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Revision 1

BASIS FOR EXCEPTION TO THE HANFORD FEDERAL FACILITY AGREEMENT AND CONSENT ORDER WASTE RETRIEVAL CRITERIA FOR SINGLE-SHELL TANK 241-C-106

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This report concerns retrieval actions only performed at SST 241-C-106. The report does not address closure actions or residual waste classification and does not constitute a decision on closure, disposal, or waste classification, including but not limited to, "waste incidental to reprocessing" (WIR) determinations under DOE Order 435.1. Portions of DOE Order 435.1 which would have permitted WIR determinations have been challenged, held invalid, and are currently under appeal. (*Natural Resources Defense Council, et al., v. Abraham, et al.*, 271 F. Supp. 3d 1260 (D. Id. 2003). DOE has appealed this decision to the 9th Circuit Court of Appeals under case number 03-35711.

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EXECUTIVE SUMMARY

This document was prepared to comply with *Hanford Federal Facility Agreement and Consent Order* (HFFACO) (Ecology et al. 1989) Milestones M-45-05H and M-45-05M-T01. This document presents the basis for the Washington State Department of Ecology and the U.S. Environmental Protection Agency to approve an exception to the waste retrieval criteria established in HFFACO for single-shell tank 241-C-106. On the basis of the information presented in this document, the U.S. Department of Energy concludes that there is no technical, risk reduction, or economic justification to support deployment of retrieval technologies to further retrieve waste from single-shell tank 241-C-106. Based on that conclusion, the U.S. Department of Energy requests the Washington State Department of Ecology and U.S. Environmental Protection Agency concur that retrieval of waste from single-shell tank 241-C-106 is complete.

In response to HFFACO, Appendix H, Attachment 2, Criteria #2, a review of the two retrieval technology deployments in single-shell tank 241-C-106 was completed. The review determined that the limits of technology for retrieval of waste from single-shell tank 241-C-106 have been reached for these technologies. Section 2.1 documents that sluicing (the initial retrieval technology deployed in 1998-1999 to resolve high-heat safety issues) and modified sluicing and acid dissolution (the retrieval technology demonstration under the HFFACO for modified sluicing in a sludge tank completed in 2003) have both been demonstrated to have reached the limit of their technical ability to effectively retrieve waste from single-shell tank 241-C-106.

In response to HFFACO, Appendix H, Attachment 2, Criteria #3, an analysis of currently available additional alternate waste retrieval technologies has been completed and summarized in Section 2.2. This analysis compares four alternatives for deployment of currently available additional technologies (i.e., two modified sluicing alternatives under alternative configurations, the mobile retrieval system, and modified sluicing followed by use of the vacuum retrieval system). The alternatives evaluation includes documentation of the cost and schedule for each alternative as well as comparative analysis of the relative performance against waste retrieval functions and six criteria (i.e., cost, schedule, risk to workers, risk to human health and the environment, ease of implementation, and impact on the River Protection Project mission). The analysis shows there is sufficient uncertainty about whether the deployment of available alternate technologies would reduce the waste volume remaining in single-shell tank 241-C-106 to the HFFACO retrieval criteria that no further consideration of deployment is warranted.

Additional waste retrieval may require from 12 to 18 months to complete and may cost from $5.7 to $13.5 million. Figure ES-1 illustrates the cost per cubic foot of additional waste removed by alternative and compares those costs to those experienced under the 2003 retrieval campaign. As indicated, the four waste retrieval alternatives would cost from approximately $35,000 to $84,000 per cubic foot if it assumed that approximately 160 cubic feet of waste could be removed. There is no guarantee that 160 cubic feet or any other volume of waste would actually be removed. The 2003 campaign cost was $5,170 per cubic feet of waste removed, while retrieving 4,340 cubic feet of waste. Deployment of any waste retrieval technology would result in increased radiological, chemical, and industrial risk to workers and place added constraints on near-term double-shell tank space (90,000 to 1.87 million gal) available for retrieval of waste from other single-shell tanks. Potential future waste retrieval technologies were also identified and described; however, these technologies are not sufficiently mature to support additional assessment of their retrieval effectiveness, cost, or deployment schedules.

In response to HFFACO, Appendix H, Attachment 2, Criteria #4, Section 2.3 summarizes the volume and characteristics of waste remaining in single-shell tank 241-C-106. At its peak during operation, single-shell tank 241-C-106 contained as much as 530,000 gallons of waste. Between 1980 and 1998 approximately 40,000 cubic feet of waste was removed from single-shell tank 241-C-106. Cumulatively, the two retrieval campaigns have removed approximately 30,400 cubic feet of waste from single-shell tank 241-C-106 (Figure ES-2). The 1998-1999 campaign using sluicing removed approximately 25,940 cubic feet of waste and the 2003 campaign using liquid pumping followed by modified slicing and acid dissolution retrieved at least 4,340 cubic feet of waste. There is approximately 370 cubic feet (liquids and solids) remaining in the tank. The 95% upper confidence level volume of waste remaining in single-shell tank 241-C-106 is approximately 467 cubic feet and at the 95% lower confidence level the volume is approximately 275 cubic feet. The chemical and radiological characteristics have been analyzed in accordance with the approved data quality objectives (RPP-13889, *Tank 241-C-106 Component Closure Action Data Quality Objectives*). The current inventory of contaminants of potential concern includes approximately 0.165 curies of technetium-99 and 3.79 kg of chromium (the primary drivers of long-term human health risk via the groundwater pathway). The total curies of radionuclides have been reduced from approximately 10.1 million curies in the tank prior to the 1998-1999 retrieval campaign to the current total of approximately 135,000 curies (a decrease of approximately 99%).

In response to HFFACO, Appendix H, Attachment 2, Criteria #5, an assessment of the expected impacts to human health and the environment if the residual waste is left in place has been completed. A summary of this analysis is provided in Section 2.4. Technetium-99 was identified as the primary driver of incremental lifetime cancer risk and chromium was identified as the primary driver of human health risk from chemicals. Incremental lifetime cancer risks from the residual waste in single-shell tank 241-C-106 do not exceed the U.S. Environmental Protection Agency risk threshold values of 1.0×10^{-4} to 1.0×10^{-6} or the Washington State Department of Ecology threshold of 1.0×10^{-5} for the industrial receptor at the Waste Management Area C fenceline nor do the cumulative risk for Waste Management Area C, inclusive of the single-shell tank 241-C-106 residual inventory. Based on the current residual inventory no groundwater quality standards would be exceeded. Analysis of additional retrieval indicates that further waste removal would result in insignificant reduction in health risks and groundwater quality.

Section 2.5 provides additional information regarding compliance with applicable requirements, as identified in HFFACO, Appendix H, in response to HFFACO, Appendix H, Attachment 2, Criteria #6. In May 2004, meetings between staff from the U.S. Department of Energy and Washington Department of Ecology, no additional information, beyond the information presented in this document, was identified for submission in support of this basis of exemption report.

In response to HFFACO, Appendix H, Attachment 2, Criteria #1, this document concludes that if one of the four additional available waste retrieval technologies were to be deployed the cost of the deployment would not result in a commensurate reduction in expected impacts to human health or the environment sufficient to warrant further retrieval actions in single-shell tank

241-C-106. As Figure ES-3 illustrates, the 2003 waste retrieval campaign resulted in a reduction of the volume of waste in the tank to at most 467 cubic feet (at the 95% upper confidence level) at a cost of approximately $22.4 million. The current peak incremental lifetime cancer risk for the inventory in the residual waste is 2.48×10^{-8} (or 2.5 in 100 million). The cost for retrieving waste from current levels to the HFFACO retrieval criteria (within the limit of volume measurement and technical performance uncertainty) would range from $5.7 to $13.5 million, assuming a waste volume reduction of approximately 160 cubic feet from current levels. This volume of waste reduction, if a corresponding reduction in the contaminants that drive risk occurred, would only provide an approximate reduction in the incremental lifetime cancer risk associated with the residual waste in single-shell tank 241-C-106 of 5.1×10^{-9} (or 5 in 1 billion).

Figure ES-1. Comparison of the Cost per Cubic Foot of Waste Retrieval between the 2003 Retrieval Campaign and the Additional Retrieval Technology Alternatives.

