Kg	2.56E-05	2.31E+00
Cresol	Kg	2.94E-04	5.80E-02
Curium-243/244	Ci	1.34E-06	7.55E+00
Cyanide	Kg	3.04E-05	7.82E-02
Cyclohexanone	Kg	2.43E-05	3.44E-02
Di-n-butylphthalate	Kg	4.48E-05	4.21E-03
Di-n-octylphthalate	Kg	6.72E-05	2.38E-02
Ethyl acetate	Kg	1.86E-07	1.26E-04
Ethyl ether	Kg	2.50E-07	1.13E-04
Ethylbenzene	Kg	5.12E-07	2.01E-04
Europium	Kg	1.54E-05	6.23E-01
Europium-152	Ci	7.18E-05	6.27E+01
Europium-154	Ci	2.44E-05	8.13E+01
Europium-155	Ci	5.27E-05	7.80E+01
Fluoranthene	Kg	6.72E-05	1.43E-02
Fluoride	Kg	1.93E-03	5.42E-01
Formate	Kg	1.48E-02	3.53E+01
Glycolate	Kg	1.22E-02	2.92E+01
Hexachlorobutadiene	Kg	3.84E-05	5.27E-03
Hexachloroethane	Kg	3.52E-07	7.57E-05
Hexone	Kg	2.18E-07	1.73E-04
Hydroxide (free)	Kg	2.25E+00	Not measured
Iodine-129	Ci	4.25E-07	6.31E-04
Iron	Kg	2.94E-05	2.07E+02
Isobutanol	Kg	2.11E-04	2.86E-02
Lanthanum	Kg	3.20E-05	2.45E+00
Lead	Kg	3.33E-04	2.57E+01
Lithium	Kg	1.79E-05	1.13E-01

Table 2-2. Liquid and Sludge Inventories -Nominal Case

Constituent	Inventory Unit	Liquid Inventory	Sludge Inventory
Magnesium	Kg	3.33E-04	7.11E+00
Manganese	Kg	1.31E-05	5.50E+02
m-Cresol	Kg	1.98E-04	9.22E-02
Mercury	Kg	9.65E-07	1.93E+00
Methylenechloride	Kg	2.88E-07	9.85E-05
Molybdenum	Kg	4.48E-05	3.06E-01
Morpholine, 4-nitroso-	Kg	8.00E-05	1.19E-02
Naphthalene	Kg	3.84E-05	9.56E-03
Neodymium	Kg	1.28E-04	9.02E+00
Neptunium-237	Kg	8.44E-08	7.69E-02
Nickel	Kg	7.29E-05	3.02E+01
Nickel-63	Ci	2.32E-06	7.30E+01
Niobium	Kg	6.40E-04	4.24E+00
Niobium-94	Ci	8.37E-06	1.88E+01
Nitrate	Kg	1.93E-02	4.61E+01
Nitrite	Kg	1.74E-02	4.15E+01
Nitrobenzene	Kg	3.10E-05	1.00E-02
N-Nitroso-di-n-propylamine	Kg	8.32E-05	1.35E-02
Oxalate	Kg	3.92E-01	3.32E+02
Palladium	Kg	9.85E-04	7.07E+00
Pentachlorophenol	Kg	7.36E-05	1.03E-02
Phenol	Kg	8.64E-05	4.71E-02
Phosphate	Kg	3.03E-02	4.15E+01
Phosphorus	Kg	1.09E-02	2.94E+01
Plutonium-238	Ci	1.72E-06	2.71E+00
Plutonium-239/240	Ci	1.57E-06	2.04E+01
Potassium	Kg	4.48E-03	1.77E+01
Praseodymium	Kg	1.79E-04	5.40E+00
Pyrene	Kg	5.12E-05	2.30E-02
Pyridine	Kg	4.48E-05	1.44E-02
Radium-226	Ci	8.71E-04	4.17E+02
Rhodium	Kg	3.84E-04	2.45E+00
Rubidium	Kg	7.17E-03	2.41E+01
Ruthenium	Kg	2.29E-04	2.41E+00
Ruthenium/Rhodium-106	Ci	6.38E-04	3.37E+02
Samarium	Kg	1.41E-04	2.51E+00
Selenium	Kg	4.22E-04	2.94E+00
Selenium-79	Ci	1.02E-06	9.59E-03
Silicon	Kg	4.82E-03	1.60E+01
Silver	Kg	3.07E-05	7.85E+00
Sodium	Kg	3.13E+00	1.86E+02
Strontium	Kg	3.01E-06	1.83E+00
Strontium-89/90	Ci	1.41E-02	6.61E+04
Sulfate	Kg	2.06E-02	4.92E+01
Sulfide	Kg	2.02E-03	1.35E-01
Sulfur	Kg	1.60E-03	1.30E+00
Tantalum	Kg	2.69E-04	2.41E+00
Technetium-99	Kg	2.01E-07	9.71E-03

Table 2-2. Liquid and Sludge Inventories -Nominal Case

Constituent	Inventory Unit	Liquid Inventory	Sludge Inventory
Tellurium	Kg	5.50E-04	2.41E+00
Tetrachloroethene	Kg	1.98E-07	1.06E-04
Thallium	Kg	3.60E-04	7.07E+00
Thorium	Kg	1.41E-04	3.12E+00
Thorium-230	Kg	2.24E-09	4.64E-05
Thorium-232	Kg	1.00E-07	5.10E+00
Tin	Kg	8.96E-04	2.41E+00
Titanium	Kg	7.68E-06	3.86E-01
Toluene	Kg	2.75E-07	9.48E-05
Trans-1,3-Dichloropropene	Kg	2.05E-07	8.21E-05
Trichloroethene	Kg	4.48E-07	1.62E-04
Trichlorofluoromethane	Kg	2.43E-07	1.20E-04
Tritium	Ci	1.09E-06	1.02E-02
Tungsten	Kg	1.66E-02	4.72E+00
Uranium	Kg	4.80E-04	2.94E+00
Uranium-233	Kg	5.53E-09	1.89E-04
Uranium-234	Kg	1.57E-08	1.52E-04
Uranium-235	Kg	1.86E-06	1.79E-02
Uranium-236	Kg	2.56E-08	2.68E-04
Uranium-238	Kg	2.81E-04	2.69E+00
Vanadium	Kg	3.33E-05	2.94E-01
Vinyl chloride	Kg	2.82E-07	5.77E-05
Xylene (m & p)	Kg	1.73E-06	2.28E-04
Xylene (o)	Kg	2.82E-07	7.15E-05
Xylenes (total)	Kg	1.44E-06	3.02E-04
Yttrium	Kg	6.40E-06	1.70E+00
Zinc	Kg	4.31E-05	2.13E+00
Zirconium	Kg	2.05E-05	2.79E+00
Aroclors (Total PCBs)	Kg	3.20E-07	1.36E-03
Curium-242	Ci	3.24E-09	1.58E-01
Curium-243	Ci	5.37E-08	3.02E-01
Curium-244	Ci	1.29E-06	7.25E+00
Plutonium-239	Ci	1.30E-06	1.68E+01
Plutonium-240	Ci	2.77E-07	3.58E+00
Plutonium-241	Ci	3.07E-06	3.97E+01
Thorium-228	Ci	2.26E-09	5.75E-04

2.2 CASE 2 – INVENTORIES BASED ON MEAN CONCENTRATIONS AND 95% UPPER CONFIDENCE LEVEL FOR VOLUME

In this case, the inventory of each waste constituent was computed based on the mean concentration, mean density (for solids), and the 95% UCL for volumes (14.2 ft^3 for liquid and 452 ft^3 for sludge). Table 2-3 provides the liquid and sludge inventories for this case.

Table 2-3. Liquid and Sludge Inventories –95% Upper Confidence Level for Volume Case

Constituent	Inventory Unit	Liquid Inventory	Sludge Inventory
1,1,1-Trichloroethane	Kg	2.41E-07	1.45E-04
1,1,2,2-Tetrachloroethane	Kg	3.46E-07	1.06E-04
1,1,2-Trichloro-1,2,2-trifluoroethane	Kg	6.83E-07	1.62E-04
1,1,2-Trichloroethane	Kg	2.17E-07	1.06E-04
1,1-Dichloroethene	Kg	4.38E-07	1.71E-04
1,2,4-Trichlorobenzene	Kg	5.23E-07	1.63E-04
1,2-Dichlorobenzene	Kg	4.82E-05	2.70E-02
1,2-Dichloroethane	Kg	2.17E-07	1.05E-04
1,4-Dichlorobenzene	Kg	4.02E-05	2.60E-02
1-Butanol	Kg	2.33E-04	2.70E-02
2,4,5-Trichlorophenol	Kg	1.21E-04	1.38E-02
2,4,6-Trichlorophenol	Kg	1.17E-04	1.46E-02
2,4-Dinitrotoluene	Kg	5.23E-05	1.89E-02
2,6-Bis(1,1-dimethylethyl)-4-methylphenol	Kg	6.83E-05	1.83E-02
2-Butanone	Kg	7.69E-06	5.56E-04
2-Chlorophenol	Kg	1.09E-04	2.60E-02
2-Ethoxyethanol	Kg	5.23E-05	1.42E-02
2-Methylphenol	Kg	1.13E-04	5.10E-02
2-Nitrophenol	Kg	1.05E-04	3.10E-02
2-Nitropropane	Kg	8.44E-07	2.53E-04
4-Chloro-3-methylphenol	Kg	1.29E-04	9.50E-03
4-Nitrophenol	Kg	1.25E-04	1.42E-02
Acenaphthene	Kg	6.43E-05	3.00E-02
Acetate	Kg	1.86E-02	4.45E+01
Acetone	Kg	2.95E-05	1.61E-03
Actinium-228	Ci	4.62E-05	9.80E+01
Aluminum	Kg	3.77E-02	4.82E+02
Americium-241	Ci	1.69E-06	8.23E+01
Ammonium Ion by IC	Kg	3.96E-03	1.22E+00
Antimony	Kg	2.73E-04	1.50E+00
Antimony-125	Ci	2.60E-04	7.98E+01
Arsenic	Kg	3.65E-04	3.63E+00
Barium	Kg	1.45E-05	2.06E+00
Benzene	Kg	3.70E-07	1.01E-04

Table 2-3. Liquid and Sludge Inventories –95% Upper Confidence Level for Volume Case

Constituent	Inventory Unit	Liquid Inventory	Sludge Inventory
Beryllium	Kg	1.13E-05	7.13E-02
Bismuth	Kg	6.91E-04	3.71E+00
Boron	Kg	2.71E-04	1.50E+00
Bromide	Kg	2.34E-02	5.61E+01
Butylbenzylphthalate	Kg	3.26E-05	5.30E-03
Cadmium	Kg	3.86E-05	1.82E+00
Calcium	Kg	1.38E-04	1.48E+02
Carbon disulfide	Kg	3.86E-07	1.50E-04
Carbon tetrachloride	Kg	3.54E-07	1.91E-04
Carbon-14	Ci	1.21E-06	1.04E-02
Cerium	Kg	3.54E-04	7.19E+00
Cerium/Praseodymium-144	Ci	4.89E-04	3.47E+02
Cesium-134	Ci	4.01E-05	2.19E+01
Cesium-137	Ci	1.75E-01	1.82E+03
Chloride	Kg	7.08E-03	7.74E+00
Chlorobenzene	Kg	2.17E-07	1.25E-04
Chloroform	Kg	2.65E-07	1.54E-04
Chromium	Kg	3.22E-05	4.77E+00
Cobalt	Kg	7.88E-05	4.74E-01
Cobalt-60	Ci	1.04E-05	2.27E+01
Copper	Kg	3.22E-05	2.91E+00
Cresol	Kg	3.70E-04	7.30E-02
Curium-243/244	Ci	1.69E-06	9.51E+00
Cyanide	Kg	3.82E-05	9.84E-02
Cyclohexanone	Kg	3.06E-05	4.33E-02
Di-n-butylphthalate	Kg	5.63E-05	5.30E-03
Di-n-octylphthalate	Kg	8.44E-05	3.00E-02
Ethyl acetate	Kg	2.33E-07	1.58E-04
Ethyl ether	Kg	3.14E-07	1.43E-04
Ethylbenzene	Kg	6.43E-07	2.53E-04
Europium	Kg	1.93E-05	7.84E-01
Europium-152	Ci	9.03E-05	7.90E+01
Europium-154	Ci	3.06E-05	1.02E+02
Europium-155	Ci	6.62E-05	9.82E+01
Fluoranthene	Kg	8.44E-05	1.79E-02
Fluoride	Kg	2.42E-03	6.83E-01
Formate	Kg	1.86E-02	4.45E+01
Glycolate	Kg	1.54E-02	3.67E+01
Hexachlorobutadiene	Kg	4.82E-05	6.64E-03
Hexachloroethane	Kg	4.42E-07	9.54E-05
Hexone	Kg	2.73E-07	2.18E-04
Hydroxide (free)	Kg	2.82E+00	Not measured
Iodine-129	Ci	5.33E-07	7.95E-04
Iron	Kg	3.70E-05	2.61E+02
Isobutanol	Kg	2.65E-04	3.60E-02
Lanthanum	Kg	4.02E-05	3.08E+00
Lead	Kg	4.18E-04	3.23E+01
Lithium	Kg	2.25E-05	1.43E-01

Table 2-3. Liquid and Sludge Inventories -95% Upper Confidence Level for Volume Case

Constituent	Inventory Unit	Liquid Inventory	Sludge Inventory
Magnesium	Kg	4.18E-04	8.96E+00
Manganese	Kg	1.64E-05	6.93E+02
m-Cresol	Kg	2.49E-04	1.16E-01
Mercury	Kg	1.21E-06	2.43E+00
Methylenechloride	Kg	3.62E-07	1.24E-04
Molybdenum	Kg	5.63E-05	3.85E-01
Morpholine, 4-nitroso-	Kg	1.01E-04	1.50E-02
Naphthalene	Kg	4.82E-05	1.20E-02
Neodymium	Kg	1.61E-04	1.14E+01
Neptunium-237	Kg	1.06E-07	9.68E-02
Nickel	Kg	9.17E-05	3.81E+01
Nickel-63	Ci	2.91E-06	9.19E+01
Niobium	Kg	8.04E-04	5.34E+00
Niobium-94	Ci	1.05E-05	2.36E+01
Nitrate	Kg	2.42E-02	5.80E+01
Nitrite	Kg	2.18E-02	5.22E+01
Nitrobenzene	Kg	3.90E-05	1.26E-02
N-Nitroso-di-n-propylamine	Kg	1.05E-04	1.69E-02
Oxalate	Kg	4.92E-01	4.18E+02
Palladium	Kg	1.24E-03	8.91E+00
Pentachlorophenol	Kg	9.25E-05	1.30E-02
Phenol	Kg	1.09E-04	5.94E-02
Phosphate	Kg	3.80E-02	5.22E+01
Phosphorus	Kg	1.37E-02	3.70E+01
Plutonium-238	Ci	2.16E-06	3.41E+00
Plutonium-239/240	Ci	1.98E-06	2.56E+01
Potassium	Kg	5.63E-03	2.23E+01
Praseodymium	Kg	2.25E-04	6.80E+00
Pyrene	Kg	6.43E-05	2.90E-02
Pyridine	Kg	5.63E-05	1.81E-02
Radium-226	Ci	1.09E-03	5.25E+02
Rhodium	Kg	4.82E-04	3.09E+00
Rubidium	Kg	9.01E-03	3.03E+01
Ruthenium	Kg	2.87E-04	3.03E+00
Ruthenium/Rhodium-106	Ci	8.02E-04	4.25E+02
Samarium	Kg	1.77E-04	3.17E+00
Selenium	Kg	5.31E-04	3.71E+00
Selenium-79	Ci	1.28E-06	1.21E-02
Silicon	Kg	6.05E-03	2.02E+01
Silver	Kg	3.86E-05	9.88E+00
Sodium	Kg	3.94E+00	2.34E+02
Strontium	Kg	3.78E-06	2.30E+00
Strontium-89/90	Ci	1.77E-02	8.32E+04
Sulfate	Kg	2.59E-02	6.19E+01
Sulfide	Kg	2.54E-03	1.69E-01
Sulfur	Kg	2.01E-03	1.64E+00
Tantalum	Kg	3.38E-04	3.03E+00

Table 2-3. Liquid and Sludge Inventories –95% Upper Confidence Level for Volume Case

Constituent	Inventory Unit	Liquid Inventory	Sludge Inventory
Technetium-99	Kg	2.52E-07	1.22E-02
Tellurium	Kg	6.91E-04	3.03E+00
Tetrachloroethene	Kg	2.49E-07	1.33E-04
Thallium	Kg	4.52E-04	8.91E+00
Thorium	Kg	1.77E-04	3.93E+00
Thorium-230	Kg	2.81E-09	5.85E-05
Thorium-232	Kg	1.26E-07	6.42E+00
Tin	Kg	1.13E-03	3.03E+00
Titanium	Kg	9.65E-06	4.85E-01
Toluene	Kg	3.46E-07	1.19E-04
Trans-1,3-Dichloropropene	Kg	2.57E-07	1.03E-04
Trichloroethene	Kg	5.63E-07	2.04E-04
Trichlorofluoromethane	Kg	3.06E-07	1.51E-04
Tritium	Ci	1.37E-06	1.29E-02
Tungsten	Kg	2.09E-02	5.94E+00
Uranium	Kg	6.03E-04	3.71E+00
Uranium-233	Kg	6.95E-09	2.38E-04
Uranium-234	Kg	1.97E-08	1.91E-04
Uranium-235	Kg	2.33E-06	2.25E-02
Uranium-236	Kg	3.21E-08	3.37E-04
Uranium-238	Kg	3.53E-04	3.39E+00
Vanadium	Kg	4.18E-05	3.71E-01
Vinyl chloride	Kg	3.54E-07	7.27E-05
Xylene (m & p)	Kg	2.17E-06	2.87E-04
Xylene (o)	Kg	3.54E-07	9.00E-05
Xylenes (total)	Kg	1.81E-06	3.80E-04
Yttrium	Kg	8.04E-06	2.14E+00
Zinc	Kg	5.41E-05	2.68E+00
Zirconium	Kg	2.57E-05	3.51E+00
Aroclors (Total PCBs)	Kg	4.02E-07	1.71E-03
Curium-242	Ci	4.07E-09	1.99E-01
Curium-243	Ci	6.74E-08	3.80E-01
Curium-244	Ci	1.62E-06	9.13E+00
Plutonium-239	Ci	1.63E-06	2.11E+01
Plutonium-240	Ci	3.48E-07	4.51E+00
Plutonium-241	Ci	3.86E-06	5.00E+01
Thorium-228	Ci	2.84E-09	7.24E-04

2.3 CASE 3 – OVERALL 95% UPPER CONFIDENCE LEVEL INVENTORIES

In this case, the overall 95% UCL for inventory of each constituent was calculated based on a statistical method described in RPP-6924, *Statistical Methods for Estimating the Uncertainty in the Best-Basis Inventories.* This method is based on computation of the nominal inventory (see Section 2.1) and an overall uncertainty (standard deviation) for the inventory. The standard deviation of the nominal inventory was calculated based on uncertainties associated with the concentration, volume, and density (for solids) measurements. Table 2-4 provides the inventory estimates for this case.

Table 2-4. Liquid and Sludge Inventories –Overall 95% Upper Confidence Level

Constituent	Inventory Unit	Liquid Inventory	Sludge Inventory
1,1,1-Trichloroethane	Kg	5.79E-07	3.47E-04
1,1,2,2-Tetrachloroethane	Kg	8.30E-07	2.54E-04
1,1,2-Trichloro-1,2,2-trifluoroethane	Kg	1.64E-06	3.88E-04
1,1,2-Trichloroethane	Kg	5.21E-07	2.54E-04
1,1-Dichloroethene	Kg	1.05E-06	4.09E-04
1,2,4-Trichlorobenzene	Kg	1.25E-06	3.90E-04
1,2-Dichlorobenzene	Kg	1.16E-04	6.47E-02
1,2-Dichloroethane	Kg	5.21E-07	2.51E-04
1,4-Dichlorobenzene	Kg	9.65E-05	6.23E-02
1-Butanol	Kg	5.60E-04	6.47E-02
2,4,5-Trichlorophenol	Kg	2.90E-04	3.31E-02
2,4,6-Trichlorophenol	Kg	2.80E-04	3.50E-02
2,4-Dinitrotoluene	Kg	1.25E-04	4.53E-02
2,6-Bis(1,1-dimethylethyl)-4-methylphenol	Kg	1.64E-04	4.39E-02
2-Butanone	Kg	8.16E-06	6.01E-04
2-Chlorophenol	Kg	2.61E-04	6.23E-02
2-Ethoxyethanol	Kg	1.25E-04	3.40E-02
2-Methylphenol	Kg	2.70E-04	1.22E-01
2-Nitrophenol	Kg	2.51E-04	7.43E-02
2-Nitropropane	Kg	2.03E-06	6.07E-04
4-Chloro-3-methylphenol	Kg	3.09E-04	2.28E-02
4-Nitrophenol	Kg	2.99E-04	3.40E-02
Acenaphthene	Kg	1.54E-04	7.19E-02
Acetate	Kg	4.46E-02	1.07E+02
Acetone	Kg	3.29E-05	1.65E-03
Actinium-228	Ci	1.11E-04	2.35E+02
Aluminum	Kg	3.78E-02	4.84E+02
Americium-241	Ci	4.05E-06	8.26E+01
Ammonium Ion by IC	Kg	4.92E-03	1.28E+00
Antimony	Kg	6.56E-04	3.59E+00
Antimony-125	Ci	6.25E-04	1.91E+02
Arsenic	Kg	8.76E-04	8.71E+00

Table 2-4. Liquid and Sludge Inventories -Overall 95% Upper Confidence Level

Constituent	Inventory Unit	Liquid Inventory	Sludge Inventory
Barium	Kg	3.47E-05	2.08E+00
Benzene	Kg	8.88E-07	2.43E-04
Beryllium	Kg	2.70E-05	1.71E-01
Bismuth	Kg	1.66E-03	8.88E+00
Boron	Kg	2.76E-04	3.59E+00
Bromide	Kg	5.63E-02	1.34E+02
Butylbenzylphthalate	Kg	7.82E-05	1.27E-02
Cadmium	Kg	9.27E-05	1.85E+00
Calcium	Kg	3.32E-04	1.52E+02
Carbon disulfide	Kg	9.27E-07	3.60E-04
Carbon tetrachloride	Kg	8.49E-07	4.59E-04
Carbon-14	Ci	1.26E-06	2.49E-02
Cerium	Kg	8.49E-04	7.28E+00
Cerium/Praseodymium-144	Ci	1.17E-03	8.33E+02
Cesium-134	Ci	9.62E-05	5.25E+01
Cesium-137	Ci	1.75E-01	1.91E+03
Chloride	Kg	7.10E-03	1.85E+01
Chlorobenzene	Kg	5.21E-07	3.00E-04
Chloroform	Kg	6.37E-07	3.69E-04
Chromium	Kg	7.72E-05	4.80E+00
Cobalt	Kg	1.89E-04	5.04E-01
Cobalt-60	Ci	2.49E-05	5.44E+01
Copper	Kg	7.72E-05	3.00E+00
Cresol	Kg	8.88E-04	1.75E-01
Curium-243/244	Ci	4.05E-06	2.28E+01
Cyanide	Kg	9.17E-05	1.01E-01
Cyclohexanone	Kg	7.34E-05	1.04E-01
Di-n-butylphthalate	Kg	1.35E-04	3.96E-02
Di-n-octylphthalate	Kg	2.03E-04	7.19E-02
Ethyl acetate	Kg	5.60E-07	3.79E-04
Ethyl ether	Kg	7.53E-07	3.42E-04
Ethylbenzene	Kg	1.54E-06	6.07E-04
Europium	Kg	4.63E-05	1.88E+00
Europium-152	Ci	2.17E-04	1.89E+02
Europium-154	Ci	7.35E-05	2.45E+02
Europium-155	Ci	1.59E-04	2.35E+02
Fluoranthene	Kg	2.03E-04	4.30E-02
Fluoride	Kg	5.82E-03	1.64E+00
Formate	Kg	4.46E-02	1.07E+02
Glycolate	Kg	3.69E-02	8.81E+01
Hexachlorobutadiene	Kg	1.16E-04	1.59E-02
Hexachloroethane	Kg	1.06E-06	2.29E-04
Hexone	Kg	6.56E-07	5.23E-04
Hydroxide (free)	Kg	2.83E+00	Not measured
Iodine-129	Ci	1.28E-06	1.90E-03
Iron	Kg	8.88E-05	2.63E+02
Isobutanol	Kg	6.37E-04	8.63E-02
Lanthanum	Kg	9.65E-05	3.09E+00
Lead	Kg	1.00E-03	3.27E+01

Table 2-4. Liquid and Sludge Inventories –Overall 95% Upper Confidence Level

Constituent	Inventory Unit	Liquid Inventory	Sludge Inventory
Lithium	Kg	5.40E-05	3.41E-01
Magnesium	Kg	1.00E-03	9.04E+00
Manganese	Kg	1.71E-05	7.04E+02
m-Cresol	Kg	5.98E-04	2.78E-01
Mercury	Kg	1.23E-06	2.82E+00
Methylenechloride	Kg	8.69E-07	2.97E-04
Molybdenum	Kg	1.35E-04	9.22E-01
Morpholine, 4-nitroso-	Kg	2.41E-04	3.60E-02
Naphthalene	Kg	1.16E-04	2.88E-02
Neodymium	Kg	3.86E-04	1.14E+01
Neptunium-237	Kg	1.08E-07	1.02E-01
Nickel	Kg	2.20E-04	3.95E+01
Nickel-63	Ci	6.98E-06	9.72E+01
Niobium	Kg	1.93E-03	5.37E+00
Niobium-94	Ci	2.53E-05	5.67E+01
Nitrate	Kg	5.82E-02	1.39E+02
Nitrite	Kg	5.24E-02	1.25E+02
Nitrobenzene	Kg	9.36E-05	3.03E-02
N-Nitroso-di-n-propylamine	Kg	2.51E-04	4.06E-02
Oxalate	Kg	4.94E-01	4.29E+02
Palladium	Kg	2.97E-03	2.13E+01
Pentachlorophenol	Kg	2.22E-04	3.12E-02
Phenol	Kg	2.61E-04	1.42E-01
Phosphate	Kg	3.82E-02	1.25E+02
Phosphorus	Kg	1.38E-02	3.72E+01
Plutonium-238	Ci	5.19E-06	8.17E+00
Plutonium-239/240	Ci	4.75E-06	2.69E+01
Potassium	Kg	1.35E-02	5.34E+01
Praseodymium	Kg	5.40E-04	6.82E+00
Pyrene	Kg	1.54E-04	6.95E-02
Pyridine	Kg	1.35E-04	4.34E-02
Radium-226	Ci	2.63E-03	1.26E+03
Rhodium	Kg	1.16E-03	7.40E+00
Rubidium	Kg	2.16E-02	7.26E+01
Ruthenium	Kg	2.91E-04	7.26E+00
Ruthenium/Rhodium-106	Ci	1.93E-03	1.02E+03
Samarium	Kg	4.25E-04	3.27E+00
Selenium	Kg	1.27E-03	8.88E+00
Selenium-79	Ci	3.07E-06	2.89E-02
Silicon	Kg	6.07E-03	2.04E+01
Silver	Kg	9.27E-05	9.92E+00
Sodium	Kg	3.95E+00	2.36E+02
Strontium	Kg	4.05E-06	2.32E+00
Strontium-89/90	Ci	1.87E-02	8.34E+04
Sulfate	Kg	6.21E-02	1.48E+02
Sulfide	Kg	6.10E-03	4.06E-01
Sulfur	Kg	2.02E-03	3.93E+00
Tantalum	Kg	8.11E-04	7.26E+00