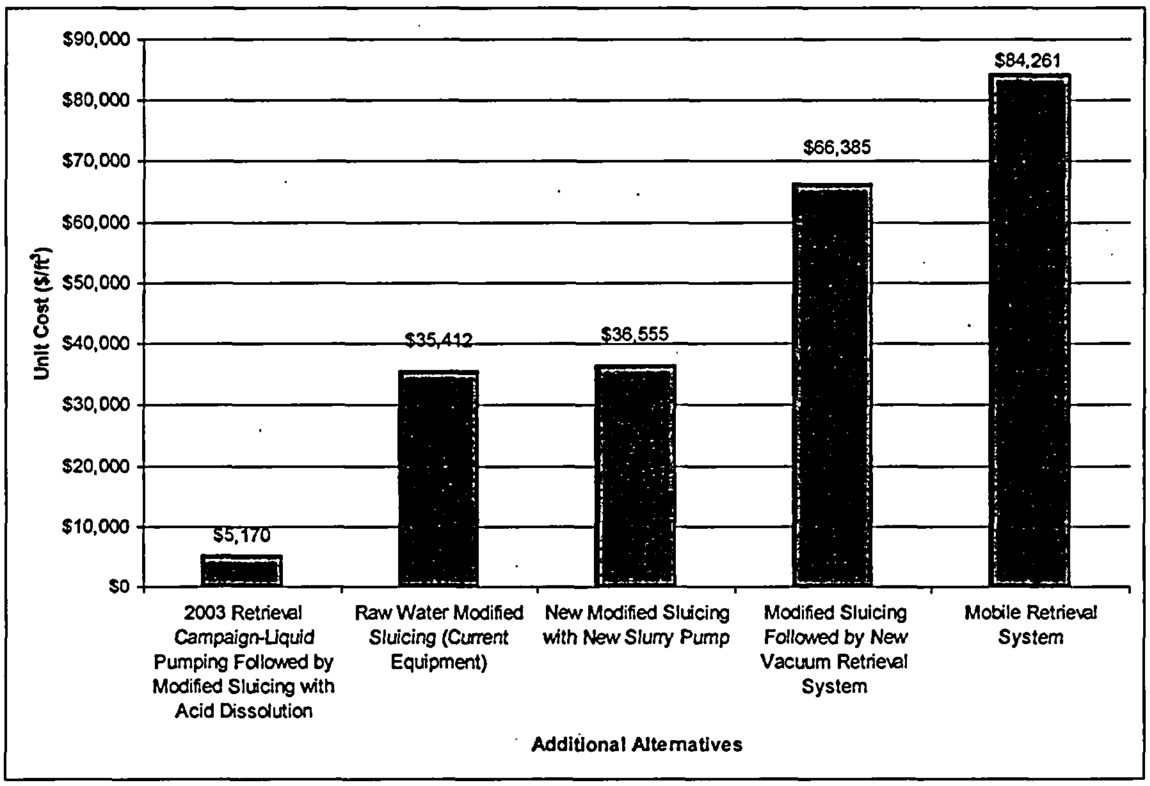
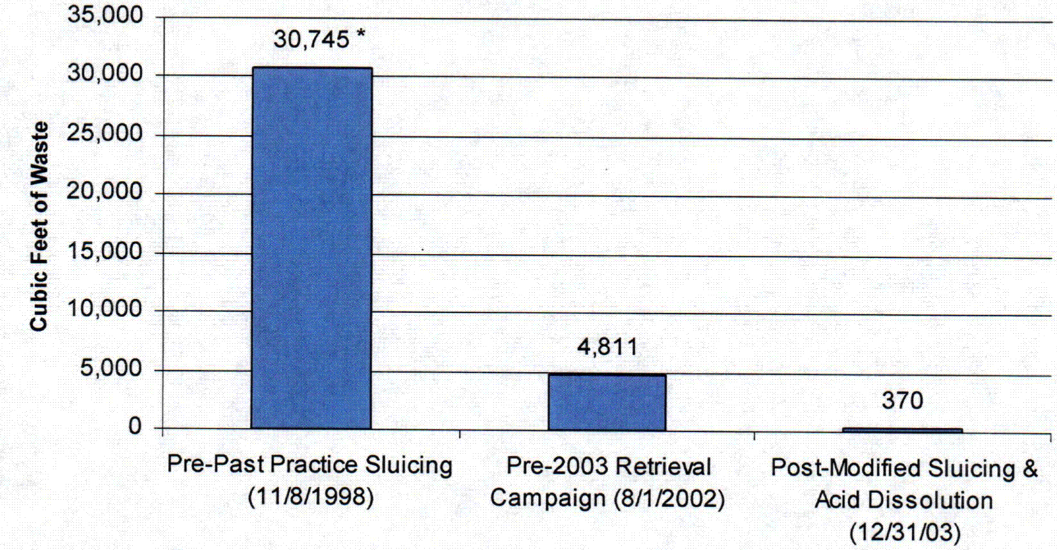
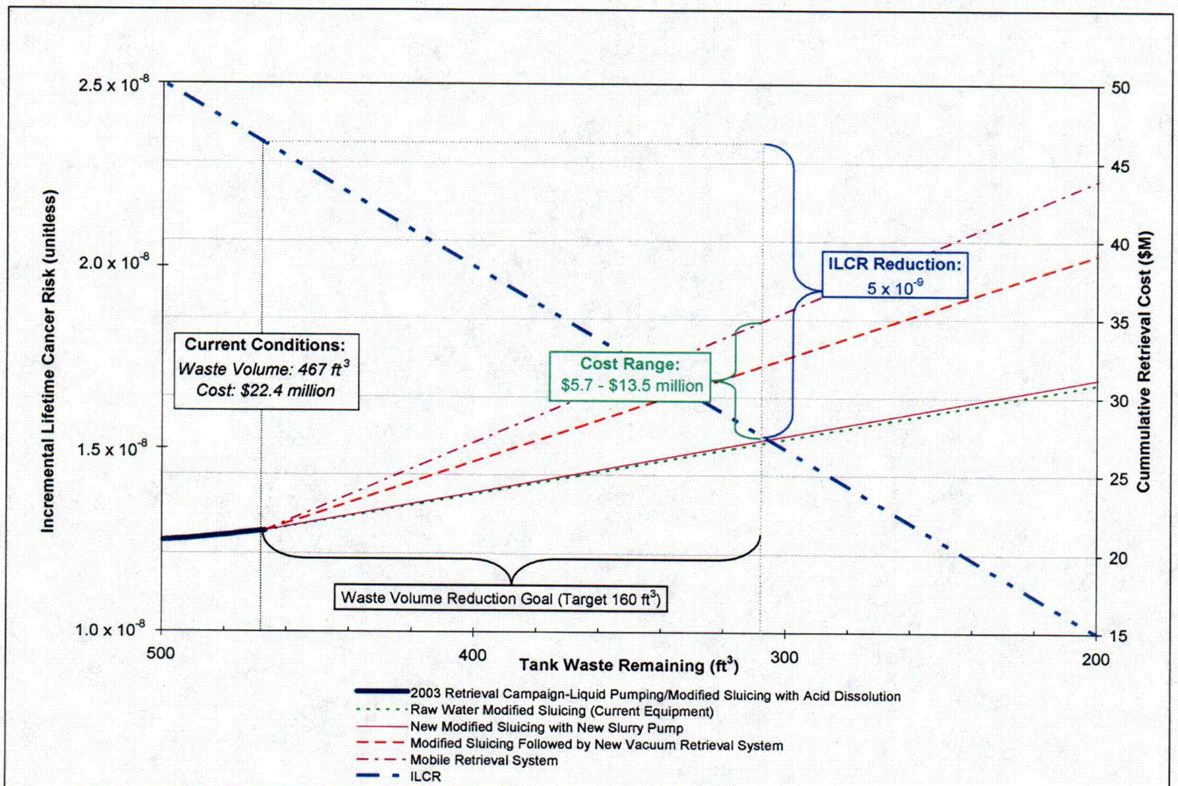


Figure ES-2. Waste Retrieval Volume Reduction for Single-Shell Tank C-106.



*Note: >40,000 cubic feet of waste was removed from SST C-106 between 1980 and 1998.

Figure ES-3. Comparison of Retrieval Cost to Human Health Risk Reduction Based on Residual Waste Volume in Single-Shell Tank 241-C-106.



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LIST OF TERMS

AEAT	AEA Technology Engineering Services
ALARA	as low as reasonably achievable
BBI	best-basis inventory
CAD	computer-aided design
CCMS	video camera/CAD modeling system
CH2M HILL	CH2M HILL Hanford Group, Inc.
COPC	contaminant of potential concern
DOE	U.S. Department of Energy
DST	double-shell tank
Ecology	Washington State Department of Ecology
EDE	effective dose equivalent.
EPA	U.S. Environmental Protection Agency
FY	fiscal year
gpm	gallons per minute
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
HI	hazard index
HIHTL	hose-in-hose transfer line
ILCR	incremental lifetime cancer risk
ITV	in-tank vehicle
MLDUA	Modified Light-Duty Utility Arm
MRS	Mobile Retrieval System
NRC	U.S. Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
RPP	River Protection Project
SST	single-shell tank
VRS	Vacuum Retrieval System
WTP	Waste Treatment Plant
WMA	Waste Management Area

1.0 INTRODUCTION

This document was prepared to comply with *Hanford Federal Facility Agreement and Consent Order* (HFFACO) (Ecology et al. 1989) Milestones M-45-05H and M-45-05M-T01. The document presents the basis for an exception to the waste retrieval criteria established in the HFFACO for single-shell tank (SST) 241-C-106 (SST C-106). The HFFACO states that the waste retrieval criteria in Milestone M-45-00 are to be applied on a tank-by-tank basis. If the U.S. Department of Energy (DOE) does not believe the criteria are achievable for a specific tank, DOE must submit a request for an exception to the U.S. Environmental Protection Agency (EPA) and Washington State Department of Ecology (Ecology). Appendix H, Attachment 2, lists the specific content requirements for the request for an exception from the waste retrieval volume limit of less than 360 ft^3 of residual waste for 100-series SSTs following completion of waste retrieval identified in Milestone M-45-00. According to Attachment 2, a request for an exception must include, as a minimum, the following information:

1. Why DOE does not believe the retrieval criteria can be met.
2. Schedule, using existing technology, to complete retrieval to the criteria – if possible.
3. Potential for future waste retrieval technology developments that could achieve the waste retrieval criteria, including estimated schedules and costs for development and deployment of technologies.
4. Volume of waste proposed to be left in place, and its chemical and radiological characteristics of that waste.
5. Expected impacts to human health and the environment if the residual waste is left in place.
6. Additional information as required by EPA and/or Ecology.

Section 2.1 responds to Criteria #2 and documents the basis for determining that completing waste retrieval to the HFFACO waste retrieval criteria is not possible "using existing technology." Section 2.2 responds to Criteria #3 and documents the basis for determining that attaining the HFFACO waste retrieval criteria is not practical using additional available retrieval technologies or "future waste retrieval technology developments." Section 2.3 responds to Criteria #3 and documents the residual waste volume and its chemical and radiological characteristics, and Section 2.4 responds to Criteria #5 and presents the "expected impacts to human health and the environment if the residual waste is left in place." Section 2.5 responds to Criteria #6 and provides additional information regarding conformance with relevant requirements as identified in HFFACO Appendix H. Section 3.0 responds to Criteria #1, drawing on the information and conclusions presented in Section 2.0 to form the basis of the position that the HFFACO retrieval criteria cannot be met.

Throughout the text of this document, numbers were rounded to two significant figures (e.g., 212 would be rounded to 210 and 0.126 would be rounded to 0.13). Numbers in tables and figures derived from supporting and referenced documents have not been rounded to preserve traceability to the source information. In certain cases, numbers in the text were not rounded to preserve the ability to understand differences between comparable numbers and/or between the number presented and those established in standards and/or requirements.

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2.0 SUMMARY OF AVAILABLE DATA AND INFORMATION

This section responds to HFFACO, Appendix H, Attachment 2, Criteria #2 to #5. The information and conclusions presented in this section support the response to Criterion #1, which is presented in Section 3.0.

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

This section responds to HFFACO, Appendix H, Attachment 2, Criteria #2: "Schedule, using existing technology to complete retrieval to the criteria." The information provided documents that the existing technologies previously deployed to retrieve waste from SST C-106 cannot complete retrieval to the HFFACO retrieval criteria.

Two retrieval technologies have been deployed to retrieve waste from SST C-106. The first technology deployed was sluicing. This technology was deployed in November 1998 and reached the limit of its capability in October 1999. In April 2003, a second retrieval campaign was initiated with the pumping of 18,000 gal of liquid from SST C-106. The second retrieval technology deployed in SST C-106 as a retrieval technology demonstration under the HFFACO was modified sluicing with acid dissolution. This technology reached the technical limit of its capability in December 2003.

2.1.1 Sluicing System Retrieval Campaign, 1998-1999

SST C-106 is a 530,000-gal tank that was used to store mixed radioactive waste since the tank was placed in service in 1947. At its peak during operation, SST C-106 contained as much as 530,000 gal of waste. 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 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, Ecology provided 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 of solid and liquid waste remained in SST C-106 (RPP-12547, *Tank 241-C-106 Residual Liquids and Solids Volume Calculation*). In

August 2002, a new measurement estimated waste volume in SST C-106 at 35,986 gal. From July 2000 to August 2002, the volume of liquids decreased by approximately 10,000 gal. The reduction in liquid volume was attributed to evaporation. For additional information regarding waste volume estimates for SST C-106, see Section 2.3.

2.1.2 Modified Sluicing and Acid Dissolution Retrieval Campaign – 2003

To remove the remaining waste in SST C-106, a retrieval demonstration campaign defined in HFFACO was initiated in April 2003. From project start through completion of retrieval activities in December 2003; the total cost for this project was approximately $22.4 million. This campaign began in April 2003 by pumping approximately 18,000 gal of liquid from SST C-106 to DST AY-102. The 2003 campaign continued through December 2003 using modified sluicing and acid dissolution removing an additional approximately 14,500 gal of waste.

Modified sluicing describes various performance enhancements over the "past-practice" sluicing techniques used to remove the bulk of SST C-106 waste (see Section 2.1.1). These enhancements included combinations of pump and nozzle designs to break up the solids and move them to the pump intake. Acid dissolution reflects the use of oxalic acid to dissolve solids. Oxalic acid, which has historically been used at the Hanford Site and other DOE sites to decontaminate tanks and equipment, was used to dissolve solids. The combination of the two methods was designed to maximize removal of the residual waste.

Through experience gained operating DOE Savannah River Site facilities the effectiveness of oxalic acid to remove contamination on waste processing equipment was documented (WSRC-TR-2003-00401, *Waste Tank Heel Chemical Cleaning Summary*). Laboratory-scale testing of acid dissolution (using a sample of the 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), followed by removal of the acid 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 also reacted with carbonates in the waste to increase solid waste porosity. Both 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. At the completion of the acid reaction, the dissolved wastes were transferred via a pump to DST AN-106.

During acid dissolution, operations were performed using oxalic acid with a concentration of 0.9 molar. For the first four batches of oxalic acid, the mixer-eductor was used to recirculate the oxalic acid in SST C-106. The acid dissolution reaction for each acid batch reached steady state (i.e., reaction complete) after an average of 7 days based on in-tank monitoring of waste pH levels. After the acid reaction reached steady state, dissolved wastes were transferred via a pump to DST AN-106.

Recirculation of the oxalic acid batches was no longer possible after removal of the mixer-eductor following the fourth 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.