Table 2-4. Liquid and Sludge Inventories –Overall 95% Upper Confidence Level

Constituent	Inventory Unit	Liquid Inventory	Sludge Inventory
Technetium-99	Kg	2.72E-07	1.29E-02
Tellurium	Kg	1.66E-03	7.26E+00
Tetrachloroethene	Kg	5.98E-07	3.20E-04
Thallium	Kg	4.93E-04	2.13E+01
Thorium	Kg	4.25E-04	3.96E+00
Thorium-230	Kg	6.76E-09	7.22E-05
Thorium-232	Kg	3.03E-07	6.89E+00
Tin	Kg	1.15E-03	7.26E+00
Titanium	Kg	2.32E-05	5.16E-01
Toluene	Kg	8.30E-07	2.86E-04
Trans-1,3-Dichloropropene	Kg	6.18E-07	2.48E-04
Trichloroethene	Kg	1.35E-06	4.89E-04
Trichlorofluoromethane	Kg	7.34E-07	3.63E-04
Tritium	Ci	3.28E-06	3.08E-02
Tungsten	Kg	2.09E-02	1.42E+01
Uranium	Kg	1.45E-03	8.88E+00
Uranium-233	Kg	7.11E-09	2.42E-04
Uranium-234	Kg	1.98E-08	1.92E-04
Uranium-235	Kg	2.34E-06	2.35E-02
Uranium-236	Kg	3.22E-08	3.65E-04
Uranium-238	Kg	3.54E-04	3.53E+00
Vanadium	Kg	1.00E-04	8.88E-01
Vinyl chloride	Kg	8.49E-07	1.74E-04
Xylene (m & p)	Kg	5.21E-06	6.87E-04
Xylene (o)	Kg	8.49E-07	2.16E-04
Xylenes (total)	Kg	4.34E-06	9.11E-04
Yttrium	Kg	1.93E-05	2.18E+00
Zinc	Kg	5.93E-05	2.72E+00
Zirconium	Kg	6.18E-05	3.56E+00
Aroclors (Total PCBs)	Kg	9.65E-07	4.10E-03
Curium-242	Ci	9.77E-09	1.99E-01
Curium-243	Ci	1.62E-07	9.11E-01
Curium-244	Ci	3.89E-06	2.19E+01
Plutonium-239	Ci	3.91E-06	2.22E+01
Plutonium-240	Ci	8.35E-07	4.74E+00
Plutonium-241	Ci	9.26E-06	5.25E+01
Thorium-228	Ci	4.01E-11	7.58E-04

3.0 REFERENCES

RPP-6924, *Statistical Methods for Estimating the Uncertainty in the Best Basis Inventories*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-7625, *Best-Basis Inventory Process Requirements*, Rev. 4, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-13889, *Tank 241-C-106 Component Closure Action Data Quality Objectives*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-18375, *Liquid Grab Sampling and Analysis Plan for Tank 241-C-106 Component Closure Action*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-18376, *Solids Grab Sampling and Analysis Plan for Tank 241-C-106 Component Closure Action*, Rev. 2, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-19866, *Calculation for the Post-Retrieval Waste Volume Determination for Tank 241-C-106*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-20226, *Analytical Results for Liquid Grab Sampling and Analysis Plan for Tank 241-C-106 Component Closure Action*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-20264, *Analytical Results for Tank 241-C-106 Solid Clamshell Samples Supporting Closure Action*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

APPENDIX A

MEAN CONCENTRATIONS AND RELATIVE STANDARD DEVIATIONS FOR LIQUID AND SLUDGE

MEAN CONCENTRATIONS AND RELATIVE STANDARD DEVIATIONS FOR LIQUID AND SLUDGE

Table A-1. Mean Concentrations and Relative Standard Deviations[1]

Constituent Name	Liquid			Sludge		
	Mean Concentration	Unit	Relative Standard Deviation	Mean Concentration	Unit	Relative Standard Deviation
1,1,1-Trichloroethane	6.00E-04	µg/mL	1.00E+00	7.23E-03	µg/g	1.00E+00
1,1,2,2-Tetrachloroethane	8.60E-04	µg/mL	1.00E+00	5.30E-03	µg/g	1.00E+00
1,1,2-Trichloro-1,2,2-trifluoroethane	1.70E-03	µg/mL	1.00E+00	8.10E-03	µg/g	1.00E+00
1,1,2-Trichloroethane	5.40E-04	µg/mL	1.00E+00	5.30E-03	µg/g	1.00E+00
1,1-Dichloroethene		µg/mL	1.00E+00	8.53E-03	µg/g	1.00E+00
1,2,4-Trichlorobenzene	1.30E-03	µg/mL	1.00E+00	8.13E-03	µg/g	1.00E+00
1,2-Dichlorobenzene	1.20E-01	µg/mL	1.00E+00	1.35E+00	µg/g	1.00E+00
1,2-Dichloroethane	5.40E-04	µg/mL	1.00E+00	5.23E-03	µg/g	1.00E+00
1,4-Dichlorobenzene	1.00E-01	µg/mL	1.00E+00	1.30E+00	µg/g	1.00E+00
1-Butanol	5.80E-01	µg/mL	1.00E+00	1.35E+00	µg/g	1.00E+00
2,4,5-Trichlorophenol	3.00E-01	µg/mL	1.00E+00	6.90E-01	µg/g	1.00E+00
2,4,6-Trichlorophenol	2.90E-01	µg/mL	1.00E+00	7.30E-01	µg/g	1.00E+00
2,4-Dinitrotoluene	1.30E-01	µg/mL	1.00E+00	9.45E-01	µg/g	1.00E+00
2,6-Bis(1,1-dimethylethyl)-4-methylphenol	1.70E-01	µg/mL	1.00E+00	9.15E-01	µg/g	1.00E+00
2-Butanone	1.91E-02	µg/mL	1.04E-01	2.78E-02	µg/g	1.26E-01
2-Chlorophenol	2.70E-01	µg/mL	1.00E+00	1.30E+00	µg/g	1.00E+00
2-Ethoxyethanol	1.30E-01	µg/mL	1.00E+00	7.10E-01	µg/g	1.00E+00
2-Methylphenol	2.80E-01	µg/mL	1.00E+00	2.55E+00	µg/g	1.00E+00
2-Nitrophenol	2.60E-01	µg/mL	1.00E+00	1.55E+00	µg/g	1.00E+00
2-Nitropropane	2.10E-03	µg/mL	1.00E+00	1.27E-02	µg/g	1.00E+00
4-Chloro-3-methylphenol	3.20E-01	µg/mL	1.00E+00	4.75E-01	µg/g	1.00E+00
4-Nitrophenol	3.10E-01	µg/mL	1.00E+00	7.10E-01	µg/g	1.00E+00
Acenaphthene	1.60E-01	µg/mL	1.00E+00	1.50E+00	µg/g	1.00E+00
Acetate	4.62E+01	µg/mL	1.00E+00	2.22E+03	µg/g	1.00E+00
Acetone	7.33E-02	µg/mL	1.54E-01	8.05E-02	µg/g	6.52E-02
Actinium-228	1.15E-04	µCi/mL	1.00E+00	4.90E+00	µCi/g	1.00E+00
Aluminum	9.37E+01	µg/mL	2.58E-03	2.41E+04	µg/g	1.98E-02
Americium-241	4.19E-06	µCi/mL	1.00E+00	4.11E+00	µCi/g	1.99E-02
Ammonium Ion by IC	9.85E+00	µg/mL	2.49E-01	6.08E+01	µg/g	9.45E-02
Antimony	6.80E-01	µg/mL	1.00E+00	7.48E+01	µg/g	1.00E+00
Antimony-125	6.48E-04	µCi/mL	1.00E+00	3.99E+00	µCi/g	1.00E+00
Arsenic	9.08E-01	µg/mL	1.00E+00	1.82E+02	µg/g	1.00E+00
Barium	3.60E-02	µg/mL	1.00E+00	1.03E+02	µg/g	2.81E-02
Benzene	9.20E-04	µg/mL	1.00E+00	5.07E-03	µg/g	1.00E+00
Beryllium	2.80E-02	µg/mL	1.00E+00	3.56E+00	µg/g	1.00E+00
Bismuth	1.72E+00	µg/mL	1.00E+00	1.85E+02	µg/g	1.00E+00
Boron	6.75E-01	µg/mL	5.08E-02	7.48E+01	µg/g	1.00E+00
Bromide	5.83E+01	µg/mL	1.00E+00	2.80E+03	µg/g	1.00E+00
Butylbenzylphthalate	8.10E-02	µg/mL	1.00E+00	2.65E-01	µg/g	1.00E+00

Table A-1. Mean Concentrations and Relative Standard Deviations[1]

Constituent Name	Liquid			Sludge		
	Mean Concentration	Unit	Relative Standard Deviation	Mean Concentration	Unit	Relative Standard Deviation
Cadmium	9.60E-02	µg/mL	1.00E+00	9.09E+01	µg/g	5.16E-02
Calcium	3.44E-01	µg/mL	1.00E+00	7.41E+03	µg/g	6.09E-02
Carbon disulfide	9.60E-04	µg/mL	1.00E+00	7.50E-03	µg/g	1.00E+00
Carbon tetrachloride	8.80E-04	µg/mL	1.00E+00	9.57E-03	µg/g	1.00E+00
Carbon-14	3.01E-06	µCi/mL	8.26E-02	5.19E-04	µCi/g	1.00E+00
Cerium	8.80E-01	µg/mL	1.00E+00	3.59E+02	µg/g	4.38E-02
Cerium/Praseodymium-144	1.22E-03	µCi/mL	1.00E+00	1.74E+01	µCi/g	1.00E+00
Cesium-134	9.97E-05	µCi/mL	1.00E+00	1.10E+00	µCi/g	1.00E+00
Cesium-137	4.34E-01	µCi/mL	9.79E-04	9.11E+01	µCi/g	9.52E-02
Chloride	1.76E+01	µg/mL	9.42E-03	3.87E+02	µg/g	1.00E+00
Chlorobenzene	5.40E-04	µg/mL	1.00E+00	6.27E-03	µg/g	1.00E+00
Chloroform	6.60E-04	µg/mL	1.00E+00	7.70E-03	µg/g	1.00E+00
Chromium	8.00E-02	µg/mL	1.00E+00	2.38E+02	µg/g	2.88E-02
Cobalt	1.96E-01	µg/mL	1.00E+00	2.37E+01	µg/g	1.08E-01
Cobalt-60	2.58E-05	µCi/mL	1.00E+00	1.14E+00	µCi/g	1.00E+00
Copper	8.00E-02	µg/mL	1.00E+00	1.45E+02	µg/g	7.40E-02
Cresol	9.20E-01	µg/mL	1.00E+00	3.65E+00	µg/g	1.00E+00
Curium-243/244	4.19E-06	µCi/mL	1.00E+00	4.75E-01	µCi/g	1.00E+00
Cyanide	9.50E-02	µg/mL	1.00E+00	4.92E+00	µg/g	7.07E-02
Cyclohexanone	7.60E-02	µg/mL	1.00E+00	2.17E+00	µg/g	1.00E+00
Di-n-butylphthalate	1.40E-01	µg/mL	1.00E+00	2.65E-01	µg/g	4.20E+00
Di-n-octylphthalate	2.10E-01	µg/mL	1.00E+00	1.50E+00	µg/g	1.00E+00
Ethyl acetate	5.80E-04	µg/mL	1.00E+00	7.90E-03	µg/g	1.00E+00
Ethyl ether	7.80E-04	µg/mL	1.00E+00	7.13E-03	µg/g	1.00E+00
Ethylbenzene	1.60E-03	µg/mL	1.00E+00	1.27E-02	µg/g	1.00E+00
Europium	4.80E-02	µg/mL	1.00E+00	3.92E+01	µg/g	1.00E+00
Europium-152	2.25E-04	µCi/mL	1.00E+00	3.95E+00	µCi/g	1.00E+00
Europium-154	7.62E-05	µCi/mL	1.00E+00	5.12E+00	µCi/g	1.00E+00
Europium-155	1.65E-04	µCi/mL	1.00E+00	4.91E+00	µCi/g	1.00E+00
Fluoranthene	2.10E-01	µg/mL	1.00E+00	8.97E-01	µg/g	1.00E+00
Fluoride	6.03E+00	µg/mL	1.00E+00	3.41E+01	µg/g	1.00E+00
Formate	4.62E+01	µg/mL	1.00E+00	2.22E+03	µg/g	1.00E+00
Glycolate	3.82E+01	µg/mL	1.00E+00	1.84E+03	µg/g	1.00E+00
Hexachlorobutadiene	1.20E-01	µg/mL	1.00E+00	3.32E-01	µg/g	1.00E+00
Hexachloroethane	1.10E-03	µg/mL	1.00E+00	4.77E-03	µg/g	1.00E+00
Hexone	6.80E-04	µg/mL	1.00E+00	1.09E-02	µg/g	1.00E+00
Hydroxide (free)	7.02E+03	µg/mL	1.41E-02	Not measured	NA	NA
Iodine-129	1.33E-06	µCi/mL	1.00E+00	3.97E-05	µCi/g	1.00E+00
Iron	9.20E-02	µg/mL	1.00E+00	1.30E+04	µg/g	2.94E-02
Isobutanol	6.60E-01	µg/mL	1.00E+00	1.80E+00	µg/g	1.00E+00
Lanthanum	1.00E-01	µg/mL	1.00E+00	1.54E+02	µg/g	7.78E-03
Lead	1.04E+00	µg/mL	1.00E+00	1.62E+03	µg/g	3.83E-02
Lithium	5.60E-02	µg/mL	1.00E+00	7.12E+00	µg/g	1.00E+00
Magnesium	1.04E+00	µg/mL	1.00E+00	4.48E+02	µg/g	3.62E-02
Manganese	4.09E-02	µg/mL	7.88E-02	3.46E+04	µg/g	4.91E-02
m-Cresol	6.20E-01	µg/mL	1.00E+00	5.80E+00	µg/g	1.00E+00

Table A-1. Mean Concentrations and Relative Standard Deviations[1]

Constituent Name	Liquid			Sludge		
	Mean Concentration	Unit	Relative Standard Deviation	Mean Concentration	Unit	Relative Standard Deviation
Mercury	3.02E-03	µg/mL	4.48E-02	1.22E+02	µg/g	1.88E-01
Methylenechloride	9.00E-04	µg/mL	1.00E+00	6.20E-03	µg/g	1.00E+00
Molybdenum	1.40E-01	µg/mL	1.00E+00	1.92E+01	µg/g	1.00E+00
Morpholine, 4-nitroso-	2.50E-01	µg/mL	1.00E+00	7.50E-01	µg/g	1.00E+00
Naphthalene	1.20E-01	µg/mL	1.00E+00	6.02E-01	µg/g	1.00E+00
Neodymium	4.00E-01	µg/mL	1.00E+00	5.67E+02	µg/g	1.99E-02
Neptunium-237	2.64E-04	µg/mL	4.98E-02	4.84E+00	µg/g	9.93E-02
Nickel	2.28E-01	µg/mL	1.00E+00	1.90E+03	µg/g	8.06E-02
Nickel-63	7.24E-06	µCi/mL	1.00E+00	4.59E+00	µCi/g	1.02E-01
Niobium	2.00E+00	µg/mL	1.00E+00	2.67E+02	µg/g	2.86E-02
Niobium-94	2.62E-05	µCi/mL	1.00E+00	1.18E+00	µCi/g	1.00E+00
Nitrate	6.03E+01	µg/mL	1.00E+00	2.90E+03	µg/g	1.00E+00
Nitrite	5.43E+01	µg/mL	1.00E+00	2.61E+03	µg/g	1.00E+00
Nitrobenzene	9.70E-02	µg/mL	1.00E+00	6.32E-01	µg/g	1.00E+00
N-Nitroso-di-n-propylamine	2.60E-01	µg/mL	1.00E+00	8.47E-01	µg/g	1.00E+00
Oxalate	1.22E+03	µg/mL	7.87E-03	2.09E+04	µg/g	6.41E-02
Palladium	3.08E+00	µg/mL	1.00E+00	4.45E+02	µg/g	1.00E+00
Pentachlorophenol	2.30E-01	µg/mL	1.00E+00	6.50E-01	µg/g	1.00E+00
Phenol	2.70E-01	µg/mL	1.00E+00	2.97E+00	µg/g	1.00E+00
Phosphate	9.46E+01	µg/mL	5.44E-03	2.61E+03	µg/g	1.00E+00
Phosphorus	3.41E+01	µg/mL	6.28E-03	1.85E+03	µg/g	2.62E-02
Plutonium-238	5.38E-06	µCi/mL	1.00E+00	1.70E-01	µCi/g	1.00E+00
Plutonium-239/240	4.92E-06	µCi/mL	1.00E+00	1.28E+00	µCi/g	9.54E-02
Potassium	1.40E+01	µg/mL	1.00E+00	1.11E+03	µg/g	1.00E+00
Praseodymium	5.60E-01	µg/mL	1.00E+00	3.40E+02	µg/g	1.60E-02
Pyrene	1.60E-01	µg/mL	1.00E+00	1.45E+00	µg/g	1.00E+00
Pyridine	1.40E-01	µg/mL	1.00E+00	9.05E-01	µg/g	1.00E+00
Radium-226	2.72E-03	µCi/mL	1.00E+00	2.62E+01	µCi/g	1.00E+00
Rhodium	1.20E+00	µg/mL	1.00E+00	1.54E+02	µg/g	1.00E+00
Rubidium	2.24E+01	µg/mL	1.00E+00	1.51E+03	µg/g	1.00E+00
Ruthenium	7.15E-01	µg/mL	3.61E-02	1.51E+02	µg/g	1.00E+00
Ruthenium/Rhodium-106	2.00E-03	µCi/mL	1.00E+00	2.12E+01	µCi/g	1.00E+00
Samarium	4.40E-01	µg/mL	1.00E+00	1.58E+02	µg/g	7.33E-02
Selenium	1.32E+00	µg/mL	1.00E+00	1.85E+02	µg/g	1.00E+00
Selenium-79	3.18E-06	µCi/mL	1.00E+00	6.04E-04	µCi/g	1.00E+00
Silicon	1.51E+01	µg/mL	2.46E-03	1.01E+03	µg/g	3.71E-02
Silver	9.60E-02	µg/mL	1.00E+00	4.94E+02	µg/g	1.99E-02
Sodium	9.80E+03	µg/mL	1.71E-03	1.17E+04	µg/g	3.67E-02
Strontium	9.40E-03	µg/mL	1.15E-01	1.15E+02	µg/g	2.82E-02
Strontium-89/90	4.40E-02	µCi/mL	1.02E-01	4.16E+03	µCi/g	1.01E-02
Sulfate	6.43E+01	µg/mL	1.00E+00	3.09E+03	µg/g	1.00E+00
Sulfide	6.32E+00	µg/mL	1.00E+00	8.47E+00	µg/g	1.00E+00
Sulfur	5.00E+00	µg/mL	2.60E-02	8.19E+01	µg/g	1.00E+00
Tantalum	8.40E-01	µg/mL	1.00E+00	1.51E+02	µg/g	1.00E+00
Technetium-99	6.28E-04	µg/mL	1.19E-01	6.11E-01	µg/g	9.81E-02
Tellurium	1.72E+00	µg/mL	1.00E+00	1.51E+02	µg/g	1.00E+00

Table A-1. Mean Concentrations and Relative Standard Deviations[1]

Constituent Name	Liquid			Sludge		
	Mean Concentration	Unit	Relative Standard Deviation	Mean Concentration	Unit	Relative Standard Deviation
Tetrachloroethene	6.20E-04	µg/mL	1.00E+00	6.67E-03	µg/g	1.00E+00
Thallium	1.12E+00	µg/mL	1.31E-01	4.45E+02	µg/g	1.00E+00
Thorium	4.40E-01	µg/mL	1.00E+00	1.96E+02	µg/g	3.79E-02
Thorium-230	7.00E-06	µg/mL	1.00E+00	2.92E-03	µg/g	2.45E-01
Thorium-232	3.14E-04	µg/mL	1.00E+00	3.21E+02	µg/g	1.17E-01
Tin	2.80E+00	µg/mL	5.79E-02	1.51E+02	µg/g	1.00E+00
Titanium	2.40E-02	µg/mL	1.00E+00	2.43E+01	µg/g	1.08E-01
Toluene	8.60E-04	µg/mL	1.00E+00	5.97E-03	µg/g	1.00E+00
Trans-1,3-Dichloropropene	6.40E-04	µg/mL	1.00E+00	5.17E-03	µg/g	1.00E+00
Trichloroethene	1.40E-03	µg/mL	1.00E+00	1.02E-02	µg/g	1.00E+00
Trichlorofluoromethane	7.60E-04	µg/mL	1.00E+00	7.57E-03	µg/g	1.00E+00
Tritium	3.40E-06	µCi/mL	1.00E+00	6.43E-04	µCi/g	1.00E+00
Tungsten	5.19E+01	µg/mL	1.09E-02	2.97E+02	µg/g	1.00E+00
Uranium	1.50E+00	µg/mL	1.00E+00	1.85E+02	µg/g	1.00E+00
Uranium-233	1.73E-05	µg/mL	5.78E-02	1.19E-02	µg/g	5.19E-02
Uranium-234	4.89E-05	µg/mL	2.49E-02	9.54E-03	µg/g	1.65E-02
Uranium-235	5.81E-03	µg/mL	7.12E-03	1.13E+00	µg/g	8.69E-02
Uranium-236	7.99E-05	µg/mL	1.03E-02	1.69E-02	µg/g	1.27E-01
Uranium-238	8.77E-01	µg/mL	1.14E-02	1.69E+02	µg/g	8.47E-02
Vanadium	1.04E-01	µg/mL	1.00E+00	1.85E+01	µg/g	1.00E+00
Vinyl chloride	8.80E-04	µg/mL	1.00E+00	3.63E-03	µg/g	1.00E+00
Xylene (m & p)	5.40E-03	µg/mL	1.00E+00	1.43E-02	µg/g	1.00E+00
Xylene (o)	8.80E-04	µg/mL	1.00E+00	4.50E-03	µg/g	1.00E+00
Xylenes (total)	4.50E-03	µg/mL	1.00E+00	1.90E-02	µg/g	1.00E+00
Yttrium	2.00E-02	µg/mL	1.00E+00	1.07E+02	µg/g	5.68E-02
Zinc	1.35E-01	µg/mL	1.36E-01	1.34E+02	µg/g	4.85E-02
Zirconium	6.40E-02	µg/mL	1.00E+00	1.76E+02	µg/g	4.42E-02
Aroclors (Total PCBs)	1.00E-03	µg/mL	1.00E+00	8.56E-02	µg/g	1.00E+00
Curium-242	Not measured	NA	NA	Not measured	NA	NA
Curium-243	Not measured	NA	NA	Not measured	NA	NA
Curium-244	Not measured	NA	NA	Not measured	NA	NA
Plutonium-239	Not measured	NA	NA	Not measured	NA	NA
Plutonium-240	Not measured	NA	NA	Not measured	NA	NA
Plutonium-241	Not measured	NA	NA	Not measured	NA	NA
Thorium-228	Not measured	NA	NA	Not measured	NA	NA

Note: [1]In accordance with the BBI protocol, the relative standard deviation is assumed to be 1 if the constituent was not detected.

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APPENDIX B

SINGLE-SHELL TANK 241-C-106 TANK RISK DATA

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Table B-1. Residual Single-Shell Tank 241-C-106 Inventory Calculated from Post-Retrieval Sample using 370 ft^3 for Volume of Residual. (6 sheets)

BBI	Class	P/S	Isotope/CASRN	Constituent	Inventory	Units	DQ
Yes	Radionuclide	Primary	3H	Tritium	1.02E-02	Ci	U
Yes	Radionuclide	Primary	14C	Carbon-14	8.24E-03	Ci	U
Yes	Radionuclide	Primary	60Co	Cobalt-60	1.80E+01	Ci	U
Yes	Radionuclide	Primary	63Ni	Nickel-63	7.30E+01	Ci	
Yes	Radionuclide	Primary	79Se	Selenium-79	9.59E-03	Ci	U
Yes	Radionuclide	Primary	90Sr	Strontium-90	6.61E+04	Ci	
Yes	Radionuclide	Primary	99Tc	Technetium-99	1.65E-01	Ci	
Yes	Radionuclide	Primary	129I	Iodine-129	6.32E-04	Ci	U
Yes	Radionuclide	Primary	137Cs	Cesium-137	1.45E+03	Ci	
Yes	Radionuclide	Primary	152Eu	Europium-152	6.27E+01	Ci	U
Yes	Radionuclide	Primary	154Eu	Europium-154	8.13E+01	Ci	U
Yes	Radionuclide	Primary	155Eu	Europium-155	7.80E+01	Ci	U
No	Radionuclide	Primary	228Th	Thorium-228	5.75E-04	Ci	
No	Radionuclide	Primary	230Th	Thorium-230	8.82E-04	Ci	
Yes	Radionuclide	Primary	232Th	Thorium-232	5.61E-04	Ci	
Yes	Radionuclide	Primary	233U	Uranium-233	1.83E-03	Ci	
Yes	Radionuclide	Primary	234U	Uranium-234	9.48E-04	Ci	
Yes	Radionuclide	Primary	235U	Uranium-235	3.87E-05	Ci	
Yes	Radionuclide	Primary	236U	Uranium-236	1.73E-05	Ci	
Yes	Radionuclide	Primary	238U	Uranium-238	9.04E-04	Ci	
Yes	Radionuclide	Primary	237Np	Neptunium-237	5.42E-02	Ci	
Yes	Radionuclide	Primary	238Pu	Plutonum-238	2.71E+00	Ci	U
Yes	Radionuclide	Primary	239Pu	Plutonum-239	1.68E+01	Ci	
Yes	Radionuclide	Primary	240Pu	Plutonum-240	3.58E+00	Ci	
Yes	Radionuclide	Primary	241Pu	Plutonum-241	3.97E+01	Ci	
Yes	Radionuclide	Primary	241Am	Amercium-241	6.53E+01	Ci	
Yes	Radionuclide	Primary	242Cm	Curium-242	1.58E-01	Ci	U
Yes	Radionuclide	Primary	243Cm	Curium-243	3.02E-01	Ci	U
Yes	Radionuclide	Primary	244Cm	Curium-244	7.25E+00	Ci	U
Yes	Radionuclide	Secondary	94Nb	Niobium-94	1.88E+01	Ci	U
Yes	Radionuclide	Secondary	106Ru	Ruthenium-106	3.37E+02	Ci	U
Yes	Radionuclide	Secondary	125Sb	Antimony-125	6.34E+01	Ci	U

Table B-1. Residual Single-Shell Tank 241-C-106 Inventory Calculated from Post-Retrieval Sample using 370 ft^3 for Volume of Residual. (6 sheets)