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 the 2003 retrieval 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. The motive force of the sluicer nozzle at this configuration of waste 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 replaced with a second sluicer nozzle. The second nozzle was installed in riser 7 and was used to break up 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.

Table 1 contains the material balance of the sluicing operations. The material balance for the sluicing operations was recorded to determine 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 this technology. An observed declining trend of waste removed for each sluicing operation ranged from 8% for the first operation to 0.3% for the final operation.

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

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

Note:
DST = double-shell tank.

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

1. **Acid Dissolution** - The purpose of the acid dissolution process was to dissolve the sludge and the solid waste prior to sluicing. The result of this reaction included increased solution density and 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, following the April 2003 pumping of 18,000 gal of liquids from SST C-106 and prior to retrieval, using modified sluicing and acid dissolution, 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 (RPP-13707, *Process Control Plan for Tank 241-C-106 Closure)* 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 was reacting with the waste and then no increase (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 some waste remained unreacted, and that the limits of this technology to further dissolve and entrain waste had been reached (RPP-20110, *Stage I Retrieval Data Report for Single-Shell Tank 241-C-106*). 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 to a smaller size either 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 (RPP-20577, *Stage II Retrieval Data Report for Single-Shell Tank 241-C-106*). Therefore, the remaining solids would not likely be entrained in 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 (RPP-19866, *Calculation for the Post-Retrieval Waste Volume Determination for Tank 241-C-106*). 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 then 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.

At the limit of waste retrieval technology performance for modified sluicing and acid dissolution, approximately 467 ft^3 of waste based on the 95% upper confidence level remained in SST C-106. The residual waste estimate based on the 95% upper confidence level reflects uncertainty in the residual waste measurement technique. The actual waste volume measurement (also known as the nominal residual waste volume) in SST C-106 at the limit of the retrieval technology was calculated consistent with the methodology identified in Appendix H, Attachment 1, to be approximately 370 ft^3. The residual waste volume at the 95% lower confidence level is 275 ft^3. See Section 2.3 for additional information regarding residual waste volume estimates and the characteristics of the residual waste remaining in SST C-106.

2.1.3 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.

2.2 EVALUATION OF WASTE RETRIEVAL TECHNOLOGIES

This section responds to HFFACO, Appendix H, Attachment 2, Criteria #3: "Potential for future waste retrieval technology development that could achieve the waste retrieval criteria, including schedules and costs for development and deployment of technologies." This section describes and compares evaluations of additional waste retrieval technologies that are currently available (i.e., do not require further research and development before deployment) consistent with the description of additional retrieval technologies provided in HFFACO, Appendix H. It also describes future potential waste retrieval technologies requiring research and development that have potential for future deployment at the Hanford Site tank farms but are not sufficiently mature to evaluate for deployment at this time. 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 technically mature to support cost, schedule, and performance evaluations.

2.2.1 Additional Available Waste 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.

2.2.1.1 Additional Available Waste Retrieval Technologies. Additional 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 planned for deployment 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 being 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 2 shows the available retrieval technologies and describes how well the technologies perform various waste retrieval functions including:

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

Many of the waste retrieval technologies that could be deployed in the near-term could satisfy multiple retrieval functions.

Table 2. 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.

2.2.1.2 Development of Retrieval Alternatives using Additional Available Technologies. A range of alternatives were identified to compare the ability of the technologies to meet performance criteria (e.g., dissolve and break up waste and mobilize and transfer waste). Alternatives were identified by combining waste retrieval technologies, as necessary, to satisfy all the functions of waste retrieval. In this section, alternatives are discussed and costs, schedules, and deployment requirements are identified. The basis for water usage and detailed cost estimates for each alternative is documented in RPP-20577, Section 4.1.3.

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" of 200 ft^3 (i.e., removal of 160 ft^3). At the 95% confidence interval of residual waste remaining in a tank, 467 ft^3 are present in the tank and the alternative retrieval technology selected must retrieve at least 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 estimation error 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; however, there are differences in costs, schedule, and water usage impacts to the DSTs and the evaporator, as well as ease of implementation and technical risk.

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:.

- MRS and VRS systems 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 will be retrieved under the alternatives is uncertain.

2.2.1.2.1 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 (RPP-20577, Appendix D). Restarting the SST C-106 modified sluicing system includes 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. For these reasons, chemical addition/modified sluicing is not evaluated further.

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

2.2.1.2.2 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 would introduce new waste to the tank and 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 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 includes 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 there would be $180,000 in evaporator costs resulting in a total retrieval and storage cost of $5.9 million. The anticipated schedule duration from start to finish is 12 months.

2.2.1.2.3 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 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 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 includes 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 $10.2 million and there would be $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.

2.2.1.2.4 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 waste retrievals are completed. The MRS would be operated to remove tank waste until the minimum goal 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 includes 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 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 there would be $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.

2.2.1.3 Comparative Evaluation of Available Waste Retrieval Alternatives. The four alternatives identified in Section 2.2.1.2 were comparatively evaluated using three methods. The first method compared how well the waste retrieval alternatives satisfied the retrieval functions identified in Section 2.2.1.1. The functions compared included: dissolving, breaking up, mobilizing, transferring, and minimizing waste. Table 3 presents the results of this comparison.

Table 3. Comparison of Retrieval Alternatives vs. Basic Retrieval Functions.

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 required 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)
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.

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 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 summarizes the results of this comparison.

- **River Protection Project (RPP) Total Retrieval and Storage 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. The costs ranged from $5.7 million for Alternative A to $13.5 million for Alternative D. The cost is an 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. Costs not included in the retrieval alternative estimates are not included in retrieval project estimates under the RPP cost estimate process.
- **Schedule** - Alternatives A and B could be completed in the shortest amount of time, 12 months. While Alternative D would require approximately 18 months to complete.
- **Cost Per Cubic Foot of Waste Volume Removed During Retrieval by Alternative** – Table 4 presents the RPP retrieval and storage total costs by alternative 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, Figure 1 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 7 to 16 times greater than experienced for the 2003 retrieval campaign.

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

The final method used to compare the alternatives was a value engineering process which is summarized below with supporting information presented in Appendix A. For the purpose of the analysis, the four alternatives identified above and a no further action case were considered. The no-action alternative assumed no further waste retrieval activities were initiated for SST C-106.

Table 4. Summary Comparison of Single-Shell Tank C-106 Retrieval Alternatives.

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
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, $2/gal cost to evaporate.

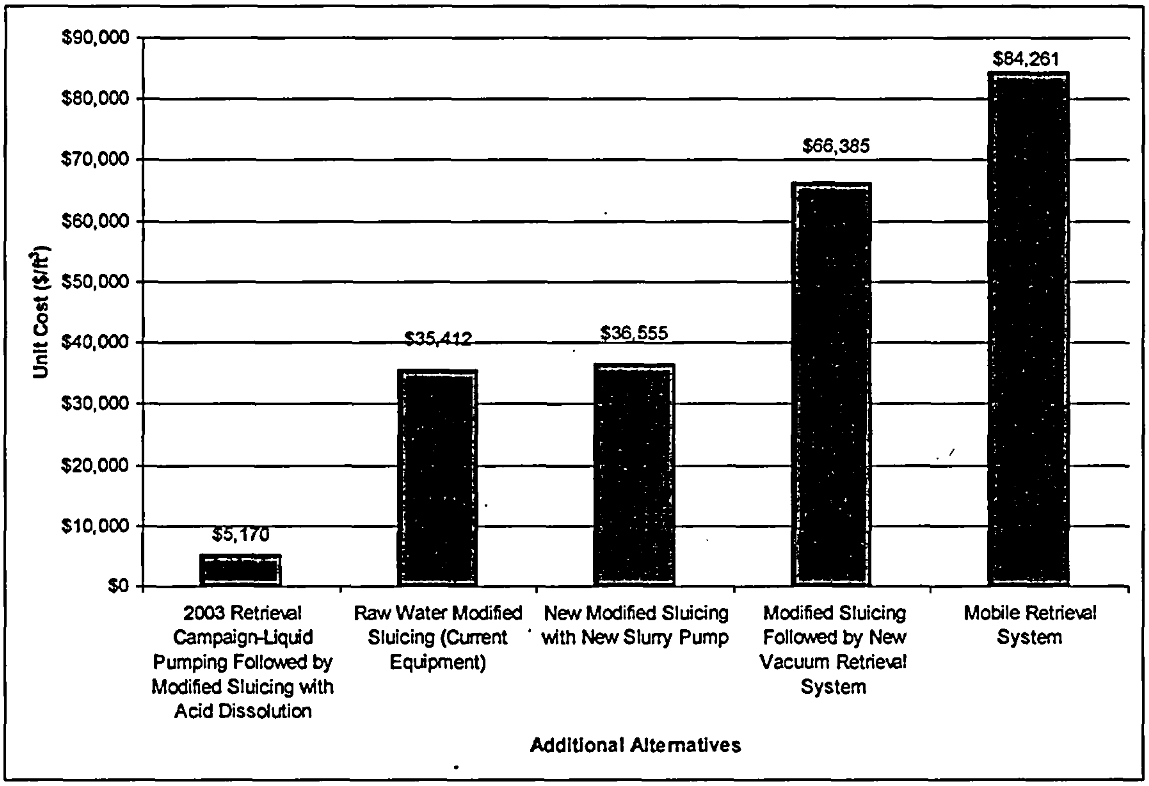
[b] For the additional retrieval alternatives waste removal was assumed at 160 ft^3.

[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.

Figure 1. Comparison of the Cost per Cubic Foot of Waste Retrieval between the 2003 Retrieval Campaign and the Additional Retrieval Technology Alternatives.



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 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 facets of the alternative. A higher value means the total duration for installing, operating, and demobilizing 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.
- **Risk to Workers for the Alternative.** This criterion includes ALARA considerations for both industrial (e.g., structural, chemical, electrical) 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.

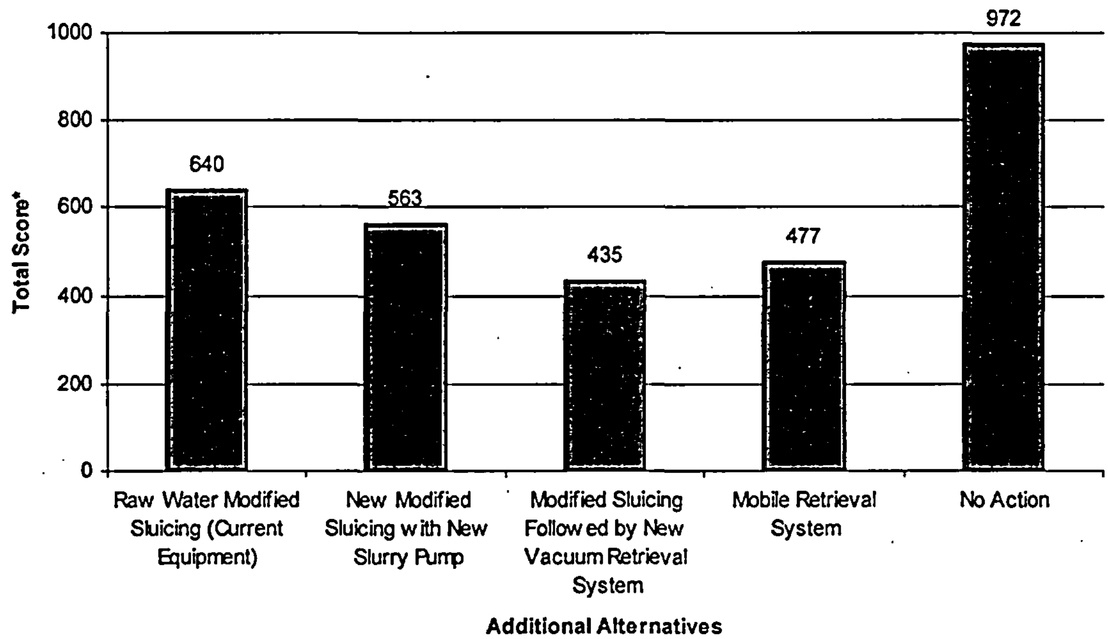
- **The Risks to the Public or Non-Occupational Personnel for the Alternative.** Usually this criterion includes near-term or long-term releases to the air or surrounding soils that account for the potential risk to the environment. A higher value means comparatively lower risk to the public for that 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 A contains the results of the paired comparison analysis. The analysis was supported by subject matter experts from the DOE Office of River Protection and CH2M HILL Hanford Group, Inc. (CH2M HILL) 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. 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 A. 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.