BBI	Class	P/S	Isotope/CASRN	Constituent	Inventory	Units	DQ
Yes	Radionuclide	Secondary	134Cs	Cesium-134	1.74E+01	Ci	U
No	Radionuclide	Secondary	144Pr	Praseodymium-144	2.76E+02	Ci	U
Yes	Radionuclide	Secondary	226Ra	Radium-226	4.17E+02	Ci	U
No	Radionuclide	Secondary	228Ac	Actinium-228	7.78E+01	Ci	U
No	Inorganic	Primary	14798-03-9	Ammonium NH4+	9.70E-01	Kg	
No	Inorganic	Primary	7440-38-2	Arsenic As	2.89E+00	Kg	U
No	Inorganic	Primary	7440-39-3	Barium Ba	1.64E+00	Kg	
No	Inorganic	Primary	7440-41-7	Beryllium Be	5.66E-02	Kg	U
No	Inorganic	Primary	7440-43-9	Cadmium Cd	1.44E+00	Kg	
Yes	Inorganic	Primary	7440-47-3	Chromium Cr	3.79E+00	Kg	
No	Inorganic	Primary	57-12-5	Cyanide CN-	7.82E-02	Kg	
Yes	Inorganic	Primary	16984-48-8	Fluoride F-	5.44E-01	Kg	U
No	Inorganic	Primary	ALKALINITY	Hydroxide OH-	2.25E+00	Kg	
Yes	Inorganic	Primary	7439-92-1	Lead Pb	2.57E+01	Kg	
Yes	Inorganic	Primary	7439-97-6	Mercury Hg	1.93E+00	Kg	
Yes	Inorganic	Primary	7440-02-0	Nickel Ni	3.02E+01	Kg	
No	Inorganic	Primary	7782-49-2	Selenium Se	2.94E+00	Kg	U
No	Inorganic	Primary	7440-22-4	Silver Ag	7.85E+00	Kg	
No	Inorganic	Primary	18496-25-8	Sulfide S2-	1.37E-01	Kg	U
No	Inorganic	Primary	7440-28-0	Thallium Tl	7.07E+00	Kg	U
No	Inorganic	Primary	7440-62-2	Vanadium V	2.94E-01	Kg	U
No	Inorganic	Primary	7440-66-6	Zinc Zn	2.13E+00	Kg	
No	Inorganic	Secondary	71-50-1	Acetate C2H3O2-	3.53E+01	Kg	U
Yes	Inorganic	Secondary	7429-90-5	Aluminum Al	3.83E+02	Kg	
No	Inorganic	Secondary	7440-36-0	Antimony Sb	1.19E+00	Kg	U
Yes	Inorganic	Secondary	7440-69-9	Bismuth Bi	2.94E+00	Kg	U
No	Inorganic	Secondary	7440-42-8	Boron B	1.19E+00	Kg	U
No	Inorganic	Secondary	24959-67-9	Bromide Br-	4.46E+01	Kg	U
Yes	Inorganic	Secondary	7440-70-2	Calcium Ca	1.18E+02	Kg	
No	Inorganic	Secondary	7440-45-1	Cerium Ce	5.71E+00	Kg	
Yes	Inorganic	Secondary	16887-00-6	Chloride Cl-	6.15E+00	Kg	U
No	Inorganic	Secondary	7440-48-4	Cobalt Co	3.76E-01	Kg	

Table B-1. Residual Single-Shell Tank 241-C-106 Inventory Calculated from Post-Retrieval Sample using 370 ft^3 for Volume of Residual. (6 sheets)

BBI	Class	P/S	Isotope/CASRN	Constituent	Inventory	Units	DQ
No	Inorganic	Secondary	7440-50-8	Copper Cu	2.31E+00	Kg	
No	Inorganic	Secondary	7440-53-1	Europium Eu	6.23E-01	Kg	U
No	Inorganic	Secondary	12311-97-6	Formate CHO2-	3.53E+01	Kg	U
No	Inorganic	Secondary	666-14-8	Glycolate C2H3O3-	2.92E+01	Kg	U
Yes	Inorganic	Secondary	7439-89-6	Iron Fe	2.07E+02	Kg	
Yes	Inorganic	Secondary	7439-91-0	Lanthanum La	2.45E+00	Kg	
No	Inorganic	Secondary	7439-93-2	Lithium Li	1.13E-01	Kg	U
No	Inorganic	Secondary	7439-95-4	Magnesium Mg	7.11E+00	Kg	
Yes	Inorganic	Secondary	7439-96-5	Manganese Mn	5.50E+02	Kg	
No	Inorganic	Secondary	7439-98-7	Molybdenum Mo	3.06E-01	Kg	U
No	Inorganic	Secondary	7440-00-8	Neodymium Nd	9.02E+00	Kg	
No	Inorganic	Secondary	7440-03-1	Niobium Nb	4.24E+00	Kg	
Yes	Inorganic	Secondary	14797-55-8	Nitrate NO3-	4.61E+01	Kg	U
Yes	Inorganic	Secondary	14797-65-0	Nitrite NO2-	4.15E+01	Kg	U
No	Inorganic	Secondary	338-70-5	Oxalate C2O42-	3.33E+02	Kg	
No	Inorganic	Secondary	7440-05-3	Palladium Pd	7.08E+00	Kg	U
Yes	Inorganic	Secondary	14265-44-2	Phosphate PO43-	4.15E+01	Kg	U
No	Inorganic	Secondary	7723-14-0	Phosphorus P	2.94E+01	Kg	
Yes	Inorganic	Secondary	7440-09-7	Potassium K	1.77E+01	Kg	U
No	Inorganic	Secondary	7440-10-0	Praseodymium Pr	5.40E+00	Kg	
No	Inorganic	Secondary	7440-16-6	Rhodium Rh	2.45E+00	Kg	U
No	Inorganic	Secondary	7440-17-7	Rubidium Rb	2.41E+01	Kg	U
No	Inorganic	Secondary	7440-18-8	Ruthenium Ru	2.41E+00	Kg	U
No	Inorganic	Secondary	7440-19-9	Samarium Sm	2.51E+00	Kg	
No	Inorganic	Secondary	7440-21-3	Silicon Si	1.60E+01	Kg	
Yes	Inorganic	Secondary	7440-23-5	Sodium Na	1.89E+02	Kg	
Yes	Inorganic	Secondary	7440-24-6	Strontium Sr	1.83E+00	Kg	
Yes	Inorganic	Secondary	14808-79-8	Sulfate SO42-	4.92E+01	Kg	U
No	Inorganic	Secondary	7704-34-9	Sulfur S	1.30E+00	Kg	U
No	Inorganic	Secondary	7440-25-7	Tantalum Ta	2.41E+00	Kg	U
No	Inorganic	Secondary	13494-80-9	Tellurium Te	2.41E+00	Kg	U
No	Inorganic	Secondary	7440-29-1	Thorium Th	3.12E+00	Kg	

Table B-1. Residual Single-Shell Tank 241-C-106 Inventory Calculated from Post-Retrieval Sample using 370 ft^3 for Volume of Residual. (6 sheets)

BBI	Class	P/S	Isotope/CASRN	Constituent	Inventory	Units	DQ
Yes	Inorganic	Secondary	7440-31-5	Tin Sn	2.41E+00	Kg	U
No	Inorganic	Secondary	7440-32-6	Titanium Ti	3.86E-01	Kg	
No	Inorganic	Secondary	7440-33-7	Tungsten W	4.73E+00	Kg	U
Yes	Inorganic	Secondary	7440-61-1	Uranium U	2.94E+00	Kg	U
No	Inorganic	Secondary	7440-65-5	Yttrium Y	1.70E+00	Kg	
Yes	Inorganic	Secondary	7440-67-7	Zirconium Zr	2.79E+00	Kg	
No	VOA	Primary	71-55-6	1,1,1-Trichloroethane	1.15E-04	Kg	U
No	VOA	Primary	79-34-5	1,1,2,2-Tetrachloroethane	8.45E-05	Kg	U
No	VOA	Primary	76-13-1	1,1,2-Trichloro-1,2,2-trifluoroethane	1.29E-04	Kg	U
No	VOA	Primary	79-00-5	1,1,2-Trichloroethane	8.44E-05	Kg	U
No	VOA	Primary	75-35-4	1,1,Dichloroethene	1.36E-04	Kg	U
No	VOA	Primary	107-06-2	1,2-Dichloroethane	8.33E-05	Kg	U
No	VOA	Primary	78-93-3	2-Butanone (MEK)	4.48E-04	Kg	
No	VOA	Primary	79-46-9	2-Nitropropane	2.02E-04	Kg	U
No	VOA	Primary	67-64-1	2-Propanone (Acetone)	1.30E-03	Kg	
No	VOA	Primary	108-10-1	4-methyl-2-pentanone (MIBK)	1.73E-04	Kg	U
No	VOA	Primary	71-43-2	Benzene	8.08E-05	Kg	U
No	VOA	Primary	75-15-0	Carbon disulfide	1.19E-04	Kg	U
No	VOA	Primary	56-23-5	Carbon tetrachloride	1.52E-04	Kg	U
No	VOA	Primary	108-90-7	Chlorobenzene	9.97E-05	Kg	U
No	VOA	Primary	75-01-4	Chloroethene (vinyl chloride)	5.80E-05	Kg	U
No	VOA	Primary	67-66-3	Chloroform	1.23E-04	Kg	U
No	VOA	Primary	75-09-2	Dichloromethane (methylene chloride)	9.88E-05	Kg	U
No	VOA	Primary	60-29-7	Diethyl ether	1.14E-04	Kg	U
No	VOA	Primary	141-78-6	Ethyl acetate	1.26E-04	Kg	U
No	VOA	Primary	100-41-4	Ethylbenzene	2.02E-04	Kg	U
No	VOA	Primary	108-38-3	m-Xylene	2.29E-04	Kg	U
No	VOA	Primary	95-47-6	o-Xylene	7.18E-05	Kg	U
No	VOA	Primary	106-42-3	p-Xylene	2.29E-04	Kg	U
No	VOA	Primary	127-18-4	Tetrachloroethene	1.06E-04	Kg	U

Table B-1. Residual Single-Shell Tank 241-C-106 Inventory Calculated from Post-Retrieval Sample using 370 ft^3 for Volume of Residual. (6 sheets)

BBI	Class	P/S	Isotope/CASRN	Constituent	Inventory	Units	DQ
No	VOA	Primary	108-88-3	Toluene	9.51E-05	Kg	U
No	VOA	Primary	542-75-6	trans-1,3,-Dichloropropene	8.23E-05	Kg	U
No	VOA	Primary	79-01-6	Trichloroethene	1.63E-04	Kg	U
No	VOA	Primary	75-69-4	Trichlorofluoromethane	1.20E-04	Kg	U
No	VOA	Primary	1330-20-7	Xylenes	3.03E-04	Kg	U
No	SVOA	Primary	120-82-1	1,2,4-Trichlorobenzene	1.30E-04	Kg	U
No	SVOA	Primary	95-95-4	2,4,5 Trichlorophenol	1.11E-02	Kg	U
No	SVOA	Primary	88-06-2	2,4,6-Trichlorophenol	1.17E-02	Kg	U
No	SVOA	Primary	121-14-2	2,4-Dinitrotoluene	1.51E-02	Kg	U
No	SVOA	Primary	128-37-0	2,6-Bis(tert-butyl)-4-methylphenol	1.46E-02	Kg	U
No	SVOA	Primary	95-57-8	2-Chlorophenol	2.07E-02	Kg	U
No	SVOA	Primary	110-80-5	2-Ethoxyethanol	1.13E-02	Kg	U
No	SVOA	Primary	95-48-7	2-Methylphenol (o-cresol)	4.06E-02	Kg	U
No	SVOA	Primary	106-44-5	4-Methylphenol (p-cresol)	9.24E-02	Kg	U
No	SVOA	Primary	83-32-9	Acenaphthene	2.39E-02	Kg	U
No	SVOA	Primary	85-68-7	Butylbenzylphthalate	4.24E-03	Kg	U
No	SVOA	Primary	108-94-1	Cyclohexanone	3.45E-02	Kg	U
No	SVOA	Primary	84-74-2	Di-n-butylphthalate	4.26E-03	Kg	
No	SVOA	Primary	117-84-0	Di-n-octylphthalate	2.39E-02	Kg	U
No	SVOA	Primary	206-44-0	Fluoranthene	1.43E-02	Kg	U
No	SVOA	Primary	87-68-3	Hexachlorobutadiene	5.31E-03	Kg	U
No	SVOA	Primary	67-72-1	Hexachloroethane	7.61E-05	Kg	U
No	SVOA	Primary	78-83-1	Isobutanol1	2.88E-02	Kg	U
No	SVOA	Primary	108-39-4	m-Cresol (3-Methylphenol)	9.24E-02	Kg	U
No	SVOA	Primary	91-20-3	Naphthalene	9.60E-03	Kg	U
No	SVOA	Primary	71-36-3	n-Butyl alcohol (1-butanol)1	2.16E-02	Kg	U
No	SVOA	Primary	98-95-3	Nitrobenzene	1.01E-02	Kg	U
No	SVOA	Primary	621-64-7	N-nitroso-di-n-propylamine	1.35E-02	Kg	U
No	SVOA	Primary	59-89-2	N-Nitrosomorpholine	1.20E-02	Kg	U
No	SVOA	Primary	59-50-7	p-Chloro-m-cresol (4-Chloro-3-methylphenol)	7.65E-03	Kg	U
No	SVOA	Primary	129-00-0	Pyrene	2.31E-02	Kg	U

Table B-1. Residual Single-Shell Tank 241-C-106 Inventory Calculated from Post-Retrieval Sample using 370 ft^3 for Volume of Residual. (6 sheets)

BBI	Class	P/S	Isotope/CASRN	Constituent	Inventory	Units	DQ
No	SVOA	Primary	110-86-1	Pyridine	1.44E-02	Kg	U
No	SVOA	Hanford SVOA TICs	106-46-7	1,4-Dichlorobenzene	2.07E-02	Kg	U
No	SVOA	Hanford Lib SVOA TICs	87-86-5	Pentachlorophenol	1.04E-02	Kg	U
No	SVOA	Hanford Lib SVOA TICs	108-95-2	Phenol	4.72E-02	Kg	U
No	SVOA	NIST SVOA TICs	95-50-1	1,2-Dichlorobenzene	2.15E-02	Kg	U
No	SVOA	NIST SVOA TICs	88-75-5	2-Nitrophenol	2.47E-02	Kg	U
No	SVOA	NIST SVOA TICs	100-02-7	4-Nitrophenol	1.14E-02	Kg	U
No	SVOA	NIST SVOA TICs	1319-77-3	Total Methylphenols	5.83E-02	Kg	U
No	PCB	Primary	11097-69-1	Aroclors (Total PCBs)	1.36E-03	Kg	U

Notes:

BBI = best-basis inventory.

CASRN = Chemical Abstract Symbol Registration Number.

DQ = Detection Qualifier Flag (U= Nondetect, Inventory for nondetects calculated at the detection limit [RPP-20226, *Analytical Results for Liquid Grab Sampling and Analysis Plan for Tank 241-C-106 Component Closure Action* and RPP-20264, *Analytical Results for Tank 241-C-106 Solid Clam Shell Samples Supporting Closure Action*]).

NIST = National Institute of Science and Technology.

P/S = Primary or Secondary Constituent (RPP-13889, *Tank 241-C-106 Component Closure Action Data Quality Objectives*).

PCB = polychlorinated biphenyl.

SVOA = semivolatile organics.

TIC = total inorganic carbon.

VOA = volatile organic analysis.

Table B-2. Results of Contaminants of Potential Concern Screening Process. (13 sheets)

CASRN	Constituent	Residual inventory[1] (Ci or kg)	WMA C fenceline concentration (pCi/L or mg/L)	Incremental lifetime cancer risk	Hazard index	Contaminant of potential concern	Screening step	Reason for inclusion in risk assessment	Reason for exclusion in risk assessment
144Pr	Praseodymium-144	1.38E+02	1.21E+03	N/A	N/A	No	1	N/A	No Toxicity Value Available
228Ac	Actinium-228	3.89E+01	3.40E+02	N/A	N/A	No	1	N/A	No Toxicity Value Available
18496-25-8	Sulfide S2-	6.83E-02	5.97E-07	N/A	N/A	No	1	N/A	No Toxicity Value Available
71-50-1	Acetate C2H3O2-	1.77E+01	1.54E-04	N/A	N/A	No	1	N/A	No Toxicity Value Available
7440-69-9	Bismuth Bi	1.47E+00	1.29E-05	N/A	N/A	No	1	N/A	No Toxicity Value Available
24959-67-9	Bromide Br-	2.23E+01	1.95E-04	N/A	N/A	No	1	N/A	No Toxicity Value Available
16887-00-6	Chloride Cl-	3.08E+00	2.69E-05	N/A	N/A	No	1	N/A	No Toxicity Value Available
7440-53-1	Europium Eu	3.11E-01	2.72E-06	N/A	N/A	No	1	N/A	No Toxicity Value Available
12311-97-6	Formate CHO2-	1.77E+01	1.54E-04	N/A	N/A	No	1	N/A	No Toxicity Value Available
666-14-8	Glycolate C2H3O3-	1.46E+01	1.28E-04	N/A	N/A	No	1	N/A	No Toxicity Value Available
7440-05-3	Palladium Pd	3.54E+00	3.09E-05	N/A	N/A	No	1	N/A	No Toxicity Value Available
14265-44-2	Phosphate PO43-	2.08E+01	1.81E-04	N/A	N/A	No	1	N/A	No Toxicity Value Available
7440-09-7	Potassium K	8.86E+00	7.74E-05	N/A	N/A	No	1	N/A	No Toxicity Value Available

Table B-2. Results of Contaminants of Potential Concern Screening Process. (13 sheets)

CASRN	Constituent	Residual inventory[1] (Ci or kg)	WMA C fenceline concentration (pCi/L or mg/L)	Incremental lifetime cancer risk	Hazard index	Contaminant of potential concern	Screening step	Reason for inclusion in risk assessment	Reason for exclusion in risk assessment
7440-16-6	Rhodium Rh	1.23E+00	1.07E-05	N/A	N/A	No	1	N/A	No Toxicity Value Available
7440-17-7	Rubidium Rb	1.20E+01	1.05E-04	N/A	N/A	No	1	N/A	No Toxicity Value Available
7440-18-8	Ruthenium Ru	1.20E+00	1.05E-05	N/A	N/A	No	1	N/A	No Toxicity Value Available
14808-79-8	Sulfate SO42-	2.46E+01	2.15E-04	N/A	N/A	No	1	N/A	No Toxicity Value Available
7704-34-9	Sulfur S	6.52E-01	5.69E-06	N/A	N/A	No	1	N/A	No Toxicity Value Available
7440-25-7	Tantalum Ta	1.20E+00	1.05E-05	N/A	N/A	No	1	N/A	No Toxicity Value Available
13494-80-9	Tellurium Te	1.20E+00	1.05E-05	N/A	N/A	No	1	N/A	No Toxicity Value Available
7440-33-7	Tungsten W	2.37E+00	2.07E-05	N/A	N/A	No	1	N/A	No Toxicity Value Available
128-37-0	2,6-Bis(tert-butyl)-4-methylphenol	7.30E-03	6.37E-08	N/A	N/A	No	1	N/A	No Toxicity Value Available
59-89-2	N-Nitrosomorpholine	6.00E-03	5.24E-08	N/A	N/A	No	1	N/A	No Toxicity Value Available
59-50-7	p-Chloro-m-cresol	3.82E-03	3.34E-08	N/A	N/A	No	1	N/A	No Toxicity Value Available
88-75-5	2-Nitrophenol	1.24E-02	1.08E-07	N/A	N/A	No	1	N/A	No Toxicity Value Available
100-02-7	4-Nitrophenol	5.69E-03	4.97E-08	N/A	N/A	No	1	N/A	No Toxicity Value Available

Table B-2. Results of Contaminants of Potential Concern Screening Process. (13 sheets)

CASRN	Constituent	Residual inventory[1] (Ci or kg)	WMA C fenceline concentration (pCi/L or mg/L)	Incremental lifetime cancer risk	Hazard index	Contaminant of potential concern	Screening step	Reason for inclusion in risk assessment	Reason for exclusion in risk assessment
1319-77-3	Total Methylphenols (Cresol)	2.91E-02	2.55E-07	N/A	N/A	No	1	N/A	No Toxicity Value Available
60-29-7	Diethyl ether	5.68E-05	4.96E-10	N/A	N/A	No	1	N/A	No Toxicity Value Available
14798-03-9	Ammonium NH4+	9.70E-01	8.47E-06	N/A	N/A	No	1	N/A	No Toxicity Value Available
7439-92-1	Lead Pb	2.57E+01	2.24E-04	N/A	N/A	No	1	N/A	No Toxicity Value Available
7440-70-2	Calcium Ca	1.18E+02	1.03E-03	N/A	N/A	No	1	N/A	No Toxicity Value Available
7440-45-1	Cerium Ce	5.71E+00	4.99E-05	N/A	N/A	No	1	N/A	No Toxicity Value Available
7439-91-0	Lanthanum La	2.45E+00	2.14E-05	N/A	N/A	No	1	N/A	No Toxicity Value Available
7439-95-4	Magnesium Mg	7.11E+00	6.21E-05	N/A	N/A	No	1	N/A	No Toxicity Value Available
7440-00-8	Neodymium Nd	9.02E+00	7.88E-05	N/A	N/A	No	1	N/A	No Toxicity Value Available
7440-03-1	Niobium Nb	4.24E+00	3.70E-05	N/A	N/A	No	1	N/A	No Toxicity Value Available
338-70-5	Oxalate C2O42-	3.33E+02	2.91E-03	N/A	N/A	No	1	N/A	No Toxicity Value Available
7723-14-0	Phosphorus P	2.94E+01	2.57E-04	N/A	N/A	No	1	N/A	No Toxicity Value Available
7440-10-0	Praseodymium Pr	5.40E+00	4.72E-05	N/A	N/A	No	1	N/A	No Toxicity Value Available

Table B-2. Results of Contaminants of Potential Concern Screening Process. (13 sheets)

CASRN	Constituent	Residual inventory[1] (Ci or kg)	WMA C fenceline concentration (pCi/L or mg/L)	Incremental lifetime cancer risk	Hazard index	Contaminant of potential concern	Screening step	Reason for inclusion in risk assessment	Reason for exclusion in risk assessment
7440-19-9	Samarium Sm	2.51E+00	2.20E-05	N/A	N/A	No	1	N/A	No Toxicity Value Available
7440-21-3	Silicon Si	1.60E+01	1.40E-04	N/A	N/A	No	1	N/A	No Toxicity Value Available
7440-23-5	Sodium Na	1.89E+02	1.65E-03	N/A	N/A	No	1	N/A	No Toxicity Value Available
7440-29-1	Thorium Th	3.12E+00	2.72E-05	N/A	N/A	No	1	N/A	No Toxicity Value Available
7440-32-6	Titanium Ti	3.86E-01	3.37E-06	N/A	N/A	No	1	N/A	No Toxicity Value Available
7440-65-5	Yttrium Y	1.70E+00	1.48E-05	N/A	N/A	No	1	N/A	No Toxicity Value Available
7440-67-7	Zirconium Zr	2.79E+00	2.44E-05	N/A	N/A	No	1	N/A	No Toxicity Value Available
63Ni	Nickel-63	7.30E+01	6.37E+02	2.14E-06	N/A	Yes	2	Contaminant Detected	N/A
90Sr	Strontium-90	6.61E+04	5.77E+05	2.15E-01	N/A	Yes	2	Contaminant Detected	N/A
99Tc	Technetium-99	1.65E-01	1.44E+00	1.99E-08	N/A	Yes	2	Contaminant Detected	N/A
137Cs	Cesium-137	1.45E+03	1.26E+04	4.13E-03	N/A	Yes	2	Contaminant Detected	N/A
228^{Th}	Thorium-228	5.75E-04	5.02E-03	8.71E-09	N/A	Yes	2	Contaminant Detected	N/A
230^{Th}	Thorium-230	8.82E-04	7.71E-03	3.69E-09	N/A	Yes	2	Contaminant Detected	N/A

Table B-2. Results of Contaminants of Potential Concern Screening Process. (13 sheets)

CASRN	Constituent	Residual inventory[1] (Ci or kg)	WMA C fenceline concentration (pCi/L or mg/L)	Incremental lifetime cancer risk	Hazard index	Contaminant of potential concern	Screening step	Reason for inclusion in risk assessment	Reason for exclusion in risk assessment
232Th	Thorium-232	5.61E-04	4.90E-03	4.65E-09	N/A	Yes	2	Contaminant Detected	N/A
233U	Uranium-233	1.83E-03	1.60E-2	5.90E-09	N/A	Yes	2	Contaminant Detected	N/A
234U	Uranium-234	9.48E-04	8.3E-03	3.00E-09	N/A	Yes	2	Contaminant Detected	N/A
235U	Uranium-235	3.87E-05	3.39E-04	1.36E-10	N/A	Yes	2	Contaminant Detected	N/A
236U	Uranium-236	1.73E-05	1.51E-04	5.20E-11	N/A	Yes	2	Contaminant Detected	N/A
238U	Uranium-238	9.04E-04	7.91E-03	3.55E-09	N/A	Yes	2	Contaminant Detected	N/A
237Np	Neptunium-237	5.42E-02	4.74E-01	1.94E-07	N/A	Yes	2	Contaminant Detected	N/A
239Pu	Plutonium-239	1.68E+01	1.47E+02	1.03E-04	N/A	Yes	2	Contaminant Detected	N/A
240Pu	Plutonium-240	3.58E+00	3.13E+01	2.19E-05	N/A	Yes	2	Contaminant Detected	N/A
241Pu	Plutonium-241	3.97E+01	3.47E+02	3.16E-06	N/A	Yes	2	Contaminant Detected	N/A
241Am	Americium-241	6.53E+01	5.71E+02	3.10E-04	N/A	Yes	2	Contaminant Detected	N/A
7440-39-3	Barium Ba	1.64E+00	1.43E-05	N/A	2.53E-06	Yes	2	Contaminant Detected	N/A
7440-43-9	Cadmium Cd	1.44E+00	1.26E-05	1.05E-10	3.30E-04	Yes	2	Contaminant Detected	N/A

Table B-2. Results of Contaminants of Potential Concern Screening Process. (13 sheets)

CASRN	Constituent	Residual inventory[1] (Ci or kg)	WMA C fenceline concentration (pCi/L or mg/L)	Incremental lifetime cancer risk	Hazard index	Contaminant of potential concern	Screening step	Reason for inclusion in risk assessment	Reason for exclusion in risk assessment
18540-29-9	Chromium Cr	3.79E+00	3.31E-05	8.92E-10	1.43E-04	Yes	2	Contaminant Detected	N/A
57-12-5	Cyanide CN-	7.82E-02	6.83E-07	N/A	3.40E-07	Yes	2	Contaminant Detected	N/A
7439-97-6	Mercury Hg	1.93E+00	1.69E-05	N/A	6.33E-03	Yes	2	Contaminant Detected	N/A
7440-02-0	Nickel Ni	3.02E+01	2.64E-04	N/A	1.31E-04	Yes	2	Contaminant Detected	N/A
7440-22-4	Silver Ag	7.85E+00	6.86E-05	N/A	1.37E-04	Yes	2	Contaminant Detected	N/A
7440-66-6	Zinc Zn	2.13E+00	1.86E-05	N/A	6.17E-07	Yes	2	Contaminant Detected	N/A
7429-90-5	Aluminum Al	3.83E+02	3.34E-03	N/A	4.64E-05	Yes	2	Contaminant Detected	N/A
7440-48-4	Cobalt Co	3.76E-01	3.29E-06	4.24E-11	4.28E-06	Yes	2	Contaminant Detected	N/A
7440-50-8	Copper Cu	2.31E+00	2.02E-05	N/A	5.01E-06	Yes	2	Contaminant Detected	N/A
7439-89-6	Iron Fe	2.07E+02	1.81E-03	N/A	6.01E-05	Yes	2	Contaminant Detected	N/A
7439-96-5	Manganese Mn	5.50E+02	4.81E-03	N/A	2.62E-03	Yes	2	Contaminant Detected	N/A
7440-24-6	Strontium Sr	1.83E+00	1.60E-05	N/A	2.67E-07	Yes	2	Contaminant Detected	N/A
84-74-2	Di-n-butylphthalate	4.26E-03	3.72E-08	N/A	4.39E-09	Yes	2	Contaminant Detected	N/A

Table B-2. Results of Contaminants of Potential Concern Screening Process. (13 sheets)