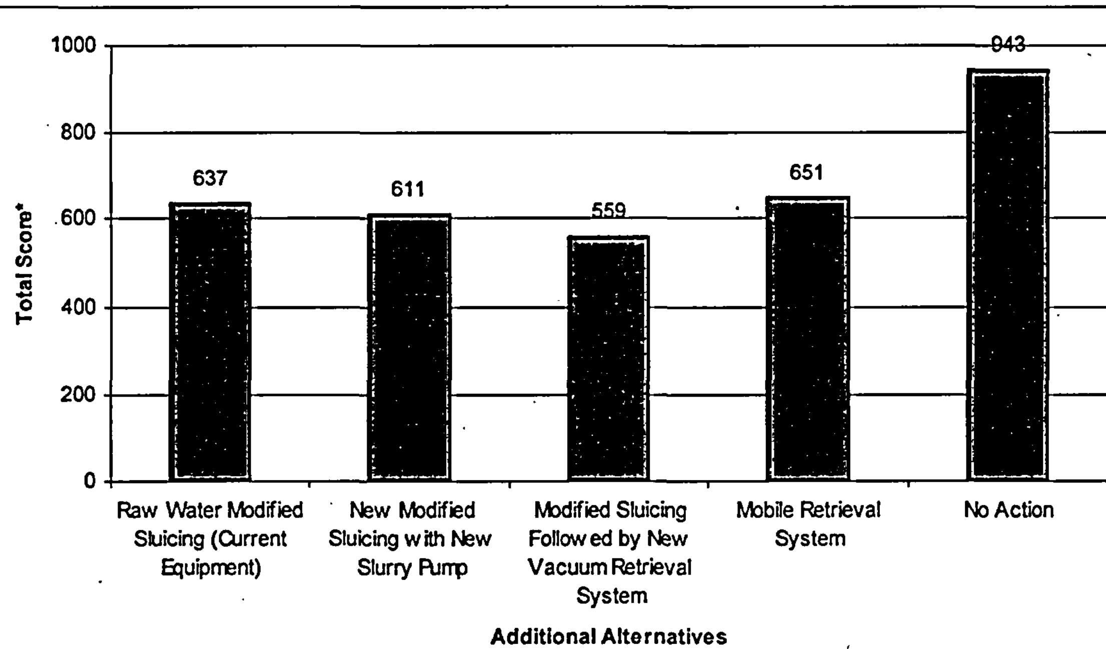
Figure 2 represents the results of the two-step analysis. The analysis determined that the highest ranked alternative based on the six evaluation criteria was to take no further action for SST C-106 waste retrieval. This result was largely driven by the relatively higher risk to workers of all of the 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 weighing of the dominant criteria (worker risk and human health and environmental risk) the weighing of these criteria were reversed (53 for human health and environment and 28 for worker risk). Figure 3 illustrates that 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 2 and 3 was that the differences in total scores between the four retrieval alternatives was diminished.

Figure 2. Relative Comparison of SST C-106 Additional Retrieval Alternatives.



*The total score for each alternative reflects a composite of the comparative ranking and weighted 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 3. Sensitivity Case Comparison of SST C-106 Additional Retrieval Alternatives.



*The total score for each alternative reflects a composite of the comparative ranking and weighted 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.

2.2.2 Potential Future Waste 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.

Past evaluations of government and industry retrieval projects have supported the identification and development of the technologies discussed in Section 2.2.1 and this section (RPP-7807, *Single-Shell Tank C-104 Full Scale Sludge/Hard Heel, Confined Sluicing and Robotics Technology Waste Retrieval Technology Functions and Requirements*, and RPP-10901, *Hanford Federal Facility Agreement and Consent Order Milestone M-45-05-T17: S-102 Initial Waste Retrieval Functions and Requirements*). The technologies discussed below 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 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 (HNF-4454, *Alternatives Generation and Analysis C-104 Single-Shell Tanks Waste Feed Delivery*). Activities that would need to be completed would include engineering, procurement, testing, and construction.

2.2.2.1 AEA Technology Power Fluidics[1]. CH2M HILL has 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. 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 National Laboratory (ORNL) with a capital cost reported at $550,000 (DOE/EM-0622, Innovative Technology Summary Report *Russian Pulsating Mixer Pump*).

A technology search and evaluation of potential technologies applicable for retrieval of saltcake waste from Hanford Site SSTs (RPP-6821, *Technology Evaluation Report for S-103 Saltcake Dissolution Retrieval Demonstration*) 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 waste, but is also suited for mobilization and retrieval of insoluble solids (e.g., sludge waste). Subsequently, an evaluation was carried out on the fluidic mixing and pumping for application in the Hanford Site SST retrieval program (RPP-7819, *An Evaluation of Power Fluidics™ Mixing and Pumping for Application in the Single Shell Tank Retrieval Program*). The AEAT test report *Single Shell Tanks Hanford Cold Test Facility Prototype Fluidic System Test Report* (2135-4-015) provides an overview of the fluidic equipment, test simulants, test program, test results, and conclusions and recommendations.

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

2.2.2.2 Russian Pulsatile Mixer Pumps/Fluidic Retrieval Systems. CH2M HILL has 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 system 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 as well as Russia, and initial results of the deployment in one of the Gunite and Associated Tanks at ORNL 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 is capable of being deployed through a 22.5-in. diameter opening.

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 and has been developed for use at the Mining and Chemical Combine nuclear facility in Zheleznogorsk, 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 were 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, *Russian Technology Advancements for Waste Mixing and Retrieval*). 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 waste retrieval. That request is under consideration.

2.2.2.3 Small Mobile Retrieval Vehicles.

- **Remotely-Operated Vehicle Systems at ORNL** - In the 1996-1998 timeframe, the team at ORNL deployed a series of hydraulically powered, remotely-operated vehicles. The first two were known as Houdini[2] vehicles and were supplied by RedZone Robotics, Inc. The system was used 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[3] (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*; Vesco et al. 2001, *Lessons Learned and Final Report for Houdini® Vehicle Remote Operations at Oak Ridge National*

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

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

Laboratory). Many features of these vehicles can be found in the unit currently developed at the Hanford Site for use in SSTs (DOE/EM-0587, Innovative Technology Summary Report *Remotely Operated Vehicle (ROV) System for Horizontal Tanks*).

- **TMR Associates VAC TRAX**[4] - 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 233-S Plutonium Facility at the Hanford Site as preparation for dismantling the building.

2.2.2.4 Tank Wall Washing at West Valley Demonstration Project. During the early stage of waste retrieval at the West Valley Demonstration Project the waste retrieval process was very efficient. As the removal of the contents moved from bulk removal to heel and 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 carbon steel tank integrity.

2.2.2.5 Dry Ice Blasting. Decontamination of 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 and 100 psi and 120 to 150 cfm (Lapointe 2004, *Sand-less Sandblasting*). The EPA identified dry ice blasting with solid pellets as a desirable alternate for cleaning metal surfaces in their fact sheet for alternatives to trichloroethane (EPA 2000, *Technical Fact Sheet for 1,1,1-Trichloroethane (TCA) Hazards and Alternatives*).

2.2.2.6 Modified Light-Duty Utility Arm (MLDUA) 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*; and DOE/EM-0406, Innovative Technology Summary Report *Light Duty Utility Arm*).

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

The LDUA has been used at Idaho National Engineering and Environmental Laboratory for gathering samples of waste heel materials in their smaller tanks. The MLDUA was used at ORNL for the cleanup of seven underground tanks, either 25 or 50 ft in diameter. The MLDUA performed various types of operations in support of the underground tank waste cleanup operations (e.g., 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, and tank wall cleaning operations with high-pressure water jets). 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.

2.2.3 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 additional available alternatives are potentially capable of retrieving residual waste from SST C-106. However, the amount of waste that could be retrieved is uncertain and therefore even following deployment of an additional retrieval technology the HFFACO retrieval criteria may not be met.
- The schedule for deployment and completion of waste retrieval for the alternatives for additional technologies range from 12 (Alternatives A and B) to 18 (Alternative D) months.
- The cost of the alternatives ranges from \$5.7 to \$13.5 million. The estimated costs do not include the costs associated with decontamination and decommissioning and/or disposal of equipment used under each alternative or the costs of treatment and disposal of the 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 \$84,000/ft^3 or a factor of 7 to 16 times greater than experienced for the 2003 retrieval campaign.

Technical uncertainty exists regarding the effectiveness of evolving technology discussed in Section 2.2.2 in removing residuals to the 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 potential retrieval 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 (HNF-4454). Activities that would need to be completed would 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 technology or combination of technologies would be required to attain the retrieval criteria.

2.3 VOLUME AND CHARACTERISTICS OF RESIDUAL WASTE

This section responds to HFFACO, Appendix H, Attachment 2, Criteria #3: "Volume of waste proposed to be left in place and it chemical and radiological characteristics of that waste." The volume of residual waste in SST C-106 was determined following completion of the 1998-1999 sluicing campaign and the 2003 modified sluicing with acid dissolution campaign. The inventory (i.e., chemical and radiological characteristics) of residual waste was calculated from grab samples taken before the introduction of the first acid dissolution batch (identified as pre-retrieval samples) and upon completion of the modified sluicing campaign (identified as post-retrieval samples).

2.3.1 Volume of Residual Waste

2.3.1.1 Volume at Completion of the 1998-1999 Sluicing Campaign. The waste volume in SST C-106 before the start of sluicing in 1998 was approximately 230,000 gal and consisted almost entirely of sludge. During the sluicing campaigns conducted in 1998 and 1999, a sludge height equivalent to 67.8 tank inches was transferred to DST AY-102. This height is equivalent to approximately 185,000 gal (HNF-5267).

Estimates of the tank waste volume at the completion of sluicing were initially calculated using a mass flowmeter (HNF-5267) and verified using additional methods (e.g., mass transfer based on Enraf[5] densitometer density profiles). Computer-aided design (CAD) waste surface topography, as described in the *Tank 241-C-106 Component Closure Action Data Quality Objectives* (RPP-13889) and known as the video camera/CAD modeling system (CCMS), was not applied to the tank waste volume until 2002 in preparation for the modified sluicing and acid dissolution campaign. Using video recordings of the inside of the tank and the CCMS, the volume of sludge (solids) and supernatant (liquids) remaining in SST C-106 was determined by two separate observations (RPP-12547).

The volume determination from the July 13, 2000, observation presented in Table 5 represents the waste volume following settling after completion of sluicing. The volume of waste remaining in SST C-106 was estimated at approximately 45,000 gal with a 4:1 liquid to solid volume ratio. Subsequent measurements reduced the liquid to solid volume ratio to 3:1 and the volume of waste to approximately 36,000 gal as calculated from the August 1, 2002, video recordings. This value represents the tank waste volume before initiation of modified sluicing and acid dissolution.

Table 5. Single-Shell Tank 241-C-106 Waste Volumes Following Completion of Sluicing. (2 sheets)

Video recording date: 07/13/2000	ft^3	gal
Volume of solids	1,210.61	9,056
Volume of liquids	4,790.59	35,836
Total volume in SST C-106	6,001.20	44,892

[5] Enraf - Nonius Series 854 is a trademark of Enraf-Nonius, N.V. Verenigde Instrumentenfabrieken, Enraf-Nonius Corporation Netherlands, Rontegenweg 1, Delft, Netherlands.

Table 5. Single-Shell Tank 241-C-106 Waste Volumes Following Completion of Sluicing. (2 sheets)

Video Recording Date: 08/01/2002	ft^3	gal
Volume of solids	1,210.61	9,056
Volume of liquids	3,600.00	26,930
Total volume in SST C-106	4,810.61	35,986

Note:

SST = single-shell tank.

2.3.1.2 Completion of Modified Sluicing and Acid Dissolution. As presented in Table 5, approximately 36,000 gal of solid and liquid waste remained in SST C-106 after completion of the sluicing campaign. In April 2003, approximately 18,000 gal of liquid waste was pumped from SST C-106 to DST AY-102. Following removal of the liquids, modified sluicing and acid dissolution were deployed to dissolve, mobilize, and remove the remaining waste to less than 360 ft^3 or to the limits of the selected technology, whichever is less (RPP-20110).

Post-retrieval waste volume determinations were conducted following completion of the final waste retrieval campaign. Using the validated CCMS methodology (RPP-18744, *Results of the Video Camera/CAD Modeling System Test*), the volume of waste remaining in SST C-106 was determined to be 370 ft^3 ± 18% at the 80% confidence interval and ± 26% at the 95% confidence interval (RPP-19866). The progress of SST C-106 waste retrieval campaigns over time, culminating in the 370 ft^3 end state volume, is presented in Figure 4.

The post-retrieval waste volume determination presented in Table 6 includes the contribution to the residual waste volume from waste in the tank bottom (liquids and solids), within abandoned in-tank equipment, and on the tank stiffener rings in accordance with the approved data quality objectives (RPP-13889). Based on the CCMS analysis, the remaining solids volume at the 95% upper confidence level, which includes the volume of the tank bottom solids, the volume in the abandoned in-tank equipment, and the volume on the stiffener rings, is 453 ft^3. The remaining liquids volume at the 95% upper confidence level is 14 ft^3. Correspondingly, the residual waste volume at the 95% lower confidence level 275 ft^3.

Table 7 presents a total curie inventory for SST C-106 at three points in time: before the 1998-1999 retrieval campaign; after the 1998-1999 retrieval campaign; and after the 2003 retrieval campaign. The table lists 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 1.8 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.

Figure 4. Single-Shell Tank 241-C-106 Waste Volume Reductions.

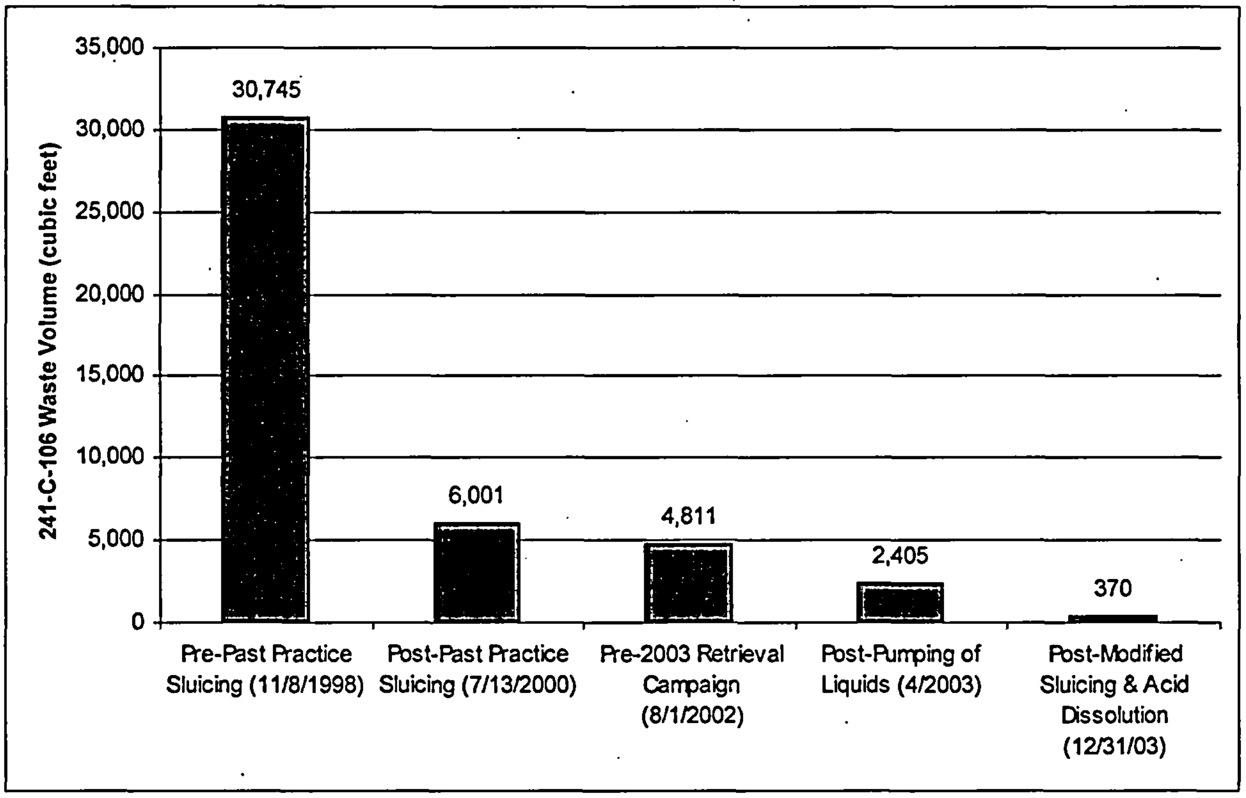


Table 6. Single-Shell Tank 241-C-106 Waste Volumes Following Completion of Modified Sluicing and Acid Dissolution.

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**

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

Table 7. 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
^{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.

2.3.2 Characteristics of Residual Waste

The SST C-106 post-retrieval risk assessment presented in the RPP-20577, Section 3.0, screened the analytes from the post-retrieval sample analysis for contaminants of potential concern (COPC). The screening identified 42 constituents (25 radionuclides and 17 nonradionuclides) of the 165 constituents identified in RPP-13889 as COPCs for evaluation in the risk assessment, including detected and nondetected constituents. The COPC inventory is presented in the sections below using analytical results from pre-retrieval and post-retrieval samples. The COPC identification process is discussed in further detail in Section 2.4.1 and in RPP-20577, Section 3.2.

2.3.2.1 Initial State. Initial state conditions are based on data from grab samples taken from riser 7 of SST C-106 on April 22, 2003 presented in RPP-20838, *Tank 241-C-106 Pre-Retrieval Selected Waste Constituent Inventory Estimates to Support the Basis for an Exception to the Waste Retrieval Criteria.* 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. Table 8 presents the estimated pre-retrieval inventory for the COPCs.

2.3.2.2 Current Conditions. The inventory of the 42 COPCs from the post-retrieval sample analysis is presented in Table 8. The COPCs identification process is discussed in further detail in Section 2.4.1. The data presented in Table 8 is based on analytical results and risk screening (RPP-20577, Appendix B, Table B-2).

The post-retrieval inventory was calculated based on the analyte concentrations (calculated per the best-basis inventory [BBI] methodology) and the residual volumes at the median values (359 ft^3 of solids and 11 ft^3 of liquids). Table 8 also presents a comparison between the inventory of SST C-106 before and after modified sluicing and acid dissolution. The comparison was calculated by dividing the post-retrieval inventory by the estimated pre-retrieval inventory for each COPC. Comparison values below 1 indicate a net reduction in the inventory.

Table 8. Residual Single-Shell Tank 241-C-106 Inventory Comparison Between Estimated Pre-Retrieval and Post-Retrieval Samples. (2 Sheets)

Class	Primary/ secondary[1]	Constituent[2]	Pre-retrieval inventory[3,5]	Post-retrieval inventory[4,5]	Units	Ratio post-/ pre-inventory
Radionuclide	Primary	60Co	6.65E+01	1.80E+01	Ci	0.27
Radionuclide	Primary	63Ni	1.05E+03	7.30E+01	Ci	0.07
Radionuclide	Primary	90Sr	1.26E+06	6.61E+04	Ci	0.05
Radionuclide	Primary	99Tc	2.87E+00	1.65E-01	Ci	0.06
Radionuclide	Primary	137Cs	3.15E+04	1.45E+03	Ci	0.05
Radionuclide	Primary	152Eu	NR	6.27E+01	Ci	N/A
Radionuclide	Primary	154Eu	7.0E+02	8.13E+01	Ci	0.12
Radionuclide	Primary	155Eu	NR	7.80E+01	Ci	N/A
Radionuclide	Primary	228Th	NR	5.75E-04	Ci	N/A
Radionuclide	Primary	230Th	3.99E-02	8.82E-04	Ci	0.02
Radionuclide	Primary	232Th	1.23E-02	5.61E-04	Ci	0.05
Radionuclide	Primary	233U	7.38E-02	1.83E-03	Ci	0.02
Radionuclide	Primary	234U	2.24E-02	9.48E-04	Ci	0.04
Radionuclide	Primary	235U	1.09E-03	3.87E-05	Ci	0.03
Radionuclide	Primary	236U	5.78E-04	1.73E-05	Ci	0.03
Radionuclide	Primary	237Np	1.09E+00	5.42E-02	Ci	0.01
Radionuclide	Primary	238U	2.65E-02	9.04E-04	Ci	0.03
Radionuclide	Primary	238Pu	N/R	2.71E+00	Ci	N/A
Radionuclide	Primary	239Pu	as 240Pu	1.68E+01	Ci	N/A
Radionuclide	Primary	240Pu	4.16E+02	3.58E+00	Ci	0.01
Radionuclide	Primary	241Pu	N/R	3.97E+01	Ci	N/A
Radionuclide	Primary	241Am	6.6E+02	6.53E+01	Ci	0.10
Radionuclide	Primary	242Cm	N/R	1.58E-01	Ci	N/A
Radionuclide	Primary	243Cm	N/R	3.02E-01	Ci	N/A
Radionuclide	Primary	244Cm	N/R	7.25E+00	Ci	N/A
Inorganic	Primary	Barium Ba	7.3E+01	1.64E+00	Kg	0.02
Inorganic	Primary	Cadmium Cd	1.7E+01	1.44E+00	Kg	0.08
Inorganic	Primary	Chromium Cr	2.9E+00	3.79E+00	Kg	1.31
Inorganic	Secondary	Copper Cu	4.93E+01	2.31E+00	Kg	0.05
Inorganic	Primary	Cyanide CN-	2.97E+00	7.82E-02	Kg	0.03
Inorganic	Primary	Mercury Hg	1.06E+01	1.93E+00	Kg	0.18
Inorganic	Primary	Nickel Ni	8.16E+02	3.02E+01	Kg	0.04
Inorganic	Primary	Silver Ag	8.98E+01	7.85E+00	Kg	0.09
Inorganic	Primary	Zinc Zn	3.30E+01	2.13E+00	Kg	0.06
Inorganic	Secondary	Aluminum Al	8.5E+03	3.83E+02	Kg	0.05
Inorganic	Secondary	Cobalt Co	9.35E+00	3.76E-01	Kg	0.04
Inorganic	Secondary	Iron Fe	1.17E+04	2.07E+02	Kg	0.02
Inorganic	Secondary	Manganese Mn	8.94E+03	5.50E+02	Kg	0.06
Inorganic	Secondary	Strontium Sr	3.59E+01	1.83E+00	Kg	0.05

Table 8. Residual Single-Shell Tank 241-C-106 Inventory Comparison Between Estimated Pre-Retrieval and Post-Retrieval Samples. (2 Sheets)

Class	Primary/ secondary[1]	Constituent[2]	Pre-retrieval inventory[3,5]	Post-retrieval inventory[4,5]	Units	Ratio post-/ pre-inventory
VOA	Primary	2-Butanone (MEK)	N/R	4.48E-04	Kg	N/A
VOA	Primary	2-Propanone (Acetone)	3.27E+01	1.30E-03	Kg	3.98E-05
SVOA	Primary	Di-n-butylphthalate	N/R	4.26E-03	Kg	N/A

Notes:

[1]Primary or secondary constituent (RPP-13889, 2004, *Tank 241-C-106 Component Closure Action Data Quality Objectives*, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington).