CASRN	Constituent	Residual inventory[1] (Ci or kg)	WMA C fenceline concentration (pCi/L or mg/L)	Incremental lifetime cancer risk	Hazard index	Contaminant of potential concern	Screening step	Reason for inclusion in risk assessment	Reason for exclusion in risk assessment
78-93-3	2-Butanone (MEK)	4.48E-04	3.91E-09	N/A	3.34E-10	Yes	2	Contaminant Detected	N/A
67-64-1	2-Propanone (Acetone)	1.30E-03	1.14E-08	N/A	1.24E-10	Yes	2	Contaminant Detected	N/A
3H	Tritium	5.11E-03	4.46E-02	3.01E-11	N/A	No	3	N/A	ILCR or HI < screening threshold
14C	Carbon-14	4.12E-03	3.60E-02	2.80E-10	N/A	No	3	N/A	ILCR or HI < screening threshold
79Se	Selenium-79	4.80E-03	4.19E-02	1.53E-09	N/A	No	3	N/A	ILCR or HI < screening threshold
129I	Iodine-129	3.16E-04	2.76E-03	2.05E-09	N/A	No	3	N/A	ILCR or HI < screening threshold
7440-38-2	Arsenic As	1.443356	1.26E-05	5.62E-08	4.22E-04	No	3	N/A	ILCR or HI < screening threshold
7440-41-7	Beryllium Be	2.83E-02	2.47E-07	2.77E-12	1.72E-06	No	3	N/A	ILCR or HI < screening threshold
16984-48-8	Fluoride F-	0.2720425	2.38E-06	N/A	3.94E-07	No	3	N/A	ILCR or HI < screening threshold
7782-49-2	Seleniun Se	1.4717202	1.29E-05	N/A	2.55E-05	No	3	N/A	ILCR or HI < screening threshold
7440-28-0	Thallium Tl	3.5374614	3.09E-05	N/A	4.65E-03	No	3	N/A	ILCR or HI < screening threshold
7440-62-2	Vanadium V	0.1471675	1.29E-06	N/A	2.67E-06	No	3	N/A	ILCR or HI < screening threshold
7440-36-0	Antimony Sb	0.5943721	5.19E-06	N/A	1.53E-04	No	3	N/A	ILCR or HI < screening threshold

Table B-2. Results of Contaminants of Potential Concern Screening Process. (13 sheets)

CASRN	Constituent	Residual inventory[1] (Ci or kg)	WMA C fenceline concentration (pCi/L or mg/L)	Incremental lifetime cancer risk	Hazard index	Contaminant of potential concern	Screening step	Reason for inclusion in risk assessment	Reason for exclusion in risk assessment
7440-42-8	Boron B	0.5943712	5.19E-06	N/A	5.77E-07	No	3	N/A	ILCR or HI < screening threshold
7439-93-2	Lithium Li	5.66E-02	4.94E-07	N/A	2.45E-07	No	3	N/A	ILCR or HI < screening threshold
7439-98-7	Molybdenum Mo	0.152833	1.34E-06	N/A	2.65E-06	No	3	N/A	ILCR or HI < screening threshold
14797-55-8	Nitrate NO3-	23.051267	2.01E-04	N/A	1.25E-06	No	3	N/A	ILCR or HI < screening threshold
14797-65-0	Nitrite NO2-	20.74614	1.81E-04	N/A	1.79E-05	No	3	N/A	ILCR or HI < screening threshold
7440-31-5	Tin Sn	1.2031239	1.05E-05	N/A	1.90E-07	No	3	N/A	ILCR or HI < screening threshold
7440-61-1	Uranium U	1.4717489	1.29E-05	4.95E-11	8.05E-06	No	3	N/A	ILCR or HI < screening threshold
120-82-1	1,2,4-Trichlorobenzene	6.48E-05	5.66E-10	N/A	1.74E-09	No	3	N/A	ILCR or HI < screening threshold
95-95-4	2,4,5 Trichlorophenol	0.0055299	4.83E-08	N/A	6.41E-09	No	3	N/A	ILCR or HI < screening threshold
88-06-2	2,4,6-Trichlorophenol	5.85E-03	5.11E-08	3.77E-12	6.69E-06	No	3	N/A	ILCR or HI < screening threshold
121-14-2	2,4-Dinitrotoluene	0.0075286	6.58E-08	N/A	3.28E-07	No	3	N/A	ILCR or HI < screening threshold
95-57-8	2-Chlorophenol	1.04E-02	9.06E-08	N/A	1.90E-07	No	3	N/A	ILCR or HI < screening threshold
110-80-5	2-Ethoxyethanol	5.66E-03	4.95E-08	N/A	2.86E-09	No	3	N/A	ILCR or HI < screening threshold

Table B-2. Results of Contaminants of Potential Concern Screening Process. (13 sheets)

CASRN	Constituent	Residual inventory[1] (Ci or kg)	WMA C fenceline concentration (pCi/L or mg/L)	Incremental lifetime cancer risk	Hazard index	Contaminant of potential concern	Screening step	Reason for inclusion in risk assessment	Reason for exclusion in risk assessment
95-48-7	2-Methylphenol (o-cresol)	0.0203041	1.77E-07	N/A	3.72E-08	No	3	N/A	ILCR or HI < screening threshold
106-44-5	4-Methylphenol (p-cresol)	4.62E-02	4.03E-07	N/A	8.34E-07	No	3	N/A	ILCR or HI < screening threshold
83-32-9	Acenaphthene	0.0119428	1.04E-07	N/A	4.15E-08	No	3	N/A	ILCR or HI < screening threshold
85-68-7	Butylbenzylphthalate	2.12E-03	1.85E-08	N/A	1.18E-09	No	3	N/A	ILCR or HI < screening threshold
108-94-1	Cyclohexanone	1.72E-02	1.50E-07	N/A	2.97E-10	No	3	N/A	ILCR or HI < screening threshold
117-84-0	Di-n-octylphthalate	0.0119508	1.04E-07	N/A	8.95E-07	No	3	N/A	ILCR or HI < screening threshold
206-44-0	Fluoranthene	0.0071601	6.25E-08	N/A	1.00E-07	No	3	N/A	ILCR or HI < screening threshold
87-68-3	Hexachlorobutadiene	2.65E-03	2.32E-08	5.95E-11	2.05E-06	No	3	N/A	ILCR or HI < screening threshold
67-72-1	Hexachloroethane	3.80E-05	3.32E-10	1.50E-13	4.55E-09	No	3	N/A	ILCR or HI < screening threshold
78-83-1	Isobutanol1	0.0144062	1.26E-07	N/A	4.15E-09	No	3	N/A	ILCR or HI < screening threshold
108-39-4	m-Cresol (3-Methylphenol)	4.62E-02	4.03E-07	N/A	8.48E-08	No	3	N/A	ILCR or HI < screening threshold
91-20-3	Naphthalene	4.80E-03	4.19E-08	N/A	4.86E-06	No	3	N/A	ILCR or HI < screening threshold
71-36-3	n-Butyl alcohol (1-butanol)1	0.0108183	9.45E-08	N/A	1.13E-06	No	3	N/A	ILCR or HI < screening threshold

Table B-2. Results of Contaminants of Potential Concern Screening Process. (13 sheets)

CASRN	Constituent	Residual inventory[1] (Ci or kg)	WMA C fenceline concentration (pCi/L or mg/L)	Incremental lifetime cancer risk	Hazard index	Contaminant of potential concern	Screening step	Reason for inclusion in risk assessment	Reason for exclusion in risk assessment
98-95-3	Nitrobenzene	5.03E-03	4.40E-08	N/A	8.35E-06	No	3	N/A	ILCR or HI < screening threshold
621-64-7	N-nitroso-di-n-propylamine	6.77E-03	5.91E-08	1.21E-09	N/A	No	3	N/A	ILCR or HI < screening threshold
129-00-0	Pyrene	1.15E-02	1.01E-07	N/A	1.48E-07	No	3	N/A	ILCR or HI < screening threshold
110-86-1	Pyridine	7.21E-03	6.30E-08	N/A	6.25E-07	No	3	N/A	ILCR or HI < screening threshold
106-46-7	1,4-Dichlorobenzene	1.03E-02	9.04E-08	5.86E-11	7.58E-08	No	3	N/A	ILCR or HI < screening threshold
87-86-5	Pentachlorophenol	5.20E-03	4.54E-08	2.53E-11	2.46E-08	No	3	N/A	ILCR or HI < screening threshold
108-95-2	Phenol	2.36E-02	2.06E-07	N/A	6.89E-09	No	3	N/A	ILCR or HI < screening threshold
95-50-1	1,2-Dichlorobenzene	0.0107447	9.39E-08	N/A	1.68E-07	No	3	N/A	ILCR or HI < screening threshold
71-55-6	1,1,1-Trichloroethane	5.76E-05	5.03E-10	N/A	9.64E-11	No	3	N/A	ILCR or HI < screening threshold
79-34-5	1,1,2,2-Tetrachloroethane	4.22E-05	3.69E-10	2.33E-12	N/A	No	3	N/A	ILCR or HI < screening threshold
76-13-1	1,1,2-Trichloro-1,2,2-trifluoroethane	6.46E-05	5.65E-10	N/A	6.71E-12	No	3	N/A	ILCR or HI < screening threshold
79-00-5	1,1,2-Trichloroethane	4.22E-05	3.69E-10	6.43E-13	9.26E-10	No	3	N/A	ILCR or HI < screening threshold
75-35-4	1,1,Dichloroethene	6.80E-05	5.94E-10	N/A	1.15E-09	No	3	N/A	ILCR or HI < screening threshold

Table B-2. Results of Contaminants of Potential Concern Screening Process. (13 sheets)

CASRN	Constituent	Residual inventory[1] (Ci or kg)	WMA C fenceline concentration (pCi/L or mg/L)	Incremental lifetime cancer risk	Hazard index	Contaminant of potential concern	Screening step	Reason for inclusion in risk assessment	Reason for exclusion in risk assessment
107-06-2	1,2-Dichloroethane	4.17E-05	3.64E-10	1.03E-12	3.61E-08	No	3	N/A	ILCR or HI < screening threshold
79-46-9	2-Nitropropane	1.01E-04	8.82E-10	2.34E-10	1.53E-08	No	3	N/A	ILCR or HI < screening threshold
108-10-1	4-methyl-2-pentanone (MIBK)	8.67E-05	7.57E-10	N/A	1.82E-10	No	3	N/A	ILCR or HI < screening threshold
71-43-2	Benzene	4.04E-05	3.53E-10	3.30E-13	4.99E-09	No	3	N/A	ILCR or HI < screening threshold
75-15-0	Carbon disulfide	5.97E-05	5.22E-10	N/A	3.13E-10	No	3	N/A	ILCR or HI < screening threshold
56-23-5	Carbon tetrachloride	7.61E-05	6.65E-10	1.26E-12	1.04E-08	No	3	N/A	ILCR or HI < screening threshold
108-90-7	Chlorobenzene	4.99E-05	4.36E-10	N/A	2.84E-09	No	3	N/A	ILCR or HI < screening threshold
75-01-4	Chloroethene (vinyl chloride)	2.90E-05	2.53E-10	6.25E-13	1.73E-09	No	3	N/A	ILCR or HI < screening threshold
67-66-3	Chloroform	6.13E-05	5.35E-10	1.22E-12	5.94E-08	No	3	N/A	ILCR or HI < screening threshold
75-09-2	Dichloromethane	4.94E-05	4.32E-10	2.93E-14	1.21E-10	No	3	N/A	ILCR or HI < screening threshold
141-78-6	Ethyl acetate	6.29E-05	5.49E-10	N/A	6.02E-12	No	3	N/A	ILCR or HI < screening threshold
100-41-4	Ethylbenzene	1.01E-04	8.81E-10	9.95E-14	4.13E-10	No	3	N/A	ILCR or HI < screening threshold
108-38-3	m-Xylene	1.15E-04	1.00E-09	N/A	3.53E-09	No	3	N/A	ILCR or HI < screening threshold

Table B-2. Results of Contaminants of Potential Concern Screening Process. (13 sheets)

CASRN	Constituent	Residual inventory[1] (Ci or kg)	WMA C fenceline concentration (pCi/L or mg/L)	Incremental lifetime cancer risk	Hazard index	Contaminant of potential concern	Screening step	Reason for inclusion in risk assessment	Reason for exclusion in risk assessment
95-47-6	o-Xylene	3.59E-05	3.14E-10	N/A	1.10E-09	No	3	N/A	ILCR or HI < screening threshold
106-42-3	p-Xylene	1.15E-04	1.00E-09	N/A	3.53E-09	No	3	N/A	ILCR or HI < screening threshold
127-18-4	Tetrachloroethene	5.31E-05	4.64E-10	1.05E-13	9.28E-10	No	3	N/A	ILCR or HI < screening threshold
108-88-3	Toluene	4.75E-05	4.15E-10	N/A	3.84E-10	No	3	N/A	ILCR or HI < screening threshold
542-75-6	trans-1,3,-Dichloropropene	4.12E-05	3.59E-10	2.49E-13	6.35E-09	No	3	N/A	ILCR or HI < screening threshold
79-01-6	Trichloroethene	8.13E-05	7.10E-10	8.94E-12	1.33E-08	No	3	N/A	ILCR or HI < screening threshold
75-69-4	Trichlorofluoromethane	6.02E-05	5.26E-10	N/A	2.81E-10	No	3	N/A	ILCR or HI < screening threshold
1330-20-7	Xylenes	1.52E-04	1.32E-09	N/A	4.66E-09	No	3	N/A	ILCR or HI < screening threshold
11097-69-1	Aroclors (Total PCBs)	6.80E-04	5.94E-09	1.06E-10	1.69E-05	No	3	N/A	ILCR or HI < screening threshold
60Co	Cobalt-60	9.02E+00	7.88E+01	4.38E-05	N/A	Yes	5	Primary Constituent	N/A
152Eu	Europium-152	3.14E+01	2.74E+02	9.24E-05	N/A	Yes	5	Primary Constituent	N/A
154Eu	Europium-154	4.07E+01	3.55E+02	1.21E-04	N/A	Yes	5	Primary Constituent	N/A
155Eu	Europium-155	3.90E+01	3.41E+02	4.78E-06	N/A	Yes	5	Primary Constituent	N/A

Table B-2. Results of Contaminants of Potential Concern Screening Process. (13 sheets)

CASRN	Constituent	Residual inventory[1] (Ci or kg)	WMA C fenceline concentration (pCi/L or mg/L)	Incremental lifetime cancer risk	Hazard index	Contaminant of potential concern	Screening step	Reason for inclusion in risk assessment	Reason for exclusion in risk assessment
238Pu	Plutonium-238	1.35E+00	1.18E+01	8.04E-06	N/A	Yes	5	Primary Constituent	N/A
242Cm	Curium-242	7.88E-02	6.89E-01	1.38E-07	N/A	Yes	5	Primary Constituent	N/A
243Cm	Curium-243	1.51E-01	1.32E+00	6.88E-07	N/A	Yes	5	Primary Constituent	N/A
244Cm	Curium-244	3.63E+00	3.17E+01	1.38E-05	N/A	Yes	5	Primary Constituent	N/A
94Nb	Niobium-94	9.39E+00	8.20E+01	5.05E-05	N/A	No	6	N/A	Contaminant Immobile, Kd>0.6
106Ru	Ruthenium-106	1.69E+02	1.47E+03	3.26E-04	N/A	No	6	N/A	Short-Lived Half-Life = (1.02 yr)
125Sb	Antimony-125	3.17E+01	2.77E+02	1.86E-05	N/A	No	6	N/A	Short-Lived Half-Life = (1.02 yr)
134Cs	Cesium-134	8.70E+00	7.60E+01	2.69E-05	N/A	No	6	N/A	Contaminant Immobile, Kd>0.6
226Ra	Radium-226	2.08E+02	1.82E+03	4.77E-03	N/A	No	6	N/A	Contaminant Immobile, Kd>0.6

Notes:

Shaded cells are reported as nondetect for that analyte.

[1]*Inventory in risk assessment calculated at ½ the detection limit.*

CASRN = Chemical Abstract Symbol Registration Number.

HI = hazard index.

ILCR = incremental lifetime cancer risk.

PCB = polychlorinated biphenyl.

WMA = Waste Management Area.

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APPENDIX C

DETAILED COST BACKUP FOR RETRIEVAL ALTERNATIVES

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Table C-1. Summary of Costs for Retrieval Alternatives.

Alternate	Description	Subtotal	Contingency	%	Total
A	Raw water modified sluicing (Current Equipment)	$1,604,958	$320,992	20	$1,925,950
B	New modified sluicing with New Slurry Pump	$4,534,988	$1,133,747	25	$5,668,735
C	Modified sluicing followed by New Vacuum Retrieval System	$7,824,302	$2,347,291	30	$10,171,593
D	Mobile Retrieval System	$10,101,364	$3,030,409	30	$13,131,774
Estimate Type	"Planning/Feasibility" or "Order of Magnitude"				
Lead Estimator	A. K. Larson INITIAL				
Project Manager Approval	M. H. Sturges/T. L. Sams INITIAL				
Date Issued	May 5, 2004				

Notes:

The degree of accuracy for this type of estimate is assumed to be approximately + or - 40% (Reference DOE G 430.1-1, Cost Estimating Guide, Chapter 4 - Types of Cost Estimates, dated 03-28-97). Contingency percentages were provided by the CH2M HILL Retrieval/Closure Special Projects Manager and applied at each alternative Total Project Cost estimate total as shown on this summary report.

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Table C-2. Detail Backup for Alternative A. (2 Sheets)

Description	Quantity	Unit	Labor unit cost	Total labor hours	Labor rate	Labor dollars	Material unit cost	Material dollars	Subcontract dollars	Total dollars
PROJECT MANAGEMENT										
Assume Project Management @ 15% of TPC	1	LS	2790	2790	$75.00	$209,250.00	$0.00	$0.00	--	$209,250.00
ENGINEERING										
Prepare Design ECN's (simple)	10	EA	60	600	$90.00	$0.00	$0.00	$0.00	$54,000.00	$54,000.00
CH2M HILL Design Support	10	EA	20	200	$70.00	$14,000.00	$0.00	$0.00	--	$14,000.00
Title III Engineering @ 30% of Construction	1	LS	0	0	$0.00	$0.00	$0.00	$0.00	$12,100.00	$12,100.00
NEC Inspection	1	LS	16	16	$75.00	$1,200.00	$0.00	$0.00	--	$1,200.00
Perform IQRPE	1	LS	0	0	$0.00	$0.00	$0.00	$0.00	$5,000.00	$5,000.00
Total Engineering										$86,300.00
PROCUREMENT										
HIHTL Cover Plates (assume existing)	100	LF	0	0	$0.00	$0.00	$0.00	$0.00	--	$0.00
Slider Coupler Connection	1	EA	0	0	$0.00	$0.00	$8,000.00	$8,000.00	--	$8,000.00
Exhauster HEPA Filter	1	EA	0	0	$0.00	$0.00	$3,500.00	$3,500.00	--	$3,500.00
Sales Tax @ 8.3%	--	--	--	--	--	--	--	$954.50	--	$954.50
Total Procurement										$12,454.50
CONSTRUCTION										
Reconnect HIHTL AN-106 to C-106										
Disconnect AN-106 HIHTL @ C-103 valve box	1	LS	40	40	$53.00	$2,120.00	$200.00	$200.00	--	$2,320.00
Re-install Existing HIHTL AN-106 to HIHTL @ C-106 (Includes Sitework)	100	LF	2	200	$53.00	$10,600.00	$0.00	$0.00	--	$10,600.00
Re-Install Cover Plates	1	LS	40	40	$53.00	$2,120.00	$0.00	$0.00	--	$2,120.00
Connect Heat Trace	1	LS	24	24	$53.00	$1,272.00	$500.00	$500.00	--	$1,772.00
Tank C-106										
Re-Connect Electrical at Pump	1	LS	20	20	$53.00	$1,060.00	$200.00	$200.00	--	$1,260.00
Re-install Tank Camera	1	LS	40	40	$53.00	$2,120.00	$200.00	$200.00	--	$2,320.00
Re- Setup Retrieval System	1	LS	240	240	$53.00	$12,720.00	$2,000.00	$2,000.00	--	$14,720.00
Re-start/Re-calibrate Exhauster	1	LS	80	80	$53.00	$4,240.00	$1,000.00	$1,000.00	--	$5,240.00
Sub Total Construction	--	--	--	684	--	$36,252.00	--	$4,100.00	$0.00	$40,352.00
Productivity Factor - (Full Time Respirator Work) Assume 30%	--	--	--	205	--	$10,875.60	--	--	--	$10,875.60
Weather Delays - Assume 20%	--	--	--	178	--	$9,425.52	--	--	--	$9,425.52
Sales Tax on Materials - 8.3%	--	--	--	--	--	--	--	$340.30	--	$340.30
Total Construction	--	--	--	1067	--	$56,553.12	--	$4,440.30	$0.00	$60,993.42
Construction Support										
Prepare Work Packages (Contract)	3	EA	200	600	$75.00	$45,000.00	$0.00	$0.00	--	$45,000.00
Crane/Crane Crew (allowance)	2	DAY	0	0	$0.00	$0.00	$0.00	$0.00	$10,000.00	$10,000.00

Table C-2. Detail Backup for Alternative A. (2 Sheets)

Description	Quantity	Unit	Labor unit cost	Total labor hours	Labor rate	Labor dollars	Material unit cost	Material dollars	Subcontract dollars	Total dollars
Other Equipment Usage Charges (Pump & Water Truck)	1	LS	0	0	$0.00	$0.00	$0.00	$0.00	$7,000.00	$7,000.00
Misc CHG Engrg Support (USQ, Lock/Tag, Pre Job, Excav Permit, etc.)	1	LS	400	400	$70.00	$28,000.00	$0.00	$0.00	--	$28,000.00
HI Support 1-4 Ratio	1	LS	270	270	$66.00	$17,820.00	$0.00	$0.00	--	$17,820.00
HPT Support 1-4 Ratio	1	LS	270	270	$50.00	$13,500.00	$0.00	$0.00	--	$13,500.00
Other Support										
CHG Construction Support	1	LS	500	500	$78.00	$39,000.00	$0.00	$0.00	--	$39,000.00
Total Construction and Construction Support	--	--	--	**3107**	--	**$199,873.12**	--	**$4,440.30**	**$17,000.00**	**$221,313.42**
PROCEDURE DEVELOPMENT (assume existing procedures will be used)										**$0.00**
STARTUP AND READINESS										
Reference C-Farm CEIS Estimate ($230,000) Assume 50%	1	LS	0	0	$0.00	$0.00	$0.00	$0.00	$115,000.00	**$115,000.00**
OPERATIONS (Assume 1,870,000 Gallons)										
Assume 3 Campaigns @ 26 Shifts @ 8 hr/shift (7 man crew)	1	LS	4368	4368	$55.00	$240,240.00	$0.00	$0.00	--	$240,240.00
AN-106 DST Transfer to Other DST (Assume 3)	3	EA	256	768	$55.00	$42,240.00	$0.00	$0.00	--	$42,240.00
Misc. CHG Engrg Support (SOW's, ECN's, Maintenance, etc.)	1	LS	1720	1720	$70.00	$120,400.00	$0.00	$0.00	--	$120,400.00
Total Operations	--	--	--	--	--	--	--	--	--	**$360,640.00**
CHARACTERIZE										
Prepare Tank Sampling & Analysis Plan, Work Package(s), RWP	--	--	--	--	--	--	--	--	--	$45,000.00
Collect Samples	--	--	--	--	--	--	--	--	--	$130,000.00
Analyze Samples at 222-S Lab & Issue Format IV Data Report	--	--	--	--	--	--	--	--	--	$280,000.00
Volume Measurement & Prepare/Issue Volume Calculation	--	--	--	--	--	--	--	--	--	$25,000.00
Third-Party Data Validation, CH2M HILL Verification, & Data Upload	--	--	--	--	--	--	--	--	--	$20,000.00
Total Characterize										**$500,000.00**
REASSESS CLOSURE STATUS										**$100,000.00**
TOTAL ALTERNATIVE "A" (TPC)										**$1,604,957.92**

Notes:

Alternative A – Raw Water Modified Sluicing (Current Equipment)
For Alternative A, the current C-106 Modified Sluicing system would be restarted and operated to remove tank waste until the minimum goal is satisfied.

ESTIMATE BASIS: C-103/C-105 Tank Retrieval Systems Fair Cost Estimate (Requisition #108596) was used for the basis of this estimate. CHG Operations related information was provided by a CHG Subject Matter Expert, Operations Engineer for Project C-106 Retrieval. Assume all Construction work to be performed by Plant Forces. Project Management was applied at 15% of Total Project Cost. Title III Engineering cost was based on 30% of Construction Cost. HPT costs were developed based on a 4 to 1 ratio of construction personnel. HI Technician costs were also based on a 4 to 1 ratio of construction personnel. Estimates for Characterization and Reassess of Closure Status were provided by the CHG Retrieval/Closure Special Projects Manager. Assumed no additional procedures will be required for this activity.

Table C-3. Detail Backup for Alternative B. (3 Sheets)

Description	Quantity	Unit	Labor unit cost	Total labor hours	Labor rate	Labor dollars	Material unit cost	Material dollars	Subcontract dollars	Total dollars
PROJECT MANAGEMENT										
Assume Project Management @ 10% of TPC	1	LS	5500	5500	$75.00	$412,500.00	$0.00	$0.00	--	$412,500.00
ENGINEERING										
Prepare Design ECN's (moderate)	60	EA	80	4800	$90.00	$0.00	$0.00	$0.00	$360,000.00	$360,000.00
CH2M HILL Design Support	60	EA	20	1200	$70.00	$84,000.00	$0.00	$0.00	--	$84,000.00
Title III Engineering @ 20% of Construction	1	LS	0	0	$0.00	$0.00	$0.00	$0.00	$111,700.00	$111,700.00
NEC Inspection	1	LS	40	40	$75.00	$5,000.00	$0.00	$0.00	--	$5,000.00
Perform IQRPE	1	LS	0	0	$0.00	$0.00	$0.00	$0.00	$20,000.00	$20,000.00
Total Engineering										$580,700.00
PROCUREMENT										
HIHTL Shielding Plates	400	LF	0	0	$0.00	$0.00	$270.00	$108,000.00	--	$108,000.00
Slider Coupler Connection	1	EA	0	0	$0.00	$0.00	$8,000.00	$8,000.00	--	$8,000.00
Exhauster Pre & HEPA Filters	1	EA	0	0	$0.00	$0.00	$4,000.00	$4,000.00	--	$4,000.00
HIHTL - C-103 Valve Pit to C-106 (recirculation lines)	400	LF	0	0	$0.00	$0.00	$400.00	$160,000.00	--	$160,000.00
Upgrade AN-Farm DST Infrastructure (included w/C-103/C-105 Project)	1	EA	0	0	$0.00	$0.00	$0.00	$0.00	--	$0.00
Cover Plates - A Pit & C Pit	2	EA	0	0	$0.00	$0.00	$40,000.00	$80,000.00	--	$80,000.00
Supernatant Sluicers	2	EA	0	0	$0.00	$0.00	$70,000.00	$140,000.00	--	$140,000.00
Supernatant Sluicer Control Console (Existing)	1	EA	0	0	$0.00	$0.00	$0.00	$0.00	--	$0.00
Shield Boxes	2	EA	0	0	$0.00	$0.00	$7,000.00	$14,000.00	--	$14,000.00
Hose Supports	2	EA	0	0	$0.00	$0.00	$2,000.00	$4,000.00	--	$4,000.00
Hose Barns @ Valve Pit	25	LF	0	0	$0.00	$0.00	$411.00	$10,275.00	--	$10,275.00
Slurry Pump	1	EA	0	0	$0.00	$0.00	$500,000.00	$500,000.00	--	$500,000.00
Miscellaneous Hydraulic & Electrical Lines	1	LS	0	0	$0.00	$0.00	$2,000.00	$2,000.00	--	$2,000.00
Flexible Jumpers	5	EA	0	0	$0.00	$0.00	$7,000.00	$35,000.00	--	$35,000.00
Burial Boxes	3	EA	0	0	$0.00	$0.00	$7,000.00	$21,000.00	--	$21,000.00
Sales Tax @ 8.3%	--	--	--	--	--	--	--	$90,160.83	--	$90,160.83
Total Procurement										$1,176,435.83
CONSTRUCTION										
Reconnect HIHTL AN-106 to C-106										
Disconnect AN-106 HIHTL @ C-103 valve box	1	LS	40	40	$53.00	$2,120.00	$200.00	$200.00	--	$2,320.00
Re-install Existing HIHTL AN-106 to HIHTL @ C-106 (Includes Sitework)	100	LF	2	200	$53.00	$10,600.00	$0.00	$0.00	--	$10,600.00
Re-Install Cover Plates	1	LS	40	40	$53.00	$2,120.00	$0.00	$0.00	--	$2,120.00
Connect Heat Trace	1	LS	24	24	$53.00	$1,272.00	$500.00	$500.00	--	$1,772.00
Install Slurry Pump - B Pit C-106										
Construct/Maintain/Disassemble Pit Greenhouse	1	LS	120	120	$53.00	$6,360.00	$15,000.00	$15,000.00	--	$21,360.00
Remove Shield Cover & Hose Support	1	LS	40	40	$53.00	$2,120.00	$0.00	$0.00	--	$2,120.00
Remove Cover Plate	1	LS	80	80	$53.00	$4,240.00	$0.00	$0.00	--	$4,240.00

Table C-3. Detail Backup for Alternative B. (3 Sheets)

Description	Quantity	Unit	Labor unit cost	Total labor hours	Labor rate	Labor dollars	Material unit cost	Material dollars	Subcontract dollars	Total dollars
Remove Existing Jumper	1	LS	40	40	$53.00	$2,120.00	$0.00	$0.00	--	$2,120.00
Disconnect Electrical Connections	1	LS	40	40	$53.00	$2,120.00	$0.00	$0.00	--	$2,120.00
Remove & Dispose of Existing Pump	1	LS	240	240	$53.00	$12,720.00	$2,000.00	$2,000.00	--	$14,720.00
Install New Slurry Pump	1	LS	160	160	$53.00	$8,480.00	$500.00	$500.00	--	$8,980.00
Install New Jumpers	3	EA	40	120	$53.00	$6,360.00	$200.00	$600.00	--	$6,960.00
Re-Connect Electrical	1	LS	40	40	$53.00	$2,120.00	$500.00	$500.00	--	$2,620.00
Install Cover Plate, Hose Support & HIHTL Shield Box	1	LS	200	200	$53.00	$10,600.00	$100.00	$100.00	--	$10,700.00
Upgrade A Pit C-106										
Construct/Maintain/Disassemble Pit Greenhouse	1	LS	120	120	$53.00	$6,360.00	$15,000.00	$15,000.00	--	$21,360.00
Remove & Dispose Cover Blocks	1	LS	280	280	$53.00	$14,840.00	$1,000.00	$1,000.00	--	$15,840.00
Remove & Dispose Misc. Debris	1	LS	160	160	$53.00	$8,480.00	$500.00	$500.00	--	$8,980.00
Remove & Dispose Misc. Equipment (320 Nozzle and Jumper)	1	LS	160	160	$53.00	$8,480.00	$1,000.00	$1,000.00	--	$9,480.00
Install New Supernatant Sluicer / Jumper	1	LS	180	180	$53.00	$9,540.00	$500.00	$500.00	--	$10,040.00
Install Cover Plates, Hose Support & HIHTL Shield Boxes	1	LS	200	200	$53.00	$10,600.00	$100.00	$100.00	--	$10,700.00
Install HIHTL (A Pit to C-103/105 Valve Box)	200	LF	1	200	$53.00	$10,600.00	$0.00	$0.00	--	$10,600.00
Miscellaneous Electrical/Hydraulic Connections	1	LS	40	40	$53.00	$2,120.00	$0.00	$0.00	--	$2,120.00
Upgrade C Pit C-106										
Remove & Dispose Cover Blocks	1	LS	280	280	$53.00	$14,840.00	$1,000.00	$1,000.00	--	$15,840.00
Remove & Dispose Misc. Debris	1	LS	160	160	$53.00	$8,480.00	$500.00	$500.00	--	$8,980.00
Remove Existing Sluicer (3i)	1	LS	80	80	$53.00	$4,240.00	$1,000.00	$1,000.00	--	$5,240.00
Install New Supernatant Sluicer / Jumper	1	LS	180	180	$53.00	$9,540.00	$500.00	$500.00	--	$10,040.00
Install Cover Plates, Strongbacks & HIHTL Shield Boxes	1	LS	200	200	$53.00	$10,600.00	$100.00	$100.00	--	$10,700.00
Install HIHTL (C Pit to C-103/105 Valve Box)	200	LF	1	200	$53.00	$10,600.00	$0.00	$0.00	--	$10,600.00
Miscellaneous Electrical/Hydraulic Connections	1	LS	40	40	$53.00	$2,120.00	$0.00	$0.00	--	$2,120.00
Tank C-106										
Re-install Tank Camera	1	LS	40	40	$53.00	$2,120.00	$200.00	$200.00	--	$2,320.00
Re- Setup Retrieval System	1	LS	240	240	$53.00	$12,720.00	$2,000.00	$2,000.00	--	$14,720.00
Re-start/Re-calibrate Exhauster	1	LS	80	80	$53.00	$4,240.00	$1,000.00	$1,000.00	--	$5,240.00
Perform Construction Acceptance Test (CAT)	1	LS	200	200	$53.00	$10,600.00	$0.00	$0.00	--	$10,600.00
Grout Burial Boxes (Grout Provided by Others)	1	LS	120	120	$53.00	$6,360.00	$0.00	$0.00	--	$6,360.00
Sub Total Construction	--	--	--	4544	--	$240,832.00	--	$43,800.00	--	$284,632.00
Productivity Factor - (Full Time Respirator Work) Assume 30%	--	--	--	1363	--	$72,249.60	--	--	--	$72,249.60
Weather Delays - Assume 20%	--	--	--	1181	--	$62,616.32	--	--	--	$62,616.32
Sales Tax on Materials - 8.3%	--	--	--	--	--	--	--	$3,635.40	--	$3,635.40
Total Construction	--	--	--	7089	--	$375,697.92	--	$47,435.40	$0.00	$423,133.32
Construction Contractor General Requirements (25% of construction)	--	--	--	1772	--	$93,924.48	--	--	--	$93,924.48
Total General Requirements & Construction	--	--	--	8861	--	$469,622.40	--	$47,435.40	$0.00	$517,057.80
Construction Contractor Fee @ 8%	--	--	--	--	--	--	--	--	--	$41,364.62

Table C-3. Detail Backup for Alternative B. (3 Sheets)

Description	Quantity	Unit	Labor unit cost	Total labor hours	Labor rate	Labor dollars	Material unit cost	Material dollars	Subcontract dollars	Total dollars
CONSTRUCTION TOTAL	--	--	--	8861	--	$469,622.40	--	$47,435.40	$0.00	$558,422.42
Construction Support										
Prepare Work Packages	15	EA	200	3000	$75.00	$225,000.00	$0.00	$0.00	--	$225,000.00
Crane/Crane Crew (allowance)	20	DAY	0	0	$0.00	$0.00	$0.00	$0.00	$100,000.00	$100,000.00
Other Equipment Usage Charges (Water Truck)	1	LS	0	0	$0.00	$0.00	$0.00	$0.00	$4,200.00	$4,200.00
Misc CHG Engrg Support (USQ, Lock/Tag, Pre Job, Excav Permit, etc.)	1	LS	1500	1500	$70.00	$105,000.00	$0.00	$0.00	--	$105,000.00
HI Support 1-4 Ratio	1	LS	1770	1770	$66.00	$116,820.00	$0.00	$0.00	--	$116,820.00
HPT Support 1-4 Ratio	1	LS	1770	1770	$50.00	$88,500.00	$0.00	$0.00	--	$88,500.00
Burial Fees	675	CF	0	0	$0.00	$0.00	$0.00	$0.00	$13,500.00	$13,500.00
Other Support										
CHG Construction Management (20% of construction total)	1	LS	1770	1770	$63.00	$111,510.00	$0.00	$0.00	--	$111,510.00
TOTAL CONSTRUCTION & CONSTRUCTION SUPPORT	--	--	--	18671	--	$1,116,452.40	$0.00	$47,435.40	$117,700.00	$1,322,952.42
PROCEDURE DEVELOPMENT (assume minor procedure development)										$120,000.00
STARTUP AND READINESS										
Reference C-Farm CEIS Estimate ($230,000) Assume 100%	1	LS	0	0	$0.00	$0.00	$0.00	$0.00	$230,000.00	$230,000.00
OPERATIONS (Assume 425,000 Gallons)										
Assume 20 Shifts @ 8 hr/shift (7 man crew)	1	LS	1120	1120	$55.00	$61,600.00	$0.00	$0.00	--	$61,600.00
Misc. CHG Engrg Support (SOW's, ECN's, Maintenance, etc.)	1	LS	440	440	$70.00	$30,800.00	$0.00	$0.00	--	$30,800.00
Total Operations										$92,400.00
CHARACTERIZE										
Prepare Tank Sampling & Analysis Plan, Work Package(s), RWP	--	--	--	--	--	--	--	--	--	$45,000.00
Collect Samples	--	--	--	--	--	--	--	--	--	$130,000.00
Analyze Samples at 222-S Lab & Issue Format IV Data Report	--	--	--	--	--	--	--	--	--	$280,000.00
Volume Measurement & Prepare/Issue Volume Calculation	--	--	--	--	--	--	--	--	--	$25,000.00
Third-Party Data Validation, CH2M HILL Verification, & Data Upload	--	--	--	--	--	--	--	--	--	$20,000.00
Total Characterize										$500,000.00
REASSESS CLOSURE STATUS										$100,000.00
TOTAL ALTERNATIVE "B" (TPC)										$4,534,988.25

Notes:

Alternative B – New Modified Sluicing with New Slurry Pump

Alternative B consists of the design, procurement, construction, startup, and operation of an entirely new Modified Sluicing system specifically designed for the sludge residuals in C-106. The system would include new pumps and sluice nozzles installed in new risers designed purely to take the residual volume from current levels to below the minimum volume goal. The new slurry pump may be a progressive cavity, or other type capable of pumping solids. The existing transfer route to the AN-Farm would be used once the C-200 retrievals are completed.

ESTIMATE BASIS: C-103/C-105 Tank Retrieval Systems Fair Cost Estimate (Requisition #108596) was used for the basis of this estimate. CHG Operations related information was provided by a CHG Subject Matter Expert, Operations Engineer for Project C-106 Retrieval. Assume all Construction work to be performed by Construction Contracts. Project Management was applied at 10% of Total Project Cost. CHG Construction Management was applied at 20% of Total Construction Cost. Construction Contractor General Requirements was applied at 25% of Construction Cost. Title III Engineering cost was based on 20% of Construction Costs. HPT costs were developed based on a 4 to 1 Ratio of construction personnel. HI Technician costs were also based on a 4 to 1 ratio of construction personnel. Estimates for Characterization and Reassess of Closure Status were provided by the CHG Retrieval/Closure Special Projects Manager.

Table C-4. Detail Backup for Alternative C. (3 Sheets)

Description	Quantity	Unit	Labor unit cost	Total labor hours	Labor rate	Labor dollars	Material unit cost	Material dollars	Subcontract dollars	Total dollars
PROJECT MANAGEMENT										
Assume Project Management @ 10% of TPC	1	LS	9485	9485	$75.00	$711,375.00	$0.00	$0.00	--	$711,375.00
ENGINEERING										
Prepare Design ECN's (moderate)	70	EA	80	5600	$90.00	$0.00	$0.00	$0.00	$504,000.00	$504,000.00
CH2M HILL Design Support	70	EA	20	1400	$70.00	$98,000.00	$0.00	$0.00	--	$98,000.00
Title III Engineering @ 20% of Construction	1	LS	0	0	$0.00	$0.00	$0.00	$0.00	$163,700.00	$163,700.00
NEC Inspection	1	LS	120	120	$75.00	$9,000.00	$0.00	$0.00	--	$9,000.00
Perform IQRPE	1	LS	0	0	$0.00	$0.00	$0.00	$0.00	$30,000.00	$30,000.00
Total Engineering										$804,700.00
PROCUREMENT										
HIHTL Shielding Plates	100	LF	0	0	$0.00	$0.00	$270.00	$27,000.00	--	$27,000.00
Slider Coupler Connection	1	EA	0	0	$0.00	$0.00	$8,000.00	$8,000.00	--	$8,000.00
Exhauster Pre & HEPA Filters	1	EA	0	0	$0.00	$0.00	$4,000.00	$4,000.00	--	$4,000.00
Upgrade AN-Farm DST Infrastructure (included w/C-103/C-105 Project)	1	EA	0	0	$0.00	$0.00	$0.00	$0.00	--	$0.00
Fabricate New Risers	2	EA	0	0	$0.00	$0.00	$10,000.00	$20,000.00	--	$20,000.00
Vacuum Mast	2	EA	0	0	$0.00	$0.00	$300,000.00	$600,000.00	--	$600,000.00
Vacuum System	1	EA	0	0	$0.00	$0.00	$1,300,000.00	$1,300,000.00	--	$1,300,000.00
Control Trailer	1	EA	0	0	$0.00	$0.00	$250,000.00	$250,000.00	--	$250,000.00
Transformer (Substation Existing)	1	EA	0	0	$0.00	$0.00	$100,000.00	$100,000.00	--	$100,000.00
Water Skid	1	EA	0	0	$0.00	$0.00	$180,000.00	$180,000.00	--	$180,000.00
Air Skid	1	EA	0	0	$0.00	$0.00	$90,000.00	$90,000.00	--	$90,000.00
Electrical Distribution Skid	1	EA	0	0	$0.00	$0.00	$175,000.00	$175,000.00	--	$175,000.00
Utility Manifold Skid	1	EA	0	0	$0.00	$0.00	$150,000.00	$150,000.00	--	$150,000.00
Vacuum Hoses	1	LS	0	0	$0.00	$0.00	$100,000.00	$100,000.00	--	$100,000.00
Electrical Cables	1	LS	0	0	$0.00	$0.00	$30,000.00	$30,000.00	--	$30,000.00
Utility Hoses	1	LS	0	0	$0.00	$0.00	$10,000.00	$10,000.00	--	$10,000.00
Burial Boxes	5	EA	0	0	$0.00	$0.00	$7,000.00	$35,000.00	--	$35,000.00
Sales Tax @ 8.3%	--	--	--	--	--	--	--	$255,557.00	--	$255,557.00
Total Procurement										$3,334,557.00
CONSTRUCTION										
Reconnect HIHTL AN-106 to C-106										
Disconnect AN-106 HIHTL @ C-103 valve box	1	LS	40	40	$53.00	$2,120.00	$200.00	$200.00	--	$2,320.00
Re-install Existing HIHTL AN-106 to HIHTL @ C-106 (Includes Sitework)	100	LF	2	200	$53.00	$10,600.00	$0.00	$0.00	--	$10,600.00
Re-Install Cover Plates	1	LS	40	40	$53.00	$2,120.00	$0.00	$0.00	--	$2,120.00
Connect Heat Trace	1	LS	24	24	$53.00	$1,272.00	$500.00	$500.00	--	$1,772.00

Table C-4. Detail Backup for Alternative C. (3 Sheets)

Description	Quantity	Unit	Labor unit cost	Total labor hours	Labor rate	Labor dollars	Material unit cost	Material dollars	Subcontract dollars	Total dollars
Install Vacuum System										
Construct/Maintain/Disassemble Pit Greenhouse	1	LS	200	200	$53.00	$10,600.00	$15,000.00	$15,000.00	--	$25,600.00
Install New Risers	2	EA	750	1500	$53.00	$79,500.00	$2,000.00	$4,000.00	--	$83,500.00
Install Complete Vacuum System	1	LS	4000	4000	$53.00	$212,000.00	$500.00	$500.00	--	$212,500.00
Connect HIHTL to Vacuum Batch Vessel	1	EA	200	200	$53.00	$10,600.00	$100.00	$100.00	--	$10,700.00
Miscellaneous Vacuum Connections	1	LS	120	120	$53.00	$6,360.00	$200.00	$200.00	--	$6,560.00
Tank C-106										
Re-install Tank Camera	1	LS	40	40	$53.00	$2,120.00	$200.00	$200.00	--	$2,320.00
Re- Setup Retrieval System	1	LS	240	240	$53.00	$12,720.00	$2,000.00	$2,000.00	--	$14,720.00
Re-start/Re-calibrate Exhauster	1	LS	80	80	$53.00	$4,240.00	$1,000.00	$1,000.00	--	$5,240.00
Perform Construction Acceptance Test (CAT)	1	LS	200	200	$53.00	$10,600.00	$0.00	$0.00	--	$10,600.00
Grout Burial Boxes (Grout Provided by Others)	1	LS	200	200	$53.00	$10,600.00	$0.00	$0.00	--	$10,600.00
Sub Total Construction	--	--	--	7084	--	$375,452.00	--	$23,700.00	$0.00	$399,152.00
Productivity Factor - (Full Time Respirator Work) Assume 30%	--	--	--	2125	--	$112,635.60	--	--	--	$112,635.60
Weather Delays - Assume 20%	--	--	--	1842	--	$97,617.52	--	--	--	$97,617.52
Sales Tax on Materials - 8.3%	--	--	--	--	--	--	--	$1,967.10	--	$1,967.10
Total Construction	--	--	--	11051	--	$585,705.12	--	$25,667.10	$0.00	$611,372.22
Construction Contractor General Requirements (25% of construction)	--	--	--	2763	--	$146,426.28	--	--	--	$146,426.28
Total General Requirements & Construction	--	--	--	13814	--	$732,131.40	--	$25,667.10	$0.00	$757,798.50
Construction Contractor Fee @ 8%	--	--	--	--	--	--	--	--	--	$60,623.88
CONSTRUCTION TOTAL	--	--	--	13814	--	$732,131.40	--	$25,667.10	$0.00	$818,422.38
Construction Support										
Prepare Work Packages	20	EA	200	4000	$75.00	$300,000.00	$0.00	$0.00	--	$300,000.00
Crane/Crane Crew (allowance)	20	DAY	0	0	$0.00	$0.00	$0.00	$0.00	$100,000.00	$100,000.00
Other Equipment Usage Charges (Water Truck)	1	LS	0	0	$0.00	$0.00	$0.00	$0.00	$4,200.00	$4,200.00
Misc CHG Engrg Support (USQ, Lock/Tag, Pre Job, Excav Permit, etc.)	1	LS	2000	2000	$70.00	$140,000.00	$0.00	$0.00	--	$140,000.00
IH Support 1-4 Ratio	1	LS	2763	2763	$66.00	$182,358.00	$0.00	$0.00	--	$182,358.00
HPT Support 1-4 Ratio	1	LS	2763	2763	$50.00	$138,150.00	$0.00	$0.00	--	$138,150.00
Burial Fees	1125	CF	0	0	$0.00	$0.00	$0.00	$0.00	$22,500.00	$22,500.00
Other Support										
CHG Construction Management (20% of total construction)	1	LS	3680	3680	$63.00	$231,840.00	$0.00	$0.00		$231,840.00
TOTAL CONSTRUCTION & CONSTRUCTION SUPPORT	--	--	--	29020	--	$1,724,479.40	$0.00	$25,667.10	$126,700.00	$1,937,470.38
PROCEDURE DEVELOPMENT (assume minor procedure development)										$160,000.00
STARTUP AND READINESS										
Reference C-Farm CEIS Estimate ($230,000) Assume 100%	1	LS	0	0	$0.00	$0.00	$0.00	$0.00	$230,000.00	$230,000.00

Table C-4. Detail Backup for Alternative C. (3 Sheets)

Description	Quantity	Unit	Labor unit cost	Total labor hours	Labor rate	Labor dollars	Material unit cost	Material dollars	Subcontract dollars	Total dollars
OPERATIONS (Assume 225,000 Gallons)										
Assume 10 Shifts @ 8 hr/shift (7 man crew)	1	LS	560	560	$55.00	$30,800.00	$0.00	$0.00	--	$30,800.00
Misc. CHG Engrg Support (SOW's, ECN's, Maintenance, etc.)	1	LS	220	220	$70.00	$15,400.00	$0.00	$0.00	--	$15,400.00
Total Operations										**$46,200.00**
CHARACTERIZE										
Prepare Tank Sampling & Analysis Plan, Work Package(s), RWP	--	--	--	--	--	--	--	--	--	$45,000.00
Collect Samples	--	--	--	--	--	--	--	--	--	$130,000.00
Analyze Samples at 222-S Lab & Issue Format IV Data Report	--	--	--	--	--	--	--	--	--	$280,000.00
Volume Measurement & Prepare/Issue Volume Calculation	--	--	--	--	--	--	--	--	--	$25,000.00
Third-Party Data Validation, CH2M HILL Verification, & Data Upload	--	--	--	--	--	--	--	--	--	$20,000.00
Total Characterize										**$500,000.00**
REASSESS CLOSURE STATUS										**$100,000.00**
TOTAL ALTERNATIVE "C" (TPC)										**$7,824,302.38**

Notes:

Alternative C – Modified Sluicing (Current Equipment) Followed by New Vacuum Retrieval System
Alternative C is based on the use of Modified Sluicing to cleanup the tank bottom and remove as much as is possible in a short period of time (with minimal water). Two new risers would then be installed near or above the areas where "bergs" of waste are located on the outer edge of the tank. Vacuum system masts would be installed in the new risers to retrieve as much of the granular "bergs" that would fall within the ~20-foot vacuum mast radius. This would be a batch process where waste would be vacuumed into the batch vessel followed by water addition and slurry of the wastes to the AN-farm via the existing C-106 HIHTL.

ESTIMATE BASIS: C-103/C-105 Tank Retrieval Systems Fair Cost Estimate (Requisition #108596) was used for the basis of this estimate. CHG Operations related information was provided by a CHG Subject Matter Expert, Operations Engineer for Project C-106 Retrieval. Assume all Construction work to be performed by Construction Contracts. Project Management was applied at 10% of Total Project Cost. CHG Construction Management was applied at 20% of Total Construction Cost. Construction Contractor General Requirements was applied at 25% of Construction Cost. Title III Engineering cost was based on 20% of Construction Costs. HPT costs were developed based on a 4 to 1 Ratio of construction personnel. IH Technician costs were also based on a 4 to 1 ratio of construction personnel. Estimates for Characterization and Reassess of Closure Status were provided by the CHG Retrieval/Closure Special Projects Manager.

Table C-5. Detail Backup for Alternative D. (3 Sheets)

Description	Quantity	Unit	Labor unit cost	Total labor hours	Labor rate	Labor dollars	Material unit cost	Material dollars	Subcontract dollars	Total dollars
PROJECT MANAGEMENT										
Assume Project Management @ 10% of TPC	1	LS	12245	12245	$75.00	$918,375.00	$0.00	$0.00	--	$918,375.00
ENGINEERING										
Prepare Design ECN's (moderate)	70	EA	80	5600	$90.00	$0.00	$0.00	$0.00	$504,000.00	$504,000.00
CH2M HILL Design Support	70	EA	20	1400	$70.00	$98,000.00	$0.00	$0.00	--	$98,000.00
Title III Engineering @ 20% of Construction	1	LS	0	0	$0.00	$0.00	$0.00	$0.00	$230,800.00	$230,800.00
NEC Inspection	1	LS	200	200	$75.00	$15,000.00	$0.00	$0.00	--	$15,000.00
Perform IQRPE	1	LS	0	0	$0.00	$0.00	$0.00	$0.00	$30,000.00	$30,000.00
Total Engineering										$877,800.00
PROCUREMENT										
In-Tank Vehicle (ITV)	1	EA	0	0	$0.00	$0.00	$1,200,000.00	$1,200,000.00	--	$1,200,000.00
HIHTL Shielding Plates	100	LF	0	0	$0.00	$0.00	$270.00	$27,000.00	--	$27,000.00
Slider Coupler Connection	1	EA	0	0	$0.00	$0.00	$8,000.00	$8,000.00	--	$8,000.00
Exhauster Pre & HEPA Filters	1	EA	0	0	$0.00	$0.00	$4,000.00	$4,000.00	--	$4,000.00
Upgrade AN-Farm DST Infrastructure (included w/C-103/C-105 Project)	1	EA	0	0	$0.00	$0.00	$0.00	$0.00	--	$0.00
Fabricate New Risers	3	EA	0	0	$0.00	$0.00	$10,000.00	$30,000.00	--	$30,000.00
Vacuum Mast	2	EA	0	0	$0.00	$0.00	$300,000.00	$600,000.00	--	$600,000.00
Vacuum System	1	EA	0	0	$0.00	$0.00	$1,300,000.00	$1,300,000.00	--	$1,300,000.00
Control Trailer	1	EA	0	0	$0.00	$0.00	$250,000.00	$250,000.00	--	$250,000.00
Transformer and Substation	1	EA	0	0	$0.00	$0.00	$190,000.00	$190,000.00	--	$190,000.00
Water Skid	1	EA	0	0	$0.00	$0.00	$180,000.00	$180,000.00	--	$180,000.00
Air Skid	1	EA	0	0	$0.00	$0.00	$90,000.00	$90,000.00	--	$90,000.00
Electrical Distribution Skid	1	EA	0	0	$0.00	$0.00	$175,000.00	$175,000.00	--	$175,000.00
Utility Manifold Skid	1	EA	0	0	$0.00	$0.00	$150,000.00	$150,000.00	--	$150,000.00
Vacuum Hoses	1	LS	0	0	$0.00	$0.00	$100,000.00	$100,000.00	--	$100,000.00
Electrical Cables	1	LS	0	0	$0.00	$0.00	$30,000.00	$30,000.00	--	$30,000.00
Utility Hoses	1	LS	0	0	$0.00	$0.00	$10,000.00	$10,000.00	--	$10,000.00
Burial Boxes	6	EA	0	0	$0.00	$0.00	$7,000.00	$42,000.00	--	$42,000.00
Sales Tax @ 8.3%	--	--	--	--	--	--	--	$364,038.00	--	$364,038.00
Total Procurement										$4,750,038.00
CONSTRUCTION										
Reconnect HIHTL AN-106 to C-106										
Disconnect AN-106 HIHTL @ C-103 valve box	1	LS	40	40	$53.00	$2,120.00	$200.00	$200.00	--	$2,320.00
Re-install Existing HIHTL AN-106 to HIHTL @ C-106 (Includes Sitework)	100	LF	2	200	$53.00	$10,600.00	$0.00	$0.00	--	$10,600.00

Table C-5. Detail Backup for Alternative D. (3 Sheets)