[2] Iodine-129 was removed from the post-retrieval risk assessment because it did not pass through the screening process for COPCs. For more information on the development of COPCs see RPP-20577, Section 3.2.6.

[3] RPP-20838, 2004, *Tank 241-C-106 Pre-Retrieval Selected Waste Constituent Inventory Estimates to Support the Basis for an Exception to the Waste Retrieval Criteria*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

[4] RPP-20577, Appendix B, Table B-2 (RPP-20577, 2004, *Stage II Retrieval Data Report for Single-Shell Tank 241-C-106*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington).

[5] Inventory is presented in scientific notation. Converting scientific notation to a traditional number requires moving the decimal point either right or left (negative to the left; positive to the right) by the number to the right of the positive or negative sign. For example: 1.3E-03 is the same as 0.0013.

COPC = contaminant of potential concern.
N/A = Not applicable. Used for analytes identified in the post-retrieval sample analysis but not in the pre-retrieval sample analysis.
NR = No data reported.
SVOA = semivolatile organic analysis.
VOA = volatile organic analysis.

2.3.3 Conclusions

The volume of residual waste and the chemical and radiological characteristics of that waste is summarized in the sections above and presented in RPP-20577, Section 1.2. The volume and inventory were established in accordance with RPP-13889.

To provide perspective, the current BBI of ^{99}Tc, the primary contributor to post-closure human health impacts via the groundwater pathway, in all SSTs is approximately 15,500 Ci (http://twinweb.pnl.gov/twins.htm; 4/6/04). There are 327 Ci of ^{99}Tc in Waste Management Area (WMA) C (SST C-105 has an inventory of 81.4 Ci of ^{99}Tc). The pre-retrieval sample inventory for SST C-106 indicated a total of 2.87 Ci of ^{99}Tc. The post-retrieval sample indicates a total of 0.165 Ci of ^{99}Tc currently in SST C-106 (or 0.05% of the WMA C ^{99}Tc inventory). Figure 5 illustrates the relationship between the inventory of ^{99}Tc in WMA C to SST C-106 and the reduction in ^{99}Tc inventory in the SST C-106 residual waste from the pre-retrieval sample to the post-retrieval sample. Figure 6 illustrates the current inventory of ^{99}Tc in each of the tanks in WMA C. SST C-106 currently has a lower inventory of ^{99}Tc than any other 100-series tank in WMA C. Figure 7 illustrates the current inventory of chromium in each of the tanks in WMA C. SST C-106 currently has a lower inventory of chromium than any other tank in WMA C.

Figure 5. Change in Single-Shell Tank 241-C-106 Technetium-99 Residual Waste Inventory, Pre-Retrieval Compared to Post-Retrieval Sample Data and Total Waste Management Area C Inventory.

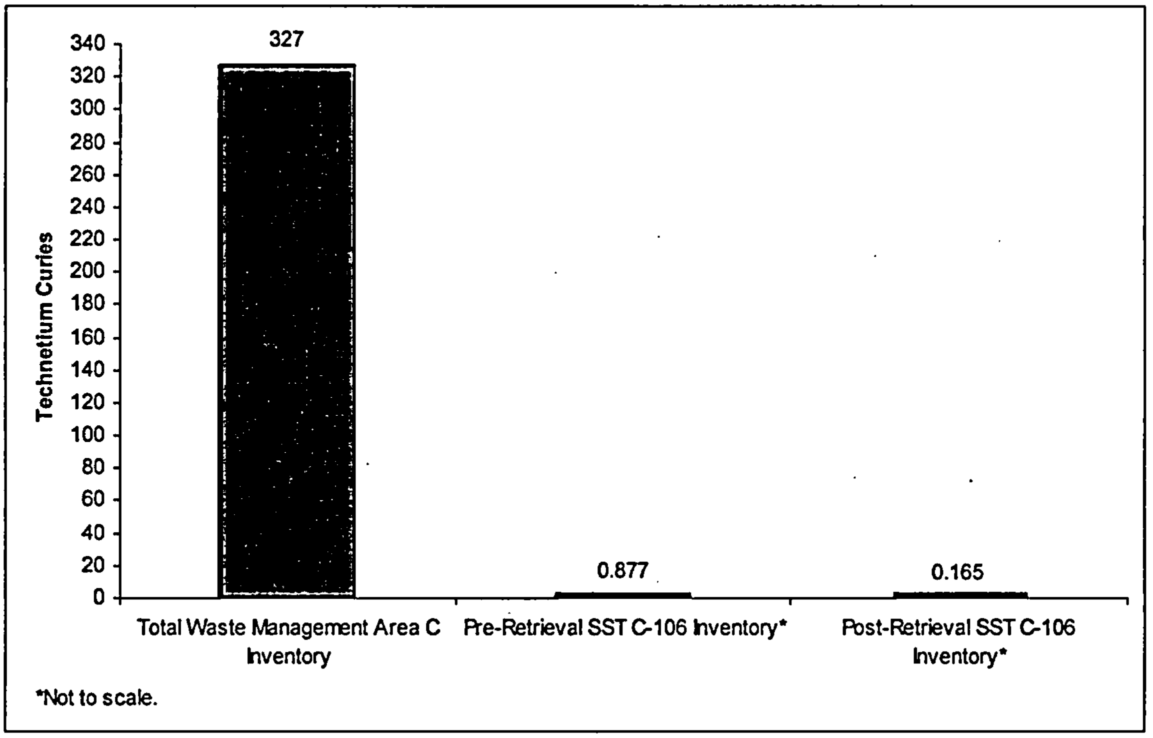


Figure 6. Current Inventory of Technetium-99 by Single-Shell Tank in Waste Management Area C.

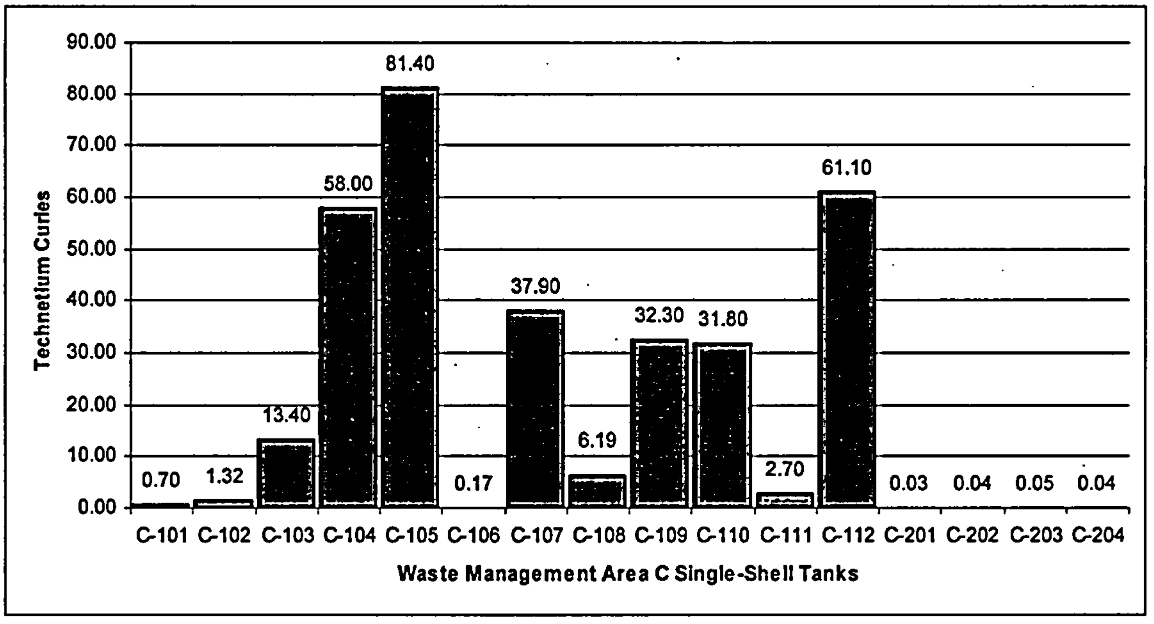
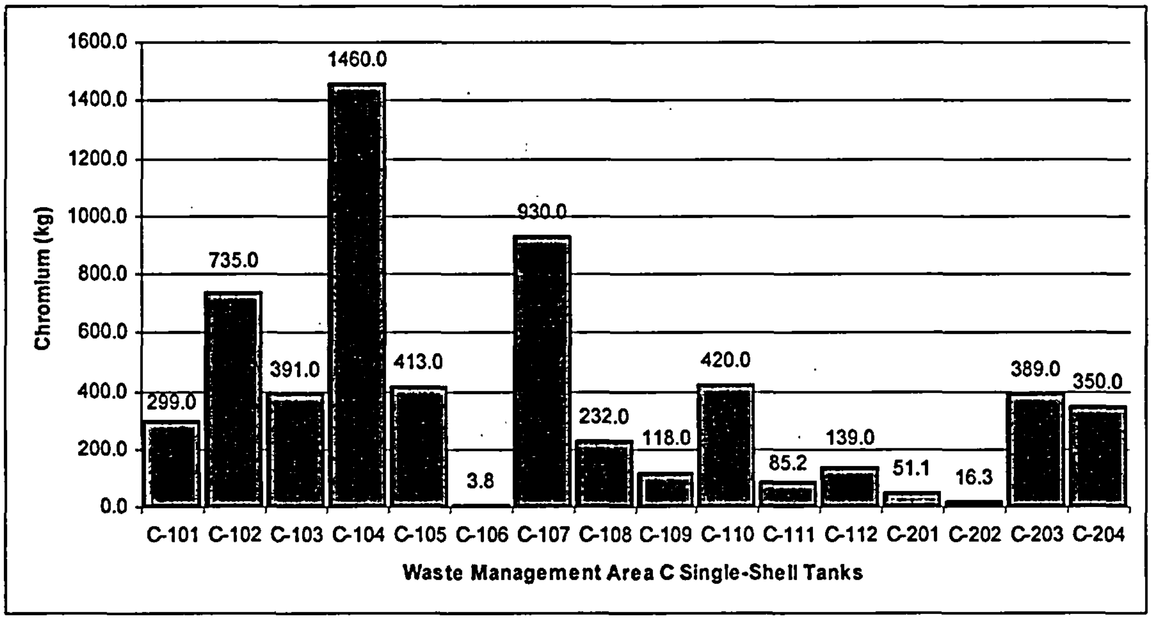


Figure 7. Current Inventory of Chromium by Single-Shell Tank in Waste Management Area C.



2.4 EXPECTED IMPACTS TO HUMAN HEALTH AND THE ENVIRONMENT

This section responds to HFFACO, Appendix H, Attachment 2, Criteria #5: "Expected impacts to human health and the environment if the residual waste is left in place." Expected impacts are based on the results of a post-retrieval assessment of impacts to human health and the environment for SST C-106. See RPP-20577, Section 3.0, for the complete post-retrieval risk assessment. This document presents summary information from the post-retrieval risk assessment provided in RPP-20577. This document provides comparative data for the industrial and residential exposure scenarios and more detailed information for the industrial receptor.

The risk assessment summarized in this document used the same methodology used in a pre-retrieval risk assessment presented in the *Single-Shell Tank System Closure Plan* (RPP-13774, Appendix C-1). All risk and environmental impact performance measures documented in RPP-13774 were included in the post-retrieval risk assessment to enable a direct comparison between the two documents. All contaminants of concern listed in RPP-13889 were evaluated.