Description	Quantity	Unit	Labor unit cost	Total labor hours	Labor rate	Labor dollars	Material unit cost	Material dollars	Subcontract dollars	Total dollars
Re-Install Cover Plates	1	LS	40	40	$53.00	$2,120.00	$0.00	$0.00	--	$2,120.00
Connect Heat Trace	1	LS	24	24	$53.00	$1,272.00	$500.00	$500.00	--	$1,772.00
Install Vacuum System										
Construct/Maintain/Disassemble Pit Greenhouse	2	EA	200	400	$53.00	$21,200.00	$15,000.00	$30,000.00	--	$51,200.00
Install New Risers (Vacuum Masts)	2	EA	750	1500	$53.00	$79,500.00	$2,000.00	$4,000.00	--	$83,500.00
Install New 42" Dia Riser (ITV)	1	EA	1500	1500	$53.00	$79,500.00	$5,000.00	$5,000.00	--	$84,500.00
Install In Tank Vehicle	1	LS	400	400	$53.00	$21,200.00	$10,000.00	$10,000.00	--	$31,200.00
Install Complete Vacuum System	1	LS	4000	4000	$53.00	$212,000.00	$500.00	$500.00	--	$212,500.00
Connect HIHTL to Vacuum Batch Vessel	1	EA	200	200	$53.00	$10,600.00	$100.00	$100.00	--	$10,700.00
Miscellaneous Electrical	1	LS	500	500	$53.00	$26,500.00	$5,000.00	$5,000.00	--	$31,500.00
Miscellaneous Vacuum Connections	1	LS	120	120	$53.00	$6,360.00	$200.00	$200.00	--	$6,560.00
Tank C-106										
Re-install Tank Camera	1	LS	40	40	$53.00	$2,120.00	$200.00	$200.00	--	$2,320.00
Re- Setup Retrieval System	1	LS	240	240	$53.00	$12,720.00	$2,000.00	$2,000.00	--	$14,720.00
Re-start/Re-calibrate Exhauster	1	LS	80	80	$53.00	$4,240.00	$1,000.00	$1,000.00	--	$5,240.00
Perform Construction Acceptance Test (CAT)	1	LS	200	200	$53.00	$10,600.00	$0.00	$0.00	--	$10,600.00
Grout Burial Boxes (Grout Provided by Others)	1	LS	240	240	$53.00	$12,720.00	$0.00	$0.00	--	$12,720.00
Sub Total Construction	--	--	--	9724	--	$515,372.00	--	$58,700.00	$0.00	$574,072.00
Productivity Factor - (Full Time Respirator Work) Assume 30%	--	--	--	2917	--	$154,611.60	--	--	--	$154,611.60
Weather Delays - Assume 20%	--	--	--	2528	--	$133,996.72	--	--	--	$133,996.72
Sales Tax on Materials - 8.3%	--	--	--	--	--	--	--	$4,872.10	--	$4,872.10
Total Construction	--	--	--	15169	--	$803,980.32	--	$63,572.10	$0.00	$867,552.42
Construction Contractor General Requirements (25% of construction)	--	--	--	3792	--	$200,995.08	--	--	--	$200,995.08
Total General Requirements & Construction	--	--	--	18962	--	$1,004,975.40	--	$63,572.10	$0.00	$1,068,547.50
Construction Contractor Fee @ 8%	--	--	--	--	--	--	--	--	--	$85,483.80
CONSTRUCTION TOTAL	--	--	--	18962	--	$1,004,975.40	--	$63,572.10	$0.00	$1,154,031.30
Construction Support										
Prepare Work Packages	25	EA	200	5000	$75.00	$375,000.00	$0.00	$0.00	--	$375,000.00
Crane/Crane Crew (allowance)	25	DAY	0	0	$0.00	$0.00	$0.00	$0.00	$125,000.00	$125,000.00
Misc CHG Engrg Support (USQ, Lock/Tag, Pre Job, Excav Permit, etc.)	1	LS	3000	3000	$70.00	$210,000.00	$0.00	$0.00	--	$210,000.00
HI Support 1-4 Ratio	1	LS	2430	2430	$66.00	$160,380.00	$0.00	$0.00	--	$160,380.00
HPT Support 1-4 Ratio	1	LS	2430	2430	$50.00	$121,500.00	$0.00	$0.00	--	$121,500.00
Burial Fees	1350	CF	0	0	$0.00	$0.00	$0.00	$0.00	$27,000.00	$27,000.00
Other Support										
CHG Construction Management (20% of total construction)	1	LS	5000	5000	$63.00	$315,000.00	$0.00	$0.00	--	$315,000.00
TOTAL CONSTRUCTION & CONSTRUCTION SUPPORT	--	--	--	36822	--	$2,186,855.40	--	$63,572.10	$152,000.00	$2,487,911.30

Table C-5. Detail Backup for Alternative D. (3 Sheets)

Description	Quantity	Unit	Labor unit cost	Total labor hours	Labor rate	Labor dollars	Material unit cost	Material dollars	Subcontract dollars	Total dollars
PROCEDURE DEVELOPMENT (assume minor procedure development)										$200,000.00
STARTUP AND READINESS										
Reference C-Farm CEIS Estimate ($230,000) Assume 100%	1	LS	0	0	$0.00	$0.00	$0.00	$0.00	$230,000.00	$230,000.00
OPERATIONS (Assume 175,000 Gallons)										
Assume 8 Shifts @ 8 hr/shift (7 man crew)	1	LS	448	448	$55.00	$24,640.00	$0.00	$0.00	--	$24,640.00
Misc. CHG Engrg Support (SOW's, ECN's, Maintenance, etc.)	1	LS	180	180	$70.00	$12,600.00	$0.00	$0.00	--	$12,600.00
Total Operations										$37,240.00
CHARACTERIZE										
Prepare Tank Sampling & Analysis Plan, Work Package(s), RWP	--	--	--	--	--	--	--	--	--	$45,000.00
Collect Samples	--	--	--	--	--	--	--	--	--	$130,000.00
Analyze Samples at 222-S Lab & Issue Format IV Data Report	--	--	--	--	--	--	--	--	--	$280,000.00
Volume Measurement & Prepare/Issue Volume Calculation	--	--	--	--	--	--	--	--	--	$25,000.00
Third-Party Data Validation, CH2M HILL Verification, & Data Upload	--	--	--	--	--	--	--	--	--	$20,000.00
Total Characterize										$500,000.00
REASSESS CLOSURE STATUS										$100,000.00
TOTAL ALTERNATIVE "D" (TPC)										$10,101,364.30

Notes:

Alternative D – Mobile Retrieval System
The Mobile Retrieval System (MRS) consists of a Vacuum Retrieval System in combination with an In-tank Vehicle (ITV). Alternative D consists of the design, procurement, construction, startup, and operation of a new MRS specifically designed for the sludge residuals in C-106. The existing transfer route to the AN-Farm would be used once the C-200 retrievals are completed. The MRS would operate to remove tank waste until the minimum goal is satisfied. The MRS does generate some water from the vacuum system and requires significant water to transfer wastes to the AN-Farm.

ESTIMATE BASIS: C-103/C-105 Tank Retrieval Systems Fair Cost Estimate (Requisition #108596) was used for the basis of this estimate. CHG Operations related information was provided by a CHG Subject Matter Expert, Operations Engineer for Project C-106 Retrieval. Assume all Construction work to be performed by Construction Contracts. Project Management was applied at 10% of Total Project Cost. CHG Construction Management was applied at 20% of Total Construction Cost. Construction Contractor General Requirements was applied at 25% of Construction Cost. Title III Engineering cost was based on 20% of Construction Costs. HPT costs were developed based on a 4 to 1 Ratio of construction personnel. IH Technician costs were also based on a 4 to 1 ratio of construction personnel. Estimates for Characterization and Reassess of Closure Status were provided by the CHG Retrieval/Closure Special Projects Manager.

APPENDIX D

WATER USAGE DATA

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Table D-1. Water Usage Summary Table.

Alt.	Title	Mobilize waste to pump intake	Recirculated supernatant	Transfer to DST receiver tank	Line flushing	Volume measure	Caustic addition	Increased DST storage needed	Increased evaporator volume
A	Raw Water Modified Sluicing (Current Equipment)	1,810,000	N/A	N/A	5,000	40,000	15,000	1,870,000	1,870,000
B	New Modified Sluicing with New Slurry Pump	425,000	425,000	N/A	35,000	40,000	15,000	90,000	90,000
C	Modified Sluicing Followed by New Vacuum Retrieval System	70,000	N/A	80,000	20,000	40,000	15,000	225,000	225,000
D	Mobile Retrieval System	20,000	N/A	80,000	20,000	40,000	15,000	175,000	175,000

Notes:

DST = double-shell tank.
N/A = not applicable.

D1.0 WATER USAGE BASIS FOR THE FOUR ALTERNATIVES TO SUPPORT CONTINUED SST C-106 WASTE RETRIEVAL

The sluicing efficiency in the 2003 SST C-106 sluicing campaign had gradually tapered off to a very low percentage of solids in the slurry transferred to tank 241-AN-106. As shown in Table D-2, sluicing efficiencies decreased over the duration of the retrieval as indicated by the decrease in the volume of waste removed. The second sluicer was installed after the first two sluicing runs to increase the efficiency of the waste removal. However, the efficiency of removal continued to decrease.

Table D-2. 2003 Single-Shell Tank C-106 Sluicing Results for each sluicing run (volumes in gallons).

Estimated waste before sluicing	Water used	Calculated waste removed	Efficiency percent
9,701	56,160	4,873	8
7,425	46,472	1,607	3.3
5,738	59,228	857	1.4
4,334	83,501	217	0.3

The amount of waste left in the tank during the above SST C-106 sluicing campaign, including waste in equipment and on the stiffener rings, is approximately 370 ft^3 (2771 gallons). The amount of waste remaining in the tank based on the upper limit of the 95% confidence interval is about 3,500 gallons. To assure that the residual waste volume will be less than 360 ft^3 (at the lower limit of the 95% confidence interval), the final waste volume would need to about 2,050 gallons. Therefore, approximately 1,450 gallons would be required to be removed from the tank.

Based on past practice sluicing, the 2003 SST C-106 sluicing campaign and sluicing experience and the performance expectations of technologies scheduled for deployment, the following volume estimates were generated for the alternatives.

D2.0 ALTERNATIVE A - RAW WATER MODIFIED SLUICING

Sluicing with this alternative is continued with current equipment. At the restart of sluicing, retrieval efficiencies are assumed to start above the minimum efficiencies observed in the 2003 retrieval campaign due to potential increase in efficiencies possibly realized by operational experience. However, the efficiency is expected to drop over the duration of the retrieval due to the diminished affect to break up the solid material. Given these assumptions, the estimate of water volume for recovery is shown in Table D-3. For the first 80,000 gallons of water, the amount of waste removed is 237 gallons. This is slightly more than the recovery using 83,000 gallons in the last sluicing run. A recovery efficiency of 0.07% is assumed for the remainder of the operation. Total water used for sluicing considering these assumptions is 1,810,000 gallons.

Table D-3. Alternative A – Raw Water Sluicing Using Current Equipment (Volumes are in Gallons)

Waste Volume (start)	Water Used	(Cumulative water usage)	Assumed Efficiency (% solids in slurry)	Waste Removed	Waste Remaining
3500	10,000	(10,000)	1.0	100	3400
3400	10,000	(20,000)	0.5	50	3350
3350	10,000	(30,000)	0.3	30	3320
3320	10,000	(40,000)	0.2	20	3300
3300	10,000	(50,000)	0.1	10	3290
3290	10,000	(60,000)	0.1	10	3280
3280	10,000	(70,000)	0.1	10	3270
3270	10,000	(80,000)	0.07	7	3263
3263	1,730,000	(1,810,000)	0.07	1211	2052

However, if the waste removal process using the first 80,000 gallons of water is not as efficient as indicated or if the extended efficiency is less than 0.07%, additional water usage would be required to remove 1,450 gallons of waste.

It is recognized that most of the alternatives, including Alternative A are subjected to additional water being introduced into the tank besides the sluicing water. Each alternative uses line flushing water, a volume measurement batch (40,000 gallons), and a caustic addition. Therefore, with these additions included in the original estimate, the total volume increase in DST volume from Alternative A is estimated to be 1,870,000 gallons.

D3.0 ALTERNATIVE B – NEW MODIFIED SLUICING WITH A NEW SLURRY PUMP

In this retrieval alternative, recycled supernatant is used along with a new slurry pump. These are added theoretically to improve retrieval efficiencies. Assuming these new efficiencies are realized, approximately 420 gallons are retrieved with the first 80,000 gallons of sluicing.

Table D-4. Alternative B - Recycled Sluicing with New Slurry Pump (Volumes are in Gallons). (2 sheets)

Waste Volume (start)	Volume Used for sluicing	(Cumulative sluicing volume)	Assumed Efficiency (% solids in slurry)	Waste Removed	Waste Remaining
3500	10,000	(10,000)	1.0	100	3400
3400	10,000	(20,000)	1.0	100	3300

Table D-4. Alternative B - Recycled Sluicing with New Slurry Pump (Volumes are in Gallons). (2 sheets)

Waste Volume (start)	Volume Used for sluicing	(Cumulative sluicing volume)	Assumed Efficiency (% solids in slurry)	Waste Removed	Waste Remaining
3300	10,000	(30,000)	0.5	50	3250
3250	10,000	(40,000)	0.5	50	3200
3200	10,000	(50,000)	0.3	30	3170
3170	10,000	(60,000)	0.3	30	3140
3140	10,000	(70,000)	0.3	30	3110
3110	10,000	(80,000)	0.3	30	3080
3090	345,000	(425,000)	0.3	1035	2045

This performance results in nearly twice as much recovered waste with 83,000 gallons than was achieved with Alternative A. The estimated efficiency results from the expectation that the actual performance of the new sluicing nozzles and the new slurry pump will be improved. After the first 80,000 gallons of sluicing, the efficiency is assumed to remain at 0.3% for the remainder of the run. This efficiency is similar to the efficiency during the last sluicing run described by Alternative A (<0.3%). However, these efficiencies may not be achievable through to the completion of the campaign.

The total volume for retrieval is 425,000 gallons. However, the sluicing medium is supernatant from the DST, and the total volume increase in DST volume for Alternative B is estimated to be 90,000 gallons. If the waste removal using the first 80,000 gallons is not as successful as shown or if the extended efficiency is less than 0.3%, additional sluicing would be required to remove 1,450 gallons of waste.

D4.0 ALTERNATIVES C – MODIFIED SLUICING FOLLOWED BY NEW VACUUM RETRIEVAL SYSTEM

In this configuration, modified sluicing with existing equipment is used to remove waste until the efficiency drops as shown in Table D-5. The remainder of the waste is removed using a vacuum retrieval system. The vacuum system uses a very small amount of water for in-tank retrieval including transfer water to transfer the waste to the DST AN-106.

Table D-5. Alternative C - Modified Sluicing Followed by Vacuum Retrieval (Volumes are in Gallons).

Waste Volume (start)	Water Used	(Cumulative water usage)	Assumed Efficiency (% solids in slurry)	Waste Removed	Waste Remaining
3,500	10,000	(10,000)	1.0	100	3,400
3,400	10,000	(20,000)	0.5	50	3,350
3,350	10,000	(30,000)	0.3	30	3,320
3,320	10,000	(40,000)	0.2	20	3,300
3,300	10,000	(50,000)	0.1	10	3,290
3,290	20,000	(70,000)	vacuum	1,240	2,050

The first 50,000 gallons of water removes about 210 gallons of waste, and the vacuum system removes an additional 1,240 gallons. The total volume increase in DST volume for Alternative C is estimated to be 225,000 gallons. However, if the waste removal during the first 50,000 gallons of water is not as successful as shown or if the vacuum system is not as efficient as estimated, additional water usage would be required to remove 1,450 gallons of waste.

D5.0 ALTERNATIVE D – MOBILE RETRIEVAL SYSTEM

In this configuration, the system uses water as efficiently as the vacuum system in Alternative C without the use of sluicing. The total volume increase in DST volume from this operation is estimated to be 175,000 gallons. If the waste removal is not as efficient as estimated, additional water usage would be required to remove 1,450 gallons of waste.

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APPENDIX E

SINGLE-SHELL TANK 241-C-106 INVENTORY PROJECTIONS FOR VARYING VOLUMES

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Table E-1. 241-C-106 Inventory Projections for Varying Volumes for Radionuclides. (8 sheets)

CAS	Constituent	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)
		500 cu.ft.	450 cu.ft.	400 cu.ft.	359 cu.ft.	300 cu.ft.	250 cu.ft.	200 cu.ft.	150 cu.ft.	100 cu.ft.
N/A	Aroclors (Total PCBs)	1.89E-03	1.70E-03	1.52E-03	1.36E-03	1.14E-03	9.47E-04	7.58E-04	5.68E-04	3.79E-04
100-02-7	4-Nitrophenol	1.59E-02	1.43E-02	1.27E-02	1.14E-02	9.51E-03	7.93E-03	6.34E-03	4.76E-03	3.17E-03
100-41-4	Ethylbenzene	2.81E-04	2.53E-04	2.25E-04	2.02E-04	1.69E-04	1.41E-04	1.12E-04	8.43E-05	5.62E-05
106-42-3	p-Xylene	3.20E-04	2.88E-04	2.56E-04	2.30E-04	1.92E-04	1.60E-04	1.28E-04	9.60E-05	6.40E-05
106-46-7	1,4-Dichlorobenzene	2.88E-02	2.59E-02	2.31E-02	2.07E-02	1.73E-02	1.44E-02	1.15E-02	8.64E-03	5.76E-03
107-06-2	1,2-Dichloroethane	1.16E-04	1.04E-04	9.28E-05	8.33E-05	6.96E-05	5.80E-05	4.64E-05	3.48E-05	2.32E-05
108-10-1	4-Methyl-2-pentanone (hexone)	2.42E-04	2.17E-04	1.93E-04	1.73E-04	1.45E-04	1.21E-04	9.66E-05	7.25E-05	4.83E-05
108-38-3	*m*-Xylene	3.20E-04	2.88E-04	2.56E-04	2.30E-04	1.92E-04	1.60E-04	1.28E-04	9.60E-05	6.40E-05
108-88-3	Toluene	1.32E-04	1.19E-04	1.06E-04	9.51E-05	7.95E-05	6.62E-05	5.30E-05	3.97E-05	2.65E-05
108-90-7	Chlorobenzene	1.39E-04	1.25E-04	1.11E-04	9.97E-05	8.34E-05	6.95E-05	5.56E-05	4.17E-05	2.78E-05
108-94-1	Cyclohexanone	4.80E-02	4.32E-02	3.84E-02	3.45E-02	2.88E-02	2.40E-02	1.92E-02	1.44E-02	9.60E-03
108-95-2	Phenol	6.58E-02	5.92E-02	5.26E-02	4.72E-02	3.95E-02	3.29E-02	2.63E-02	1.97E-02	1.32E-02
110-80-5	2-Ethoxyethanol	1.58E-02	1.42E-02	1.26E-02	1.13E-02	9.46E-03	7.89E-03	6.31E-03	4.73E-03	3.15E-03
110-86-1	Pyridine	2.01E-02	1.81E-02	1.61E-02	1.44E-02	1.21E-02	1.00E-02	8.04E-03	6.03E-03	4.02E-03
117-84-0	Di-n-octylphthalate	3.33E-02	3.00E-02	2.66E-02	2.39E-02	2.00E-02	1.66E-02	1.33E-02	9.99E-03	6.66E-03
120-82-1	1,2,4-Trichlorobenzene SV	1.81E-04	1.63E-04	1.44E-04	1.30E-04	1.08E-04	9.03E-05	7.22E-05	5.42E-05	3.61E-05
121-14-2	2,4-Dinitrotoluene	2.10E-02	1.89E-02	1.68E-02	1.51E-02	1.26E-02	1.05E-02	8.39E-03	6.29E-03	4.19E-03
12311-97-6	Formate by IC-DIONEX 500 col	4.92E+01	4.43E+01	3.94E+01	3.53E+01	2.95E+01	2.46E+01	1.97E+01	1.48E+01	9.85E+00
127-18-4	Tetrachloroethene	1.48E-04	1.33E-04	1.18E-04	1.06E-04	8.87E-05	7.39E-05	5.91E-05	4.43E-05	2.96E-05

Table E-1. 241-C-106 Inventory Projections for Varying Volumes for Radionuclides. (8 sheets)

CAS	Constituent	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)
		500 cu.ft.	450 cu.ft.	400 cu.ft.	359 cu.ft.	300 cu.ft.	250 cu.ft.	200 cu.ft.	150 cu.ft.	100 cu.ft.
128-37-0	2,6-bis(tert-butyl)4Methylphenol	2.03E-02	1.83E-02	1.63E-02	1.46E-02	1.22E-02	1.02E-02	8.13E-03	6.10E-03	4.07E-03
129-00-0	Pyrene	3.22E-02	2.89E-02	2.57E-02	2.31E-02	1.93E-02	1.61E-02	1.29E-02	9.65E-03	6.43E-03
1319-77-3	3 & 4 Methylphenol Total	2.57E-01	2.31E-01	2.05E-01	1.84E-01	1.54E-01	1.28E-01	1.03E-01	7.70E-02	5.14E-02
1319-77-3	Total Methylphenols (cresol)	8.12E-02	7.31E-02	6.49E-02	5.83E-02	4.87E-02	4.06E-02	3.25E-02	2.44E-02	1.62E-02
1330-20-7	Xylenes (total)	4.22E-04	3.80E-04	3.38E-04	3.03E-04	2.53E-04	2.11E-04	1.69E-04	1.27E-04	8.45E-05
13494-80-9	Tellurium-ICP-Acid Dilution	3.35E+00	3.02E+00	2.68E+00	2.41E+00	2.01E+00	1.68E+00	1.34E+00	1.01E+00	6.70E-01
141-78-6	Ethyl acetate	1.75E-04	1.58E-04	1.40E-04	1.26E-04	1.05E-04	8.75E-05	7.00E-05	5.25E-05	3.50E-05
14265-44-2	Phosphate-IC-Dionex 500 col	5.78E+01	5.20E+01	4.62E+01	4.15E+01	3.47E+01	2.89E+01	2.31E+01	1.73E+01	1.16E+01
14797-55-8	Nitrate-IC-Dionex 500 col	6.42E+01	5.78E+01	5.14E+01	4.61E+01	3.85E+01	3.21E+01	2.57E+01	1.93E+01	1.28E+01
14797-65-0	Nitrite-IC - Dionex 500 col	5.78E+01	5.20E+01	4.62E+01	4.15E+01	3.47E+01	2.89E+01	2.31E+01	1.73E+01	1.16E+01
14798-03-9	Ammonium Ion-IC-Dionex 100	1.35E+00	1.22E+00	1.08E+00	9.70E-01	8.10E-01	6.75E-01	5.40E-01	4.05E-01	2.70E-01
14808-79-8	Sulfate-IC-Dionex 500 col	6.85E+01	6.16E+01	5.48E+01	4.92E+01	4.11E+01	3.42E+01	2.74E+01	2.05E+01	1.37E+01
16887-00-6	Chloride-IC-Dionex 500 col	8.57E+00	7.71E+00	6.85E+00	6.15E+00	5.14E+00	4.28E+00	3.43E+00	2.57E+00	1.71E+00
16984-48-8	Fluoride-IC-Dionex 500 col	7.58E-01	6.82E-01	6.06E-01	5.44E-01	4.55E-01	3.79E-01	3.03E-01	2.27E-01	1.52E-01

Table E-1. 241-C-106 Inventory Projections for Varying Volumes for Radionuclides. (8 sheets)

CAS	Constituent	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)
		500 cu.ft.	450 cu.ft.	400 cu.ft.	359 cu.ft.	300 cu.ft.	250 cu.ft.	200 cu.ft.	150 cu.ft.	100 cu.ft.
18496-25-8	Sulfide by Microdist. & ISE	1.90E-01	1.71E-01	1.52E-01	1.37E-01	1.14E-01	9.51E-02	7.61E-02	5.71E-02	3.81E-02
206-44-0	Fluoranthene	1.99E-02	1.80E-02	1.60E-02	1.43E-02	1.20E-02	9.97E-03	7.98E-03	5.98E-03	3.99E-03
24959-67-9	Bromide-IC-Dionex 500 col	6.21E+01	5.59E+01	4.97E+01	4.46E+01	3.72E+01	3.10E+01	2.48E+01	1.86E+01	1.24E+01
338-70-5	Oxalate-IC-Dionex 500 col	4.63E+02	4.17E+02	3.71E+02	3.33E+02	2.78E+02	2.32E+02	1.85E+02	1.39E+02	9.26E+01
542-75-6	trans-1,3-Dichloropropene	1.15E-04	1.03E-04	9.17E-05	8.23E-05	6.88E-05	5.73E-05	4.59E-05	3.44E-05	2.29E-05
56-23-5	Carbon Tetrachloride	2.12E-04	1.91E-04	1.70E-04	1.52E-04	1.27E-04	1.06E-04	8.48E-05	6.36E-05	4.24E-05
57-12-5	Cyanide EDTA Addition	1.09E-01	9.80E-02	8.71E-02	7.82E-02	6.53E-02	5.45E-02	4.36E-02	3.27E-02	2.18E-02
59-50-7	4-Chloro-3-methylphenol	1.07E-02	9.59E-03	8.52E-03	7.65E-03	6.39E-03	5.33E-03	4.26E-03	3.20E-03	2.13E-03
59-89-2	N-Nitrosomorpholine	1.67E-02	1.50E-02	1.34E-02	1.20E-02	1.00E-02	8.35E-03	6.68E-03	5.01E-03	3.34E-03
60-29-7	Diethyl ether (ethyl ether)	1.58E-04	1.42E-04	1.27E-04	1.14E-04	9.49E-05	7.91E-05	6.33E-05	4.75E-05	3.16E-05
621-64-7	N-Nitroso-di-n-propylamine	1.89E-02	1.70E-02	1.51E-02	1.35E-02	1.13E-02	9.43E-03	7.54E-03	5.66E-03	3.77E-03
666-14-8	Glycolate-IC-Dionex 500 ORGACD	4.07E+01	3.66E+01	3.25E+01	2.92E+01	2.44E+01	2.03E+01	1.63E+01	1.22E+01	8.13E+00
67-64-1	Acetone	1.81E-03	1.63E-03	1.45E-03	1.30E-03	1.09E-03	9.07E-04	7.25E-04	5.44E-04	3.63E-04
67-66-3	Chloroform	1.71E-04	1.54E-04	1.37E-04	1.23E-04	1.02E-04	8.53E-05	6.83E-05	5.12E-05	3.41E-05
67-72-1	Hexachloroethane	1.06E-04	9.54E-05	8.48E-05	7.61E-05	6.36E-05	5.30E-05	4.24E-05	3.18E-05	2.12E-05
71-36-3	1-Butanol	3.01E-02	2.71E-02	2.41E-02	2.16E-02	1.81E-02	1.51E-02	1.21E-02	9.04E-03	6.03E-03

Table E-1. 241-C-106 Inventory Projections for Varying Volumes for Radionuclides. (8 sheets)

CAS	Constituent	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)
		500 cu.ft.	450 cu.ft.	400 cu.ft.	359 cu.ft.	300 cu.ft.	250 cu.ft.	200 cu.ft.	150 cu.ft.	100 cu.ft.
71-43-2	Benzene	1.13E-04	1.01E-04	9.00E-05	8.08E-05	6.75E-05	5.63E-05	4.50E-05	3.38E-05	2.25E-05
71-50-1	Acetate by IC-Dionex 500 col	4.92E+01	4.43E+01	3.94E+01	3.53E+01	2.95E+01	2.46E+01	1.97E+01	1.48E+01	9.85E+00
71-55-6	1,1,1-Trichloroethane	1.60E-04	1.44E-04	1.28E-04	1.15E-04	9.62E-05	8.02E-05	6.41E-05	4.81E-05	3.21E-05
7429-90-5	Aluminum-ICP-Acid Dil.	5.33E+02	4.80E+02	4.27E+02	3.83E+02	3.20E+02	2.67E+02	2.13E+02	1.60E+02	1.07E+02
7439-89-6	Iron-ICP-Acid Dil.	2.89E+02	2.60E+02	2.31E+02	2.07E+02	1.73E+02	1.44E+02	1.15E+02	8.66E+01	5.77E+01
7439-91-0	Lanthanum-ICP-Acid Dil.	3.41E+00	3.07E+00	2.73E+00	2.45E+00	2.05E+00	1.71E+00	1.36E+00	1.02E+00	6.82E-01
7439-92-1	Lead-ICP-Acid Dil.	3.58E+01	3.22E+01	2.86E+01	2.57E+01	2.15E+01	1.79E+01	1.43E+01	1.07E+01	7.15E+00
7439-93-2	Lithium-ICP-Acid Dil.	1.58E-01	1.42E-01	1.26E-01	1.13E-01	9.46E-02	7.88E-02	6.31E-02	4.73E-02	3.15E-02
7439-95-4	Magnesium-ICP-Acid Dil.	9.91E+00	8.92E+00	7.93E+00	7.11E+00	5.95E+00	4.95E+00	3.96E+00	2.97E+00	1.98E+00
7439-96-5	Manganese-ICP-Acid Dil.	7.66E+02	6.90E+02	6.13E+02	5.50E+02	4.60E+02	3.83E+02	3.07E+02	2.30E+02	1.53E+02
7439-97-6	Mercury by CVAA (PE) with FIAS	2.69E+00	2.42E+00	2.15E+00	1.93E+00	1.61E+00	1.34E+00	1.08E+00	8.07E-01	5.38E-01
7439-98-7	Molybdenum-ICP-Acid Dil.	4.26E-01	3.83E-01	3.41E-01	3.06E-01	2.55E-01	2.13E-01	1.70E-01	1.28E-01	8.51E-02
7440-00-8	Neodymium-ICP-Acid Dil.	1.26E+01	1.13E+01	1.00E+01	9.02E+00	7.54E+00	6.28E+00	5.02E+00	3.77E+00	2.51E+00
7440-02-0	Nickel-ICP-Acid Dil.	4.21E+01	3.79E+01	3.37E+01	3.02E+01	2.53E+01	2.10E+01	1.68E+01	1.26E+01	8.42E+00
7440-03-1	Niobium -ICP-Acid Digest	5.90E+00	5.31E+00	4.72E+00	4.24E+00	3.54E+00	2.95E+00	2.36E+00	1.77E+00	1.18E+00