2.4.1 Inventory and Contaminants of Potential Concern

The inventory used for the pre-retrieval risk assessment (RPP-13774) was calculated from the BBI using the calculation method for tank residuals given in *Environmental Impact Statement for Retrieval, Treatment, and Disposal of Tank Waste and Closure of Single-Shell Tanks at the*

Hanford Site, Richland, WA: Inventory and Source Term Data Package, (DOE/ORP-2003-02). A description of the calculation is provided in RPP-20577.

In January 2004, a sample of the residual waste from SST C-106 was taken (see Section 2.3). That sample was used to calculate the inventory of both nonradionuclides (i.e., hazardous contaminants) and radionuclides left in SST C-106. This inventory includes all analytes listed in RPP-13889. Inventory from the January 2004 sample was used in the post-retrieval risk assessment.

A tiered approach was used to identify COPCs for the SST C-106 waste retrieval sample (RPP-20577, Section 3.2.2). The first tier of the COPCs selection process was used to identify those constituents with available toxicity values. For those constituents with available toxicity values, ILCR or hazard quotient values were calculated and compared to a risk screening threshold value (i.e., 1% of the Ecology ILCR threshold of 1.0×10^{-5} or the HI threshold of 1.0). The second tier was used to identify nondetected constituents that should be considered as COPCs.

A total of 165 constituents were reported by the laboratory and considered in the COPC screening process. Of the 165 constituents reported, a total of 42 constituents (25 radionuclides and 17 nonradionuclides) were identified as COPCs and evaluated in the risk assessment. Iodine-129 was removed from the post-retrieval risk assessment because it did not pass through the risk screening process for COPCs because the ILCR was less than 1% or 1×10^{-7} of the performance objective of an ILCR of 1×10^{-5} (RPP-20577, Section 3.2.5.1 and Appendix B, Table B-2). For more information on the development of COPCs see RPP-20577, Section 3.2.6. The following constituents were identified as COPCs because they were detected in the post-retrieval sample from SST C-106:

^{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 RPP-13889:

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

2.4.2 Impacts to Human Health and the Environment

2.4.2.1 Human Health Risk Metrics. This section addresses changes in long-term human health risk due to changes in the source term remaining in SST C-106 after retrieval. The same assumptions (e.g., residual immobilization barrier design and performance), except for the inventory of the residual source term given in *Single-Shell Tank System Closure Plan* (SST Closure Plan) (RPP-13774, Attachment C-1), are applied to this risk assessment. The source term inventories that changed in this risk assessment are residual tank waste and hypothetical retrieval leaks. For residual tank waste, actual samples from the tank are used to calculate residual inventories. No retrieval leak occurred, therefore, the post-retrieval risk assessment did not include a hypothetical retrieval leak inventory for SST C-106 (RPP-20110). The results for ancillary equipment residuals, past ancillary equipment leaks, and past tank leaks did not change. For those results, see RPP-13774, Attachment C-1.

The ILCR, hazard index (HI), and radiological drinking water dose for the industrial and residential receptors are estimated using peak modeled groundwater concentrations at the WMA C fenceline from the residual tank waste and are presented in Table 9.

All risk metrics given in this section are reported at the WMA C fenceline which is consistent with the methodologies in the SST Closure Plan (see RPP-20577, Section 3.0 for a more detailed presentation of the risk assessment results by receptor). The ILCR 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). For example, an ILCR of 1.0×10^{-6} would indicate that an individual experiencing a lifetime exposure to the contaminants of concern under the exposure scenario analyzed would have a 1 in 1 million potential to experience a cancer that would otherwise have not been experienced if the individual had not been exposed to contaminants under the conditions postulated in the risk assessment scenario. It is important to note that an ILCR does not necessarily equate to a risk of fatality due to cancer. It only expresses the risk of experiencing cancer (fatal and/or nonfatal) due to exposure under the assumptions postulated for the risk scenarios adopted in the risk assessment.

The post-retrieval sample inventory results for industrial ILCR is almost a factor of 4 smaller than that calculated using the SST Closure Plan inventory. The differences between the SST Closure Plan inventory and post-retrieval sample inventory also are reflected in the HI and radiological drinking water dose, which decreased by a factor of approximately 7 for each metric.

For ILCR, ^{99}Tc is the primary contributor to this metric (contributing approximately 99% of the ILCR) for radiological contaminants. The reduction in risk between using the SST Closure Plan inventory and the post-retrieval sample inventory is directly related to the reduction of ^{99}Tc inventory and the removal of ^{129}I as a COPC. Technetium-99 inventory used in the SST Closure Plan was 0.46 Ci, and the post-retrieval sample inventory was 0.165 Ci, a reduction by a factor of approximately 3.

For nonradionuclides, chromium is the primary contributor to ILCR (contributing approximately 95% of the ILCR). The reduction in the chromium inventory between the SST Closure Plan risk assessment and the post-retrieval risk assessment is the reason for the reduction in ILCR for nonradionuclides.

Table 9. Cumulative ILCR, HI, and Radiological Drinking Water Dose from Peak Groundwater Concentration at the WMA C Fenceline Related to Residual Waste Volume in Single-Shell Tank 241-C-106.

Metric	Industrial receptor		Residential receptor		Year of peak
	SST Closure Plan inventory	Post-retrieval sample inventory	SST Closure Plan inventory	Post-retrieval sample inventory	
Radioactive chemicals ILCR[a] (unitless)	$7.8x10^{-8}$	$2.0x10^{-8}$	$1.5x10^{-6}$	$4.8x10^{-7}$	5609
Nonradioactive chemicals ILCR[a] (unitless)	$6.0 x10^{-9}$	$8.9x10^{-10}$	$1.3x10^{-8}$	$2.0x10^{-9}$	5614
Hazard index[b] (unitless)	$9.9x10^{-4}$	$1.4x10^{-4}$	$5.5x10^{-3}$	$7.9x10^{-4}$	5614
Radiological dose via drinking water[c] (mrem/yr EDE)	$3.5x10^{-3}$	$5.2x10^{-4}$	$1.0x10^{-2}$	$1.5x10^{-3}$	5606

Notes:

[a] ILCR target value is 1.0×10^{-4} to 1.0×10^{-6} for radioactive constituents (EPA/540/R-99/006, *Radiation Risk Assessment at CERCLA Sites: Q & A Directive* 9200.4-31P). ILCR target value is < 1.0×10^{-5} nonradioactive constituents.
[b] Noncarcinogenic HI is < 1.0.
[c] Groundwater dose target value is < 4 mrem/yr (1 L/day ingestion for 250 days for industrial receptor, and 2 L/day for 365 days for residential receptor).
EDE = effective dose equivalent.
HI = hazard index.
ILCR = incremental lifetime cancer risk.
SST = single-shell tank.
WMA = Waste Management Area.

For the HI metric the primary contributor to this risk metric is chromium then it contributes to almost 95% of the HI. The difference in the value for this risk metric between inventories used in the SST Closure Plan and the post-retrieval sample results is the lower inventory of chromium (factor of 6.5 lower) and the removal of nitrite, and nitrate as a COPC from the screening process. The total HI for the industrial receptor for SST C-106 residuals is a factor of almost 7,000 below the target value of 1. The total HI the residential receptor SST C-106 residuals is a factor of almost 1,300 below the target value of 1.

2.4.2.2 Effects on Drinking Water Standards. Estimated long-term groundwater quality effects for each residual inventory are compared to the primary drinking water standards (i.e., maximum contaminant level) in Table 10. The changes in concentration for these parameters reflect the change in inventory between SST Closure Plan and post-retrieval sample.

Table 10. Comparison of Groundwater Impacts at the WMA C Fenceline from Single-Shell Tank 241-C-106 between Single-Shell Tank Closure Plan Inventory and Post-Retrieval Sample Inventory.

Constituent	SST closure plan 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 concentrations shown are 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.
SST = single-shell tank.
WMA = Waste Management Area.

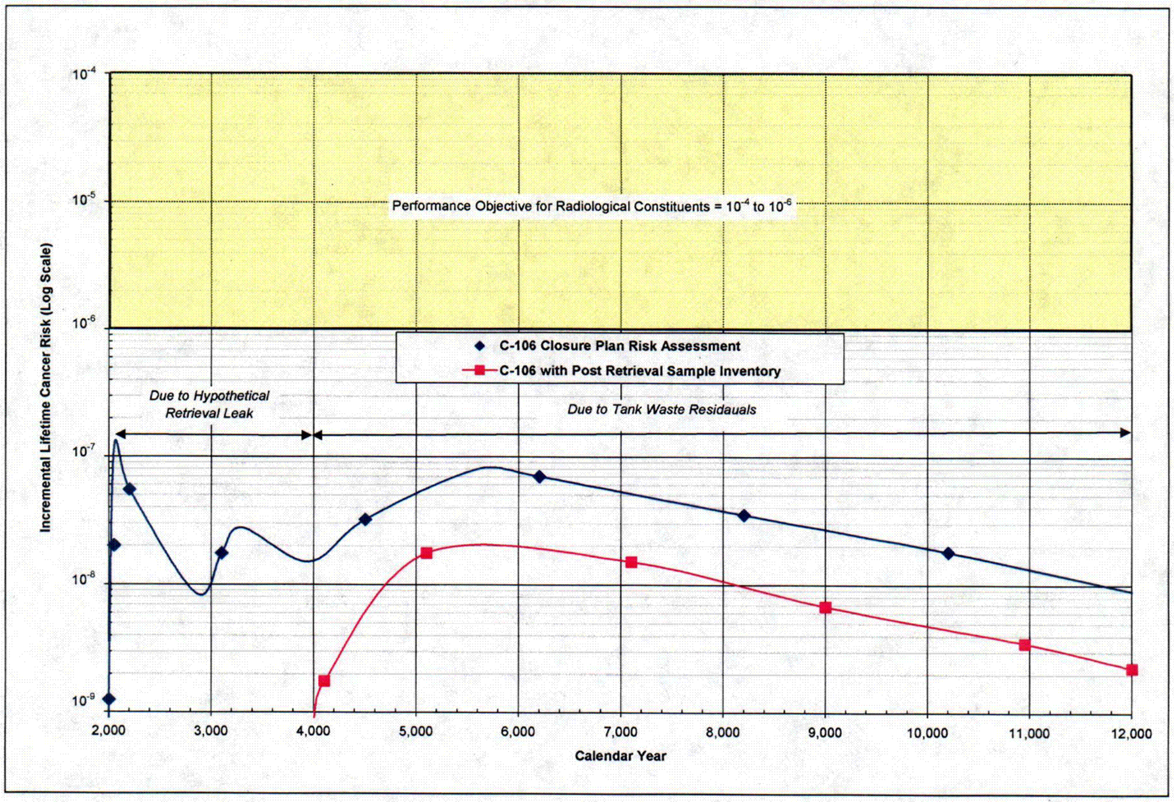
2.4.2.3 Cumulative Effects of Component Source Terms. The base case evaluated for SST C-106 in the SST Closure Plan risk assessment includes contribution to risk metrics from residual tank waste after retrieval to 360 ft^3 and an 8,000-gal retrieval leak (RPP-13774, Attachment C-1). Past leak and adjacent ancillary equipment source terms are identified as applicable; however, these source terms are addressed cumulatively in the WMA C risk assessment given in RPP-13774, Attachment C-1. This section focuses on the changes to the SST Closure Plan risk assessment caused by the 370 ft^3 end state volume and the associated radiological and chemical inventory (i.e., COPCs) calculated from post-retrieval sample. A waste retrieval leak from SST C-106 was not considered in the post-retrieval risk assessment, because no waste retrieval leaks were reported during waste retrieval operations or indicated by post-retrieval monitoring (RPP-20110, Section 2.4).

This risk assessment, like the assessment presented in RPP-13774, Attachment C-1, includes the cumulative risk of source terms from within WMA C (including SST C-106). Neither risk assessment calculates risk for source terms external to WMA C. However, future risk assessments performed in support of HFFACO M-45-00 milestones will, as required, perform cumulative risk analysis for source terms within and external to WMAs.