Table E-1. 241-C-106 Inventory Projections for Varying Volumes for Radionuclides. (8 sheets)

CAS	Constituent	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)
		500 cu.ft.	450 cu.ft.	400 cu.ft.	359 cu.ft.	300 cu.ft.	250 cu.ft.	200 cu.ft.	150 cu.ft.	100 cu.ft.
7440-05-3	Palladium -ICP-Acid Dil	9.85E+00	8.87E+00	7.88E+00	7.08E+00	5.91E+00	4.93E+00	3.94E+00	2.96E+00	1.97E+00
7440-09-7	Potassium-ICP-Acid Dil.	2.47E+01	2.22E+01	1.97E+01	1.77E+01	1.48E+01	1.23E+01	9.87E+00	7.40E+00	4.94E+00
7440-10-0	Praseodymium-ICP Acid Dilution	7.52E+00	6.77E+00	6.02E+00	5.40E+00	4.51E+00	3.76E+00	3.01E+00	2.26E+00	1.50E+00
7440-16-6	Rhodium -ICP-Acid Dilution	3.42E+00	3.07E+00	2.73E+00	2.45E+00	2.05E+00	1.71E+00	1.37E+00	1.02E+00	6.83E-01
7440-17-7	Rubidium-ICP-Acid Dilution	3.35E+01	3.02E+01	2.68E+01	2.41E+01	2.01E+01	1.68E+01	1.34E+01	1.01E+01	6.70E+00
7440-18-8	Ruthenium ICP-Acid Dilution	3.35E+00	3.02E+00	2.68E+00	2.41E+00	2.01E+00	1.68E+00	1.34E+00	1.01E+00	6.70E-01
7440-19-9	Samarium-ICP-Acid Dil.	3.50E+00	3.15E+00	2.80E+00	2.51E+00	2.10E+00	1.75E+00	1.40E+00	1.05E+00	7.00E-01
7440-21-3	Silicon-ICP-Acid Dil.	2.23E+01	2.01E+01	1.79E+01	1.60E+01	1.34E+01	1.12E+01	8.93E+00	6.70E+00	4.47E+00
7440-22-4	Silver-ICP-Acid Dil.	1.09E+01	9.84E+00	8.75E+00	7.85E+00	6.56E+00	5.47E+00	4.37E+00	3.28E+00	2.19E+00
7440-23-5	Sodium-ICP-Acid Dil.	2.63E+02	2.37E+02	2.10E+02	1.89E+02	1.58E+02	1.31E+02	1.05E+02	7.89E+01	5.26E+01
7440-24-6	Strontium-ICP-Acid Dil.	2.55E+00	2.29E+00	2.04E+00	1.83E+00	1.53E+00	1.27E+00	1.02E+00	7.64E-01	5.10E-01
7440-25-7	Tantalum -ICP-Acid Dil.	3.35E+00	3.02E+00	2.68E+00	2.41E+00	2.01E+00	1.68E+00	1.34E+00	1.01E+00	6.70E-01
7440-28-0	Thallium-ICP-Acid Dil.	9.85E+00	8.87E+00	7.88E+00	7.07E+00	5.91E+00	4.93E+00	3.94E+00	2.96E+00	1.97E+00
7440-29-1	Thorium -ICP-Acid Dilution	4.34E+00	3.91E+00	3.47E+00	3.12E+00	2.61E+00	2.17E+00	1.74E+00	1.30E+00	8.69E-01
7440-31-5	Tin -ICP-Acid Dil.	3.35E+00	3.02E+00	2.68E+00	2.41E+00	2.01E+00	1.68E+00	1.34E+00	1.01E+00	6.70E-01

Table E-1. 241-C-106 Inventory Projections for Varying Volumes for Radionuclides. (8 sheets)

CAS	Constituent	Total tank inventory (Kg) 500 cu.ft.	Total tank inventory (Kg) 450 cu.ft.	Total tank inventory (Kg) 400 cu.ft.	Total tank inventory (Kg) 359 cu.ft.	Total tank inventory (Kg) 300 cu.ft.	Total tank inventory (Kg) 250 cu.ft.	Total tank inventory (Kg) 200 cu.ft.	Total tank inventory (Kg) 150 cu.ft.	Total tank inventory (Kg) 100 cu.ft.
7440-32-6	Titanium-ICP-Acid Dil.	5.37E-01	4.83E-01	4.30E-01	3.86E-01	3.22E-01	2.69E-01	2.15E-01	1.61E-01	1.07E-01
7440-33-7	Tungsten -ICP-Acid Dil.	6.59E+00	5.93E+00	5.27E+00	4.73E+00	3.96E+00	3.30E+00	2.64E+00	1.98E+00	1.32E+00
7440-36-0	Antimony-ICP-Acid Dil.	1.66E+00	1.49E+00	1.32E+00	1.19E+00	9.93E-01	8.28E-01	6.62E-01	4.97E-01	3.31E-01
7440-38-2	Arsenic-ICP-Acid Dil.	4.02E+00	3.62E+00	3.22E+00	2.89E+00	2.41E+00	2.01E+00	1.61E+00	1.21E+00	8.04E-01
7440-39-3	Barium-ICP-Acid Dil.	2.28E+00	2.05E+00	1.83E+00	1.64E+00	1.37E+00	1.14E+00	9.13E-01	6.85E-01	4.56E-01
7440-41-7	Beryllium-ICP-Acid Dil.	7.88E-02	7.10E-02	6.31E-02	5.66E-02	4.73E-02	3.94E-02	3.15E-02	2.37E-02	1.58E-02
7440-42-8	Boron-ICP-Acid Dil.	1.66E+00	1.49E+00	1.32E+00	1.19E+00	9.93E-01	8.28E-01	6.62E-01	4.97E-01	3.31E-01
7440-43-9	Cadmium-ICP-Acid Dil.	2.01E+00	1.81E+00	1.61E+00	1.44E+00	1.21E+00	1.01E+00	8.05E-01	6.04E-01	4.02E-01
7440-45-1	Cerium-ICP-Acid Dil.	7.95E+00	7.15E+00	6.36E+00	5.71E+00	4.77E+00	3.97E+00	3.18E+00	2.38E+00	1.59E+00
7440-47-3	Chromium-ICP-Acid Dil.	5.27E+00	4.75E+00	4.22E+00	3.79E+00	3.16E+00	2.64E+00	2.11E+00	1.58E+00	1.05E+00
7440-48-4	Cobalt-ICP-Acid Dil.	5.24E-01	4.72E-01	4.19E-01	3.76E-01	3.14E-01	2.62E-01	2.10E-01	1.57E-01	1.05E-01
7440-50-8	Copper-ICP-Acid Dil.	3.22E+00	2.90E+00	2.58E+00	2.31E+00	1.93E+00	1.61E+00	1.29E+00	9.66E-01	6.44E-01
7440-53-1	Europium ICP-Acid Dil.	8.67E-01	7.80E-01	6.94E-01	6.23E-01	5.20E-01	4.34E-01	3.47E-01	2.60E-01	1.73E-01
7440-61-1	Uranium-ICP-Acid Dil.	4.10E+00	3.69E+00	3.28E+00	2.94E+00	2.46E+00	2.05E+00	1.64E+00	1.23E+00	8.20E-01
7440-62-2	Vanadium-ICP-Acid Dil.	4.10E-01	3.69E-01	3.28E-01	2.94E-01	2.46E-01	2.05E-01	1.64E-01	1.23E-01	8.20E-02
7440-65-5	Yttrium -ICP-Acid Dilution	2.36E+00	2.13E+00	1.89E+00	1.70E+00	1.42E+00	1.18E+00	9.45E-01	7.09E-01	4.73E-01

Table E-1. 241-C-106 Inventory Projections for Varying Volumes for Radionuclides. (8 sheets)

CAS	Constituent	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)
		500 cu.ft.	450 cu.ft.	400 cu.ft.	359 cu.ft.	300 cu.ft.	250 cu.ft.	200 cu.ft.	150 cu.ft.	100 cu.ft.
7440-66-6	Zinc-ICP-Acid Dil.	2.97E+00	2.67E+00	2.37E+00	2.13E+00	1.78E+00	1.48E+00	1.19E+00	8.90E-01	5.93E-01
7440-67-7	Zirconium-ICP-Acid Dil.	3.89E+00	3.50E+00	3.11E+00	2.79E+00	2.33E+00	1.94E+00	1.56E+00	1.17E+00	7.78E-01
7440-69-9	Bismuth-ICP-Acid Dil.	4.10E+00	3.69E+00	3.28E+00	2.94E+00	2.46E+00	2.05E+00	1.64E+00	1.23E+00	8.20E-01
7440-70-2	Calcium-ICP-Acid Dil.	1.64E+02	1.48E+02	1.31E+02	1.18E+02	9.84E+01	8.20E+01	6.56E+01	4.92E+01	3.28E+01
75-01-4	Vinyl Chloride	8.08E-05	7.27E-05	6.46E-05	5.80E-05	4.85E-05	4.04E-05	3.23E-05	2.42E-05	1.62E-05
75-09-2	Methylene Chloride	1.38E-04	1.24E-04	1.10E-04	9.88E-05	8.26E-05	6.88E-05	5.50E-05	4.13E-05	2.75E-05
75-15-0	Carbon Disulfide	1.66E-04	1.50E-04	1.33E-04	1.19E-04	9.98E-05	8.32E-05	6.66E-05	4.99E-05	3.33E-05
75-35-4	1,1-Dichloroethene	1.89E-04	1.70E-04	1.51E-04	1.36E-04	1.14E-04	9.47E-05	7.57E-05	5.68E-05	3.79E-05
75-69-4	Trichlorofluoromethane	1.68E-04	1.51E-04	1.34E-04	1.20E-04	1.01E-04	8.39E-05	6.71E-05	5.03E-05	3.36E-05
76-13-1	1,1,2-Trichloro-1,2,2-trifluoroethane	1.80E-04	1.62E-04	1.44E-04	1.29E-04	1.08E-04	9.00E-05	7.20E-05	5.40E-05	3.60E-05
7704-34-9	Sulfur-ICP-Acid Dil.	1.82E+00	1.63E+00	1.45E+00	1.30E+00	1.09E+00	9.08E-01	7.26E-01	5.45E-01	3.63E-01
7723-14-0	Phosphorus-ICP-Acid Dil.	4.10E+01	3.69E+01	3.28E+01	2.94E+01	2.46E+01	2.05E+01	1.64E+01	1.23E+01	8.20E+00
7782-49-2	Selenium-ICP-Acid Dil.	4.10E+00	3.69E+00	3.28E+00	2.94E+00	2.46E+00	2.05E+00	1.64E+00	1.23E+00	8.20E-01
78-83-1	Isobutanol	4.01E-02	3.61E-02	3.21E-02	2.88E-02	2.41E-02	2.01E-02	1.61E-02	1.20E-02	8.03E-03
78-93-3	2-Butanone	6.23E-04	5.61E-04	4.99E-04	4.48E-04	3.74E-04	3.12E-04	2.49E-04	1.87E-04	1.25E-04
79-00-5	1,1,2-Trichloroethane	1.18E-04	1.06E-04	9.40E-05	8.44E-05	7.05E-05	5.88E-05	4.70E-05	3.53E-05	2.35E-05
79-01-6	Trichloroethene	2.26E-04	2.04E-04	1.81E-04	1.63E-04	1.36E-04	1.13E-04	9.05E-05	6.79E-05	4.53E-05
79-34-5	1,1,2,2-Tetrachloroethane	1.18E-04	1.06E-04	9.41E-05	8.45E-05	7.06E-05	5.88E-05	4.71E-05	3.53E-05	2.35E-05
79-46-9	2-Nitropropane	2.81E-04	2.53E-04	2.25E-04	2.02E-04	1.69E-04	1.41E-04	1.13E-04	8.44E-05	5.63E-05

Table E-1. 241-C-106 Inventory Projections for Varying Volumes for Radionuclides. (8 sheets)

CAS	Constituent	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)	Total tank inventory (Kg)
		500 cu.ft.	450 cu.ft.	400 cu.ft.	359 cu.ft.	300 cu.ft.	250 cu.ft.	200 cu.ft.	150 cu.ft.	100 cu.ft.
83-32-9	Acenaphthene	3.33E-02	2.99E-02	2.66E-02	2.39E-02	2.00E-02	1.66E-02	1.33E-02	9.98E-03	6.65E-03
84-74-2	Di-n-butylphthalate	5.93E-03	5.33E-03	4.74E-03	4.26E-03	3.56E-03	2.96E-03	2.37E-03	1.78E-03	1.19E-03
85-68-7	Butylbenzylphthalate	5.90E-03	5.31E-03	4.72E-03	4.24E-03	3.54E-03	2.95E-03	2.36E-03	1.77E-03	1.18E-03
87-68-3	Hexachlorobutadiene	7.39E-03	6.65E-03	5.91E-03	5.31E-03	4.44E-03	3.70E-03	2.96E-03	2.22E-03	1.48E-03
87-86-5	Pentachlorophenol	1.45E-02	1.30E-02	1.16E-02	1.04E-02	8.69E-03	7.24E-03	5.79E-03	4.35E-03	2.90E-03
88-06-2	2,4,6-Trichlorophenol	1.63E-02	1.47E-02	1.30E-02	1.17E-02	9.77E-03	8.14E-03	6.51E-03	4.89E-03	3.26E-03
88-75-5	2-Nitrophenol	3.44E-02	3.10E-02	2.75E-02	2.47E-02	2.07E-02	1.72E-02	1.38E-02	1.03E-02	6.88E-03
91-20-3	Naphthalene	1.34E-02	1.20E-02	1.07E-02	9.60E-03	8.02E-03	6.68E-03	5.35E-03	4.01E-03	2.67E-03
95-47-6	o-Xylene	1.00E-04	9.00E-05	8.00E-05	7.18E-05	6.00E-05	5.00E-05	4.00E-05	3.00E-05	2.00E-05
95-48-7	2-Methylphenol	5.66E-02	5.09E-02	4.52E-02	4.06E-02	3.39E-02	2.83E-02	2.26E-02	1.70E-02	1.13E-02
95-50-1	1,2-Dichlorobenzene	2.99E-02	2.69E-02	2.39E-02	2.15E-02	1.80E-02	1.50E-02	1.20E-02	8.98E-03	5.99E-03
95-57-8	2-Chlorophenol	2.89E-02	2.60E-02	2.31E-02	2.07E-02	1.73E-02	1.44E-02	1.16E-02	8.67E-03	5.78E-03
95-95-4	2,4,5-Trichlorophenol	1.54E-02	1.39E-02	1.23E-02	1.11E-02	9.24E-03	7.70E-03	6.16E-03	4.62E-03	3.08E-03
98-95-3	Nitrobenzene	1.40E-02	1.26E-02	1.12E-02	1.01E-02	8.41E-03	7.01E-03	5.61E-03	4.21E-03	2.80E-03
ALK	Hydroxide	2.25E+00	2.25E+00	2.25E+00	2.25E+00	2.25E+00	2.25E+00	2.25E+00	2.25E+00	2.25E+00

Notes:
CVAA = Cold vapor atomic absorption.
EDTA = ethylenediaminetetracaetic acid.
FIAS = Flow Impedance Analysis System.
ICP = inductively-coupled plasma.
N/A = not applicable.
PCB = polychlorinated biphenyl.

Table E-2. 241-C-106 Inventory Projections for Varying Volumes for Nonradionuclides. (3 sheets)

CAS	Constituent	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)
		500 cu.ft.	450 cu.ft.	400 cu.ft.	359 cu.ft.	300 cu.ft.	250 cu.ft.	200 cu.ft.	150 cu.ft.	100 cu.ft.
N/A	Actinium-228 by GEA	1.08E+02	9.76E+01	8.67E+01	7.78E+01	6.50E+01	5.42E+01	4.34E+01	3.25E+01	2.17E+01
N/A	Am-241 by TRU-SPEC Resin IonEx	9.10E+01	8.19E+01	7.28E+01	6.53E+01	5.46E+01	4.55E+01	3.64E+01	2.73E+01	1.82E+01
N/A	Antimony-125 by GEA	8.83E+01	7.95E+01	7.07E+01	6.34E+01	5.30E+01	4.42E+01	3.53E+01	2.65E+01	1.77E+01
N/A	C-14 Small Volume	1.15E-02	1.03E-02	9.18E-03	8.24E-03	6.89E-03	5.74E-03	4.59E-03	3.44E-03	2.30E-03
N/A	Ce/Pr-144 by GEA	3.84E+02	3.46E+02	3.07E+02	2.76E+02	2.31E+02	1.92E+02	1.54E+02	1.15E+02	7.69E+01
N/A	Cesium-134 by GEA	2.42E+01	2.18E+01	1.94E+01	1.74E+01	1.45E+01	1.21E+01	9.69E+00	7.27E+00	4.85E+00
N/A	Cesium-137 by GEA	2.02E+03	1.81E+03	1.61E+03	1.45E+03	1.21E+03	1.01E+03	8.06E+02	6.05E+02	4.03E+02
N/A	Curium-243/244	1.05E+01	9.47E+00	8.42E+00	7.55E+00	6.31E+00	5.26E+00	4.21E+00	3.16E+00	2.10E+00
N/A	Cobalt-60 by GEA	2.51E+01	2.26E+01	2.01E+01	1.80E+01	1.51E+01	1.26E+01	1.01E+01	7.54E+00	5.03E+00
N/A	Europium-152 by GEA	8.74E+01	7.87E+01	6.99E+01	6.27E+01	5.24E+01	4.37E+01	3.50E+01	2.62E+01	1.75E+01
N/A	Europium-154 by GEA	1.13E+02	1.02E+02	9.06E+01	8.13E+01	6.79E+01	5.66E+01	4.53E+01	3.40E+01	2.26E+01
N/A	Europium-155 by GEA	1.09E+02	9.77E+01	8.69E+01	7.80E+01	6.52E+01	5.43E+01	4.34E+01	3.26E+01	2.17E+01
N/A	Iodine-129 Waste Tank Samples	8.80E-04	7.92E-04	7.04E-04	6.32E-04	5.28E-04	4.40E-04	3.52E-04	2.64E-04	1.76E-04
N/A	Neptunium-237 by ICP/MS	7.40E-02	6.66E-02	5.92E-02	5.31E-02	4.44E-02	3.70E-02	2.96E-02	2.22E-02	1.48E-02
N/A	Nickel 63	1.02E+02	9.14E+01	8.13E+01	7.30E+01	6.10E+01	5.08E+01	4.06E+01	3.05E+01	2.03E+01
N/A	Niobium-94 by GEA	2.62E+01	2.35E+01	2.09E+01	1.88E+01	1.57E+01	1.31E+01	1.05E+01	7.85E+00	5.23E+00
N/A	Pu-238 by TRU-SPEC Resin IonEx	3.77E+00	3.39E+00	3.02E+00	2.71E+00	2.26E+00	1.88E+00	1.51E+00	1.13E+00	7.54E-01
N/A	Pu-239/240 by TRU-SPEC Resin	2.84E+01	2.55E+01	2.27E+01	2.04E+01	1.70E+01	1.42E+01	1.13E+01	8.51E+00	5.67E+00
N/A	Radium-226 by GEA	5.80E+02	5.22E+02	4.64E+02	4.17E+02	3.48E+02	2.90E+02	2.32E+02	1.74E+02	1.16E+02
N/A	Ru/Rh-106 by GEA	4.70E+02	4.23E+02	3.76E+02	3.37E+02	2.82E+02	2.35E+02	1.88E+02	1.41E+02	9.40E+01
N/A	Selenium-79 by Liquid Scint.	1.34E-02	1.20E-02	1.07E-02	9.59E-03	8.02E-03	6.68E-03	5.34E-03	4.01E-03	2.67E-03

Table E-2. 241-C-106 Inventory Projections for Varying Volumes for Nonradionuclides. (3 sheets)

CAS	Constituent	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)
		500 cu.ft.	450 cu.ft.	400 cu.ft.	359 cu.ft.	300 cu.ft.	250 cu.ft.	200 cu.ft.	150 cu.ft.	100 cu.ft.
N/A	Strontium-89/90 High Level	9.21E+04	8.29E+04	7.36E+04	6.61E+04	5.52E+04	4.60E+04	3.68E+04	2.76E+04	1.84E+04
N/A	Tc 99 by ICP/MS Acid Addition	2.30E-01	2.07E-01	1.84E-01	1.65E-01	1.38E-01	1.15E-01	9.19E-02	6.89E-02	4.60E-02
N/A	Thorium-230 by ICP/MS	1.23E-03	1.11E-03	9.83E-04	8.82E-04	7.37E-04	6.14E-04	4.91E-04	3.69E-04	2.46E-04
N/A	Thorium-232 by ICP/MS	7.81E-04	7.03E-04	6.25E-04	5.61E-04	4.69E-04	3.91E-04	3.13E-04	2.34E-04	1.56E-04
N/A	Tritium By Lachat	1.42E-02	1.28E-02	1.14E-02	1.02E-02	8.53E-03	7.11E-03	5.69E-03	4.27E-03	2.84E-03
N/A	Uranium-233 by ICP/MS Acid Add	2.55E-03	2.29E-03	2.04E-03	1.83E-03	1.53E-03	1.27E-03	1.02E-03	7.65E-04	5.10E-04
N/A	Uranium-234 by ICP/MS Acid Add	1.32E-03	1.19E-03	1.06E-03	9.48E-04	7.92E-04	6.60E-04	5.28E-04	3.96E-04	2.64E-04
N/A	Uranium-235 by ICP/MS Acid Add	5.39E-05	4.85E-05	4.31E-05	3.87E-05	3.23E-05	2.70E-05	2.16E-05	1.62E-05	1.08E-05
N/A	Uranium-236 by ICP/MS Acid Add	2.41E-05	2.17E-05	1.93E-05	1.73E-05	1.45E-05	1.20E-05	9.64E-06	7.23E-06	4.82E-06
N/A	Uranium-238 by ICP/MS Acid Add	1.26E-03	1.13E-03	1.01E-03	9.04E-04	7.56E-04	6.30E-04	5.04E-04	3.78E-04	2.52E-04
N/A	Pu-241	5.53E+01	4.98E+01	4.42E+01	3.97E+01	3.32E+01	2.77E+01	2.21E+01	1.66E+01	1.11E+01
N/A	Pu-239	2.34E+01	2.10E+01	1.87E+01	1.68E+01	1.40E+01	1.17E+01	9.35E+00	7.01E+00	4.67E+00
N/A	Pu-240	4.99E+00	4.49E+00	3.99E+00	3.58E+00	2.99E+00	2.49E+00	1.99E+00	1.50E+00	9.97E-01
N/A	Cm-242	2.20E-01	1.98E-01	1.76E-01	1.58E-01	1.32E-01	1.10E-01	8.78E-02	6.59E-02	4.39E-02
N/A	Cm-243	4.21E-01	3.79E-01	3.37E-01	3.02E-01	2.52E-01	2.10E-01	1.68E-01	1.26E-01	8.42E-02
N/A	Cm-244	1.01E+01	9.09E+00	8.08E+00	7.25E+00	6.06E+00	5.05E+00	4.04E+00	3.03E+00	2.02E+00
N/A	Thorium-228	8.01E-04	7.21E-04	6.41E-04	5.75E-04	4.80E-04	4.00E-04	3.20E-04	2.40E-04	1.60E-04

Table E-2. 241-C-106 Inventory Projections for Varying Volumes for Nonradionuclides. (3 sheets)

CAS	Constituent	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)	Total tank inventory (Ci)
		500 cu.ft.	450 cu.ft.	400 cu.ft.	359 cu.ft.	300 cu.ft.	250 cu.ft.	200 cu.ft.	150 cu.ft.	100 cu.ft.

Notes:

GEA = Gamma energy analysis.

ICP/MS = Inductively coupled plasma mass spectrometer.

N/A = not applicable.

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APPENDIX F

PAIR COMPARISON ALTERNATIVE ANALYSIS

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Table F-1. Paired Comparison.

Numerical Evaluation					
	B	C	D	E	F
A	b3	c5	a1	e3	a1
	B	c5	d1	e3	f1
		C	c5	c3	c5
			D	e3	f1
				E	e3
					F

SUMMARY EVALUATION			Base 100
ID	DESCRIPTION	VALUE	Score
A	Cost	2	5
B	Schedule	3	7
C	Risk to Workers	23	53
D	Ease of Implementation and Confidence in Technical Success	1	2
E	Risk to Human Health and Environment	12	28
F	Impacts to Mission; Resources, DST Space, Opportunity Costs, etc.	2	5
		43	100

IMPORTANCE

5 = Significantly More

3 = Moderately More

1 = Minimally More

DEFINITIONS

A. Cost of the Alternative includes all life-cycle facets of the alternative. A higher value on the subsequent rating matrix means the total cost for installing, operating, and demobilization of the particular technology is less than other technologies that are being considered. A higher value on the subsequent rating matrix means the cost for the particular technology is lower than the other alternatives being compared and that the total estimated cost contains a higher level of confidence for completing within the indicated estimate to complete.
B. Schedule for each alternative includes all life-cycle facets of the alternative. A higher value on the subsequent rating matrix means the total duration for installing, operating, and demobilization of the particular technology is shorter than other technologies that are being considered and that the schedule contains a higher level of confidence for achieving the scheduled end date.
C. Risk to workers includes ALARA considerations for both Industrial (structural, chemical, electrical, etc.) and Radiological Safety and Health. A higher value on the subsequent rating matrix means lower risk to the worker for implementing that particular technology.
D. Ease of Implementation refers to the level of difficulty that each alternative may include when installing, operating, and demobilizing equipment, instruments, etc. It also includes the level of project and technical risk associated with implementation. A higher value on the subsequent rating matrix means comparatively less difficulty for implementing and less risk for that particular alternative.
E. The Risks to the public or non-occupational personnel. Usually for near-term or long-term releases to the air or surrounding soils that account for the potential risk to the environment. A higher value on the subsequent rating matrix means comparatively lower risk to the public for that particular alternative.
F. Impacts of each alternative that could divert or delay other activities or programs that would otherwise be completed. A higher value on the subsequent rating matrix means comparatively lower impacts for that particular alternative.

Note: The analysis was supported by subject matter experts from the DOE Office of River Protection and CH2M HILL Hanford Group, Inc. and included representatives of retrieval engineering, strategic planning, process engineering, tank closure, and regulatory compliance. The analysis was based on available knowledge and engineering judgment relevant to SST C-106.

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Table F-2. Criteria Blank. (2 sheets)

10 = HIGHEST 1 = LOWEST		A. Cost	Cost Comments: A higher value means the cost for the particular technology is lower than the other alternatives and that the total estimated cost contains a higher level of confidence for completing within the indicated EAC.	B. Schedule	Schedule Comments: A higher value means the total duration for installing, operating, and demobilization of the particular technology is shorter than other technologies and that the schedule contains a higher level of confidence for achieving the scheduled end-date.	C. Risk to Workers	Risk to Workers Comments: A higher value means lower risk to the worker for implementing that particular technology.	D. Ease of Implementation and Confidence in Technical Success	Ease of Implementation and Confidence in Technical Success Comments: A higher value means comparatively less difficulty for implementing and less risk for that particular alternative to actually do what it is designed to do.	E. Risk to Human Health and Environment	Risk to Human Health and Environment Comments: A higher value means comparatively lower risk to the public and non-occupational personnel for that particular alternative.	F. Impacts to Mission; Resources, DST Space, Opportunity Costs, etc.	Impacts to Mission Comments: A higher value means comparatively lower impacts to other activities or programs that would otherwise be completed.	TOTAL
ID	Criteria Weight	5		7		53		2		28		5		
A	Raw Water Modified Sluicing (Current Equipment)	5	$1,925,950 Retrieval System Cost (reconnecting and operating) Evaporator Costs Increase by $3,740,000 Total Storage and Retrieval Life-Cycle Costs of $5,665,950 (does not include demobilization and disposal of equipment)	4	12 months start to finish duration (2 to 3 months of operating time) 1) The greater amount of evaporator use and transfers to DSTs may increase indicated duration. 2) If the operation of this alternative occurs during the MPS outage, then the duration may be impacted.	7	Since this equipment is already installed, the increase in potential risk to the work force is small. As duration increases, potential for exposure or injury increases.	6	Because the results of earlier modified sluicing campaigns indicate that the limits of technology have been achieved, there is a low probability of technical success in continuing to use modified sluicing.	7	Continuing to add large volumes of water to achieve further reduction in residual waste volume increases the probability of a leak occurring either during the modified sluicing operation or a subsequent transfer of waste to the DST receiver. Approximately 1496 gallons of residual would remain.	1	DST Storage Impact of 1,870,000 gallons. Resumption of modified sluicing in C-106 will divert people and $$ resources from other planned retrievals, e.g., C-200, C-103/C-105. Also uses evaporator capacity.	640
B	New Modified Sluicing with New Slurry Pump	5	$5,668,735 Retrieval System Cost Evaporator Costs Increase by $180,000 Total Storage and Retrieval Life-Cycle Costs of $5,848,735	5	12 months start to finish duration. With limited DST impacts, schedule confidence is good. However installations of new risers have not been done recently.	5	This option would add potential risk for the workers, since two new risers would need to be installed, the current equipment removed, and the new equipment (pump, nozzles) installed	6	There is extensive experience in installing new nozzles and pumps. There is limited experience and some difficulties with new riser installation.	7	Adding limited quantities of recycled supernatant as the sluicing medium to achieve further reduction in residual waste volume increases the probability of a leak occurring either during the modified sluicing operation or the transfers of waste between the DST receiver tank and C-106. Approximately 1496 gallons of residual would remain.	6	DST Storage Impact of 90,000 gallons. Additional modified sluicing of C-106 will divert people and $$ resources from other planned retrievals, particularly those scheduled in C-Farm beyond C-200 and C-103/C-105. Also uses evaporator capacity.	563
C	New Modified Sluicing Followed by New Vacuum Retrieval System	2	$10,171,593 Retrieval System Cost Evaporator Costs Increase by $450,000 Total Storage and Retrieval Life-Cycle Costs of $10,621,593	2	16 months start to finish duration (additional time for installing and operating the vacuum system and two new risers, plus the time for sluicing)	3	This option would add potential risk for the workers, since two new risers would need to be installed to support the installation and operation of the vacuum system.	4	Limited experience and some difficulty for installation of new risers. Higher mechanical complexity of the system. Operational experience will be gained from the C-200 series tank retrievals.	8	Adding limited quantities of water to move the waste to the vacuum intake results in a small potential impact from a leak occurring during the retrieval operation or during a transfer of waste to the DST receiver. Approximately 1496 gallons of residual would remain.	4	DST Storage Impact of 225,000 gallons. Additional modified sluicing/vacuum retrieval of C-106 will divert people and $$ resources from other planned retrievals, particularly those scheduled in C-Farm beyond C-200, e.g., C-103/C-105. Also uses evaporator capacity.	435

Table F-2. Criteria Blank. (2 sheets)

10 = HIGHEST 1 = LOWEST		A. Cost	Cost Comments: A higher value means the cost for the particular technology is lower than the other alternatives and that the total estimated cost contains a higher level of confidence for completing within the indicated EAC.	B. Schedule	Schedule Comments: A higher value means the total duration for installing, operating, and demobilization of the particular technology is shorter than other technologies and that the schedule contains a higher level of confidence for achieving the scheduled end-date.	C. Risk to Workers	Risk to Workers Comments: A higher value means lower risk to the worker for implementing that particular technology.	D. Ease of Implementation and Confidence in Technical Success	Ease of Implementation and Confidence in Technical Success Comments: A higher value means comparatively less difficulty for implementing and less risk for that particular alternative to actually do what it is designed to do.	E. Risk to Human Health and Environment	Risk to Human Health and Environment Comments: A higher value means comparatively lower risk to the public and non-occupational personnel for that particular alternative.	F. Impacts to Mission; Resources, DST Space, Opportunity Costs, etc.	Impacts to Mission Comments: A higher value means comparatively lower impacts to other activities or programs that would otherwise be completed.	TOTAL
ID	Criteria Weight	5		7		53		2		28		5		
D	Mobile Retrieval System Technology	1	$13,131,774 Retrieval System Cost Evaporator Costs Increase by $350,000 Total Retrieval and Storage Life-Cycle Costs of $13,481,774	1	18 months start to finish duration (increase time for readiness review for first time use of in-tank vehicle(ITV))	3	This option would add potential risk for the workers, since one new riser (42") would need to be installed to support the installation and operation of the MRS. The installation of first-of-a-kind equipment, i.e., ITV, adds another dimension to the risk to workers.	3	The only Hanford experience with the MRS equipment is in the Cold Test Facility.	10	Adding small quantities of water to assist the MRS system in moving the waste to the center of the tank for subsequent retrieval by the vacuum system results in a small potential impact from a leak occurring either during the retrieval operation or a transfer of waste to the DST receiver. Approximately 1496 gallons of residual would remain.	4	DST Storage Impact of 175,000 gallons. Additional retrieval from C-106 using MRS will divert people and $$ resources from other planned retrievals, particularly those scheduled in C-Farm beyond C-200 and C-103/C-105.	477
E	No Action	10	No additional cost for waste retrieval.	10	No additional time needed for retrieval.	10	Negligible additional risk to workers.	10	Easiest to implement and no technical risk.	9	No environmental risk due to leaking during retrieval. Approximately 2770 gallons of residual would remain. However initial performance assessment results indicate no significant risk difference from other alternatives.	10	This alternative allows the mission to proceed as planned.	972

APPENDIX G

MODIFIED SLUICING RETRIEVAL EFFICIENCY EVALUATION FOR TANK 241-C-106

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Calculation Sheet		Page: 1 of 9 Date: 5/12/2004
Calculation No.: **CEES-04-037-P-001**	Rev.: **0**	Title: **Modified Sluicing Retrieval Efficiency Evaluation for Tank 241-C-106**

Original and Revised Calculation/Analysis Approval

	Rev. 0 Name/Signature/Date	Rev.1 Name/Signature/Date	Rev. ___ Name/Signature/Date
Originator:	Keith Shields 5/12/04		
Checked by:	Rob Wilson 5/12/2004		
Approved by:			

Record of Revision

Revision	Reason for Revision
0	Initial development of the calculation.

Affected Documents

Document Number	Document Title	Revision Number
RPP-20658	BASIS FOR EXCEPTION TO THE HANFORD FEDERAL FACILITY AGREEMENT AND CONSENT ORDER WASTE RETRIEVAL CRITERIA FOR SINGLE-SHELL TANK 241-C-106	0

Calculation Sheet		Page: 2 of 9 Date: 5/12/2004
Calculation No.: CEES-04-037-P-001	Rev.: 0	Title Modified Sluicing Retrieval Efficiency Evaluation for Tank 241-C-106

Project No.:	Project Title
CHG 14434	241-C-106 Stage I Retrieval
Originated by: Keith Shields Date: 5/12/04	Checked by: Rob Wilson Date: 5/12/2004

1.0 INTRODUCTION

This calculation was developed to analyze the behavior of tank waste removal efficiency from modified sluicing with acid dissolution (oxalic acid) campaigns performed on single-shell tank 241-C-106 from August 2003 through December 2003. This calculation develops a mathematical estimation to describe the sluicing efficiency behavior.

2.0 CALCULATION ASSUMPTIONS/LIMITATIONS

2.1 Assumptions

- Tank wastes are assumed to be homogeneous and will continue to exhibit similar physical/chemical behavior (i.e. no sudden changes in solubility).

2.2 Limitations

- Actual tank waste is very heterogeneous. The behavior of the tank waste during sluicing operations can vary significantly based on what form (physical, chemical) the waste is in at varying locations.

3.0 METHODOLOGY

3.1 Input Data

The initial data for this assessment is taken from RPP-20110, Table 3. This table provides summary data of the amount of tank waste retrieved during four modified sluicing operations on tank 241-C-106. The data is shown in the following table.

Table 3, RPP-20110, Rev 1

Sluice Operation	Volume of Water Added (gal)	Volume Transferred (gal)	Waste Retrieved[1] (gal)	Approx. Eff. (%)
1	56,160	61,033	4,873	8
2	46,472	48,079	1,607	3.3
3	59,228	60,085	857	1.4
4	83,501	83,718	217	0.3

1 - "Waste Retrieved" is equivalent to "Volume Increase" in Table 3.

2 - "Approx. Eff." is the estimated volume percent solids.

Calculation Sheet		Page: 3 of 9 Date: 5/12/2004
Calculation No.: **CEES-04-037-P-001**	Rev.: **0**	Title: **Modified Sluicing Retrieval Efficiency Evaluation for Tank 241-C-106**

3.2 Fit Methodology

The values from Section 3.1 were plotted using Microsoft Excel™. The trendline capability of the program was used to estimate a function describing the changing behavior of the retrieval efficiency. Linear, power function, exponential and logarithmic line fits were evaluated.

4.0 CALCULATION

See attached excel spreadsheets and graphs.

5.0 RESULTS AND CONCLUSIONS

5.1 Linear Estimation Results

The graph and the results of the Excel calculation can be seen on worksheet *5.1-Linear Evaluation*. Using this method, the efficiency is expected to reach zero before the fourth campaign. The observed data shows that this is a substantial under-estimation of the actual results. This estimation method is not useful for predicting future behavior.

5.2 Logarithmic Estimation Results

The graph and the results of the Excel calculation can be seen on worksheet *5.2-Logarithmic Evaluation*. Using this method, the efficiency is expected to reach zero at approximately the fourth campaign. The observed data shows that this is a substantial under-estimation of the actual results. This estimation method is also not useful for predicting future behavior.

5.3 Power Function Estimation Results

The graph and the results of the Excel calculation can be seen on worksheet *5.3-Power Function Evaluation*. Using this method, the efficiency is slightly over-estimated for the fourth campaign but continues to decline. The estimated function displays asymptotic behavior approaching zero. The function has adequate 'fit' ($R^2 = 0.89$) to the observed data.

5.4 Exponential Estimation Results

The graph and the results of the Excel calculation can be seen on worksheet *5.4-Exponential Evaluation*. Using this method, the efficiency is most closely (very slightly over-estimated) for the fourth campaign but continues to decline. As with the power function the estimated values display asymptotic behavior approaching zero. This function shows much better 'fit' ($R^2 = 0.98$) than the power function.

5.5 Conclusions

The exponential estimation method provides the best method for mathematically describing the changing behavior of the retrieval efficiency. This method also provided the best 'fit' ($R^2 = 0.98$) to the observed data with the function:

$$efficiency = 26.533e^{-1.37[illegible](\#\ of\ Sluicing\ Operations)}$$

Calculation Sheet		Page: 4 of 9 Date: 5/12/2004
Calculation No.: CEES-04-037-P-001	Rev.: 0	Title: **Modified Sluicing Retrieval Efficiency Evaluation for Tank 241-C-106**

6.0 REFERENCES

RPP-20110, *Stage I Retrieval Data Report For Single-Shell Tank 241-C-106*, Rev 1, CH2M HILL Hanford, Inc., Richland, WA, May 2004.

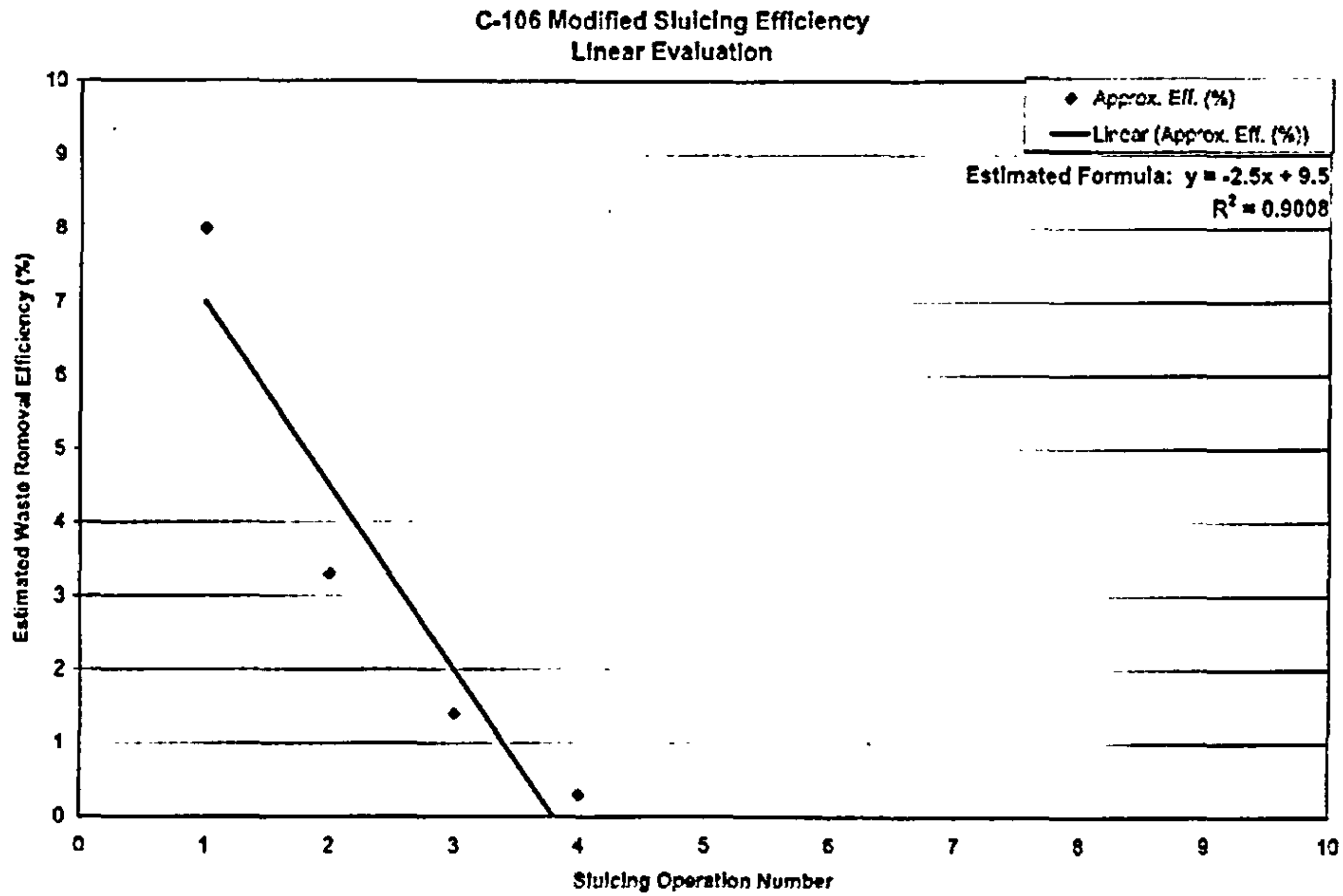
Input Data

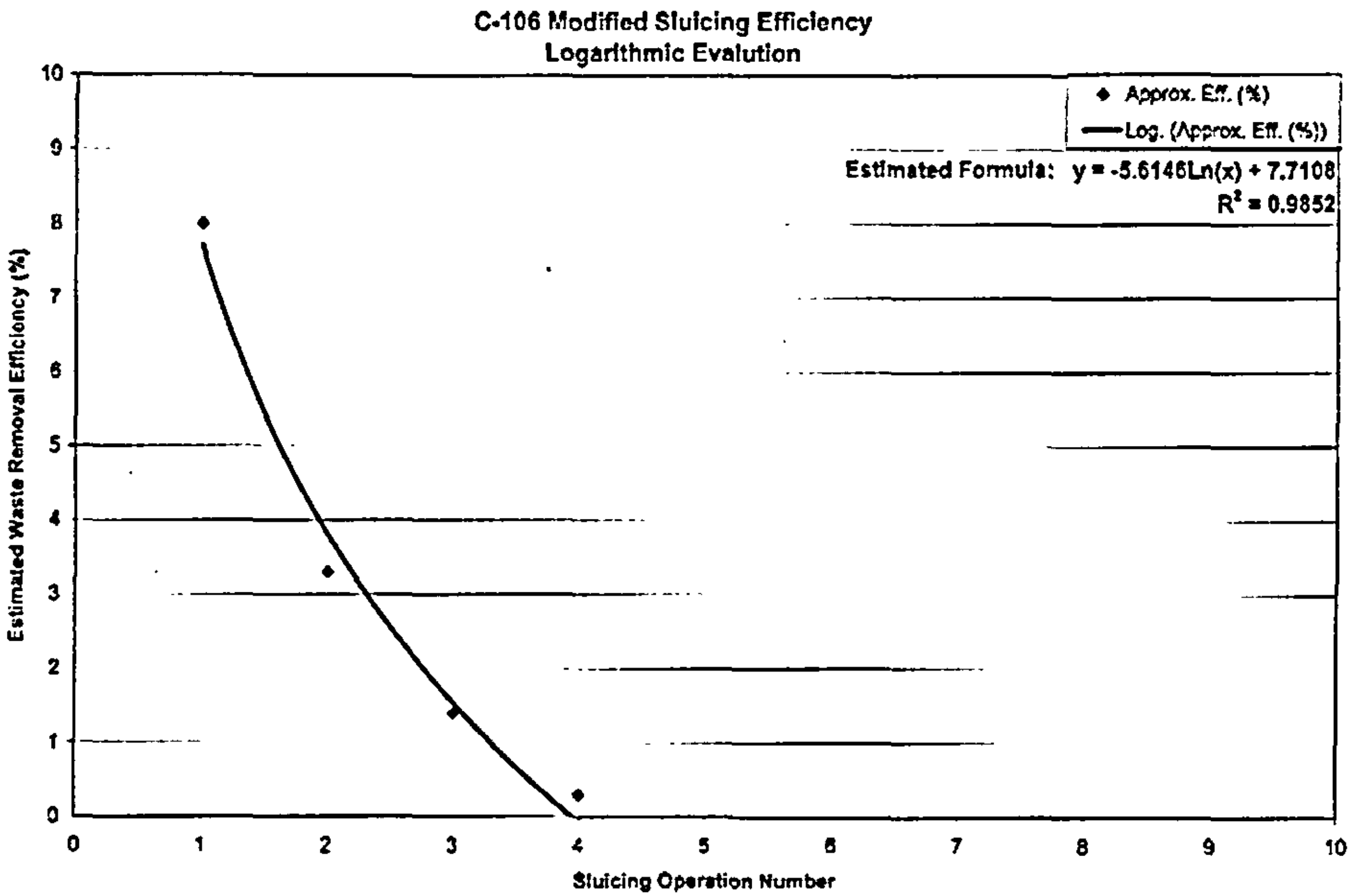
Table 3, RPP-20110, Rev 1

Sluice Operation	Volume of Water Added (gal)	Volume Transferred (gal)	Waste Retrieved[1] (gal)	Approx. Eff. (%)
1	56,160	61,033	4,873	8
2	46,472	48,079	1,607	3.3
3	59,228	60,085	857	1.4
4	83,501	83,718	217	0.3

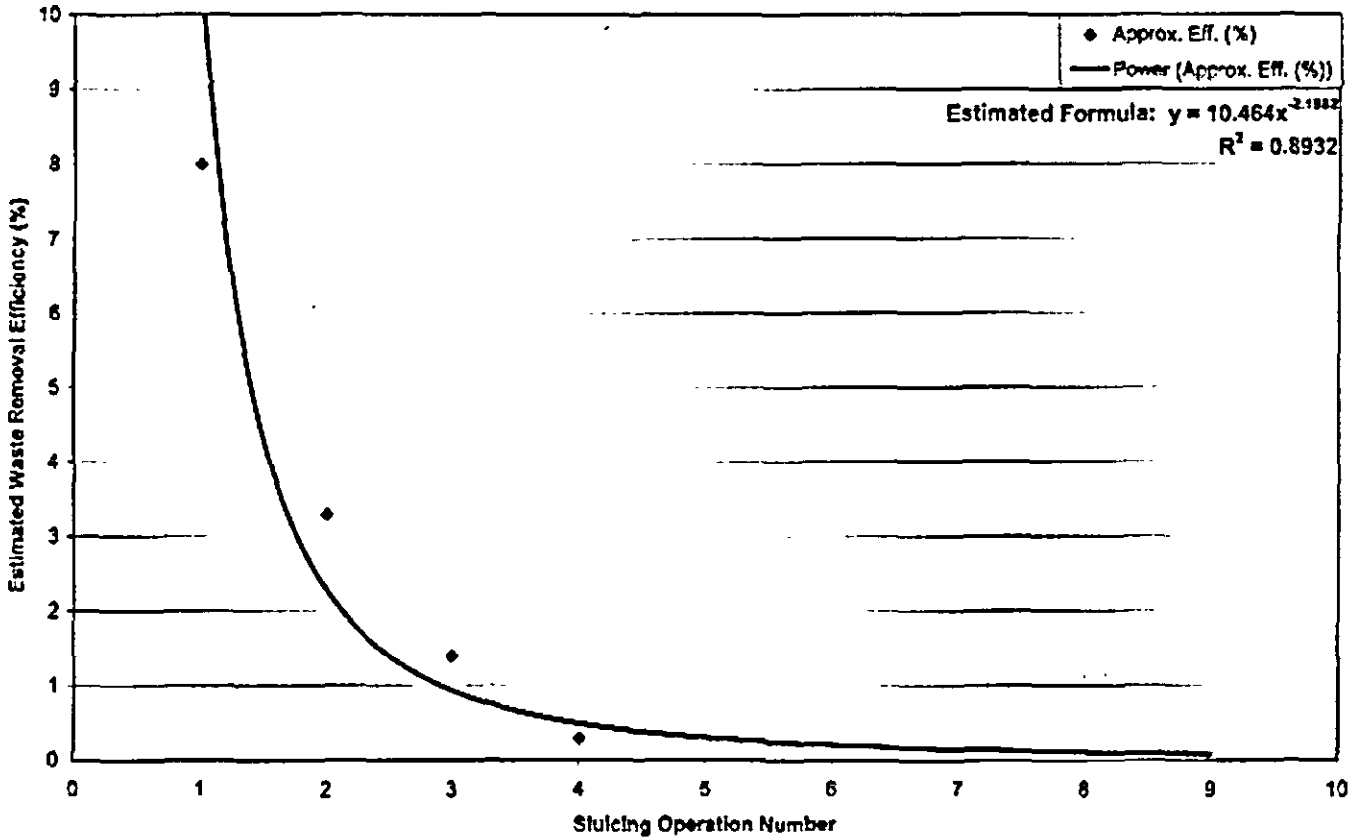
1 - "Waste Retrieved" is equivalent to "Volume Increase" in Table 3.

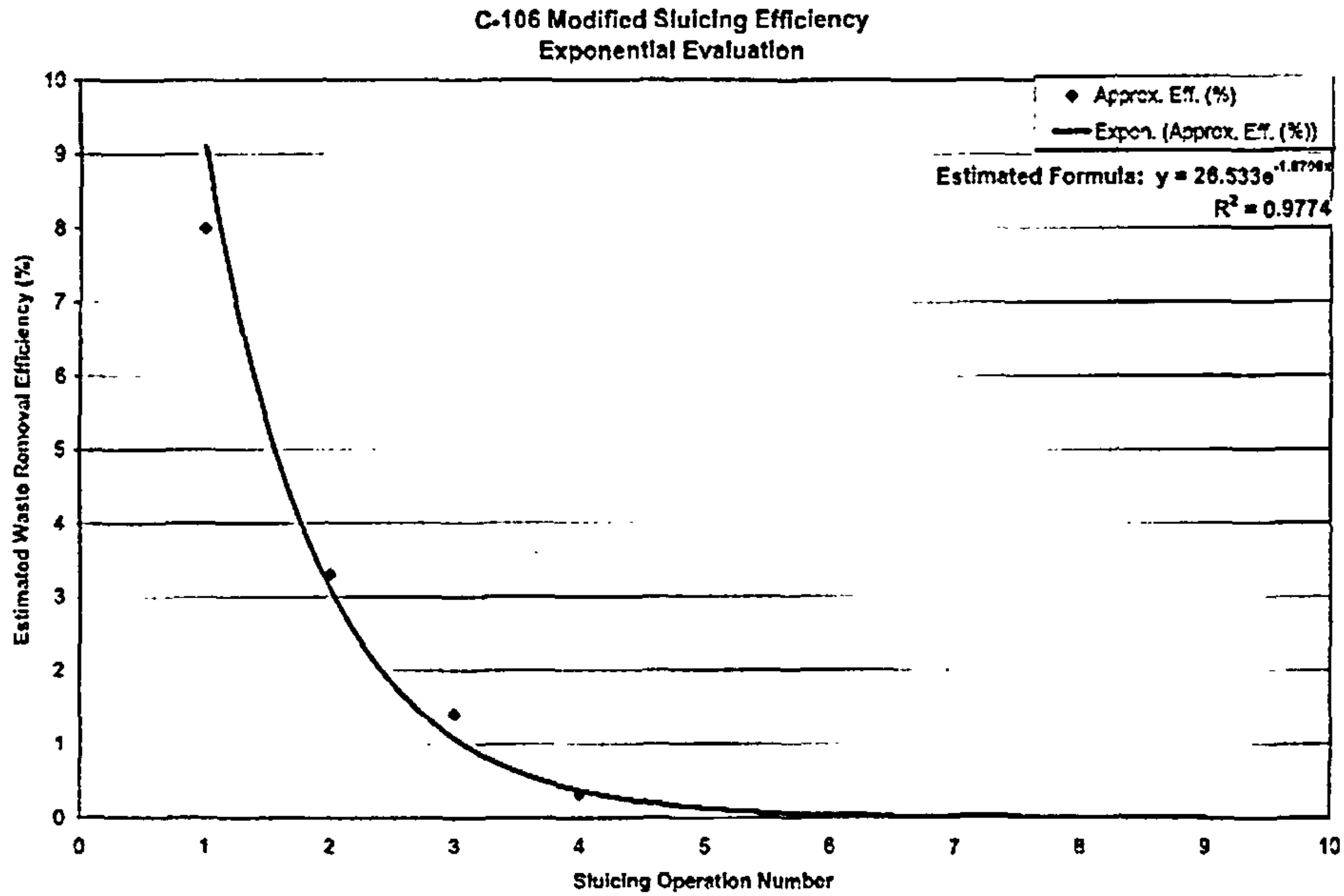
2 - "Approx. Eff." is the estimated volume percent solids.


C-106 Modified Sluicing Efficiency
Linear Evaluation
Approx. Eff. (%)
Linear (Approx. Eff. (%))
Estimated Formula: y = -2.5x + 9.5
R² = 0.9008
Estimated Waste Removal Efficiency (%)
Sluicing Operation Number
0
1
2
3
4
5
6
7
8
9
10


C-106 Modified Sluicing Efficiency
Logarithmic Evalution
◆ Approx. Eff. (%)
Log. (Approx. Eff. (%))
Estimated Formula: y = -5.6146Ln(x) + 7.7108
R² = 0.9852
Estimated Waste Removal Efficiency (%)
Sluicing Operation Number
0
1
2
3
4
5
6
7
8
9
10

C-106 Modified Sluicing Efficiency
Power Function Evaluation




C-106 Modified Sluicing Efficiency
Exponential Evaluation
Approx. Eff. (%)
Expon. (Approx. Eff. (%))
Estimated Formula: y = 26.533e
R² = 0.9774
Estimated Waste Removal Efficiency (%)
Sluicing Operation Number
0
1
2
3
4
5
6
7
8
9
10

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