2.4.2.3.1 Incremental Lifetime Cancer Risk. The cumulative contribution to ILCR for the industrial worker scenario between the different residual inventories is given in Figure 8. In this plot the following two curves are shown:

- **SST C-106: SST Closure Plan Inventory.** The peak ILCR is 1.3×10^{-7} due to the hypothetical 8,000-gal retrieval leak occurring approximately 30 years after closure. The peak ILCR for the residuals is 7.8×10^{-8} occurring in about the year 5600.
- **SST C-106: Post-Retrieval SST C-106 Sample Inventory.** The peak ILCR for this curve is 2.0×10^{-8}, which is almost a fourfold decrease over the risk calculated for the SST Closure Plan inventory. The decrease in ^{99}Tc inventory and the removal of ^{129}I as a COPC is the reason for decrease in ILCR. The peak ILCR of 2.0×10^{-8} is a factor of 500 below the performance objective of 1.0×10^{-5} for this performance metric.

Figure 8. Incremental Lifetime Cancer Risk (Radiological Constituents) for the Industrial Worker at the Waste Management Area C Fenceline.



The residential scenario (RPP-20577) for these same two curves demonstrates the same pattern given for the industrial worker shown here. However, the magnitude in risk for a residential receptor living at the site is increased by approximately a factor of 24, which represents greater use of the groundwater by the residential receptor.

The post-retrieval risk assessment also compared changes in ILCR for WMA C from the SST Closure Plan inventory to the post-retrieval inventory. The peak ILCR for WMA C in the SST Closure Plan was 1.4×10^{-5} compared to a post-retrieval WMA C cumulative ILCR peak of 1.39×10^{-5}.

2.4.2.3.2 Hazard Index. The cumulative contribution to the HI for the industrial worker between the different residual inventories is given in Figure 9. In this plot the following two curves are shown:

- **SST C-106: SST Closure Plan Inventory.** This curve is the same curve given in RPP-13774, Attachment C-1. The peak value is 9.9×10^{-4} due to the residual waste.
- **SST C-106: Post-Retrieval SST C-106 Sample Inventory.** This curve is for the residual inventory calculated using the post-retrieval sample. Leaks did not occur during waste retrieval and therefore were not considered. The peak value for this curve 1.4×10^{-4}, which is over a sevenfold decrease for the HI calculated for the SST Closure Plan inventory. The decrease is primarily due to the difference in Cr^{+6} inventory

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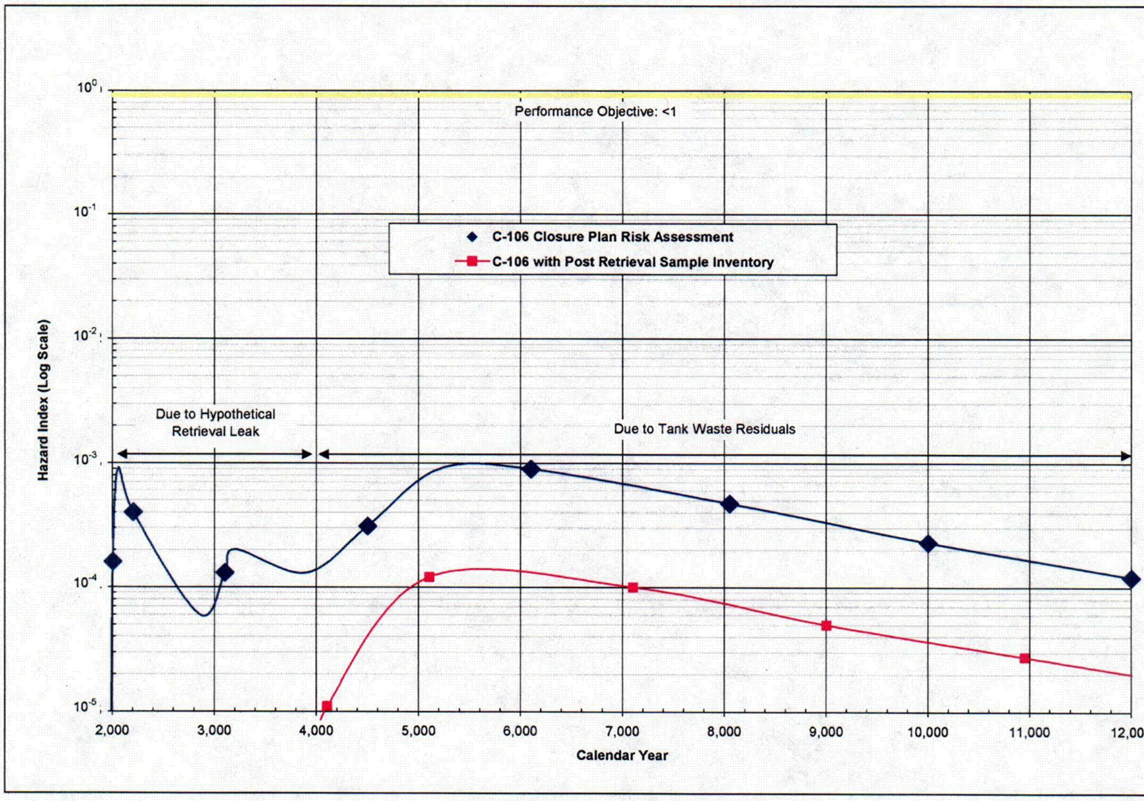
calculated from the archive sample. This is a factor of almost 7,000 below the performance objective of 1.0.

The post-retrieval risk assessment also compared changes in the HI for WMA C from the SST Closure Plan inventory to the post-retrieval inventory (RPP-20577). The peak HI for WMA C in the SST Closure Plan was 1.25×10^{-1} (Note: this is slightly higher than what was report in RPP-13774 [9.7×10^{-2}] because of the inclusion of n-Butanol from past unplanned releases) compared to a post-retrieval risk assessment peak HI of 1.23×10^{-1}.

Figure 9. Hazard Index for the Industrial Worker at the Waste Management Area C Fenceline.



2.4.2.3.3 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 10. In this plot the following two curves are shown:

- **SST C-106: SST Closure Plan Inventory.** 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 5.0×10^{-3} mrem/yr due to the retrieval leaks considered in the pre-retrieval analysis.
- **SST C-106: Post-Retrieval SST C-106 Sample Inventory.** This curve is for the residual inventory calculated using the post-retrieval sample. Leaks did not occur during waste retrieval and therefore were not considered. The peak value for this curve is 6.6×10^{-4} mrem/yr, which is almost a sevenfold decrease over the radiological dose calculated for the SST Closure Plan residual inventory. This is due to the smaller

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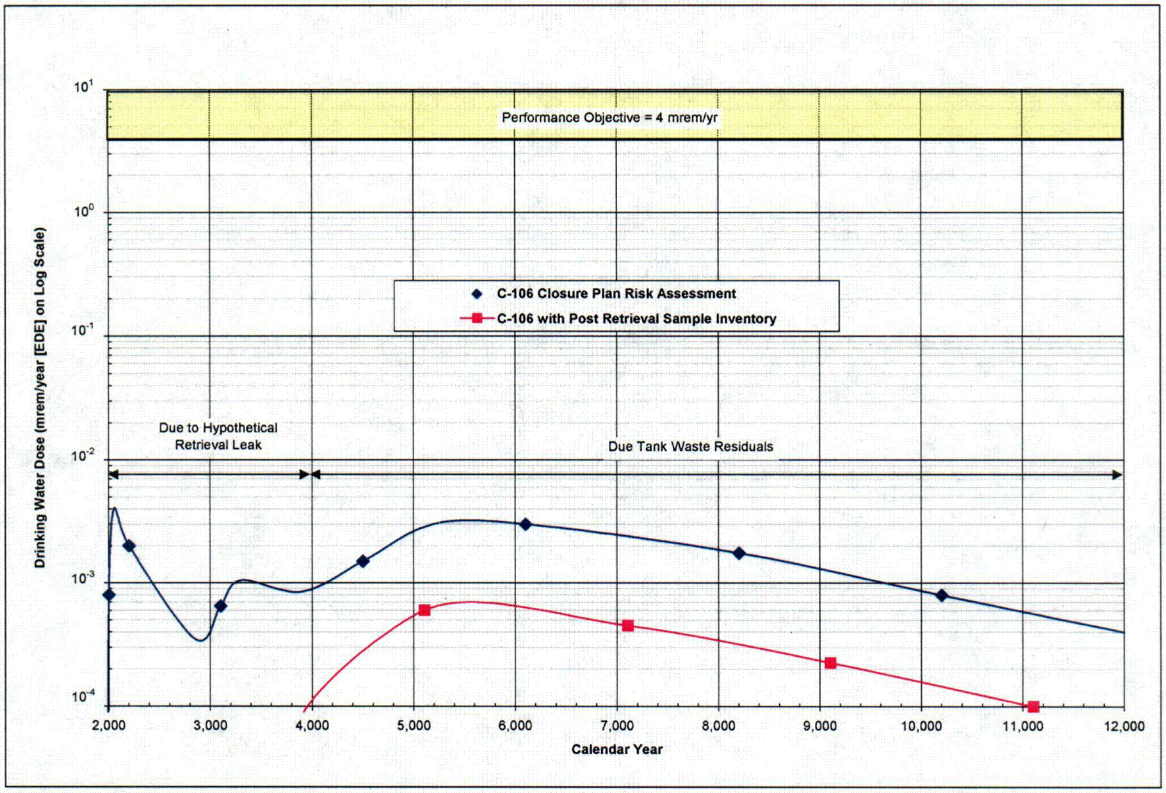
residual inventory of ^{99}Tc and ^{129}I is no longer a contaminant of concern. This is a factor of almost 6,000 below the performance objective 4 mrem/yr.

The post-retrieval risk assessment also compared changes to the radiological drinking water dose from the SST Closure Plan to the post-retrieval inventory (RPP-20577). The peak SST Closure Plan radiological dose was 4.6×10^{-1} which is well below the performance objective of 4.0. The peak radiological dose for the post-retrieval risk assessment was 4.5×10^{-4}.

Figure 10. Drinking Water Dose for the Industrial Worker at the Waste Management Area C Fenceline.



2.4.2.4 Human Health Risk Reduction as a Function of Residual Waste Volume Reduction. Table 11 provides the relative contribution of SST C-106 residual waste to the total WMA C residual waste for the industrial receptor at the WMA C fenceline at selected retrieval volumes. Table 11 and Figure 11 have been prepared to illustrate the ILCR of SST C-106 residual waste at different levels of waste retrieval. At each level of waste retrieval, the inventory for contaminants in SST C-106 has been reduced linearly based on an assumed relative reduction of ILCR established in RPP-13774 for:

- A residual volume of 360 ft^3
- The post-retrieval sample risk assessment for SST C-106 at the 95% confidence.

Table 11. Relative Contribution of Single-Shell Tank 241-C-106 Residual Waste to Total WMA C Residual Waste 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 dose (mrem/yr)	ILCR industrial	All-pathways dose (mrem/yr)	ILCR industrial	All pathways (mrem/yr)
SST Closure Plan risk assessment inventory (360 ft^3)	$1.02x10^{-6}$	$1.97x10^{-1}$	$7.84x10^{-8}$	$2.74x10^{-2}$	7.72%	13.88%
Post-retrieval sample C-106 95% upper confidence level overall for inventory of each constituent was calculated based on RPP-6924	$9.64x10^{-7}$	$1.73 x10^{-1}$	$2.61x10^{-8}$	$3.32x10^{-3}$	2.71%	1.92%
Post-retrieval sample C-106 95% upper confidence level volume (466 ft^3)	$9.63x10^{-7}$	$1.73 x10^{-1}$	$2.48x10^{-8}$	$3.15x10^{-3}$	2.58%	1.82%
Post-retrieval sample C-106 Nominal volume (370 ft^3)	$9.57x10^{-7}$	$1.73 x10^{-1}$	$1.97x10^{-8}$	$2.50x10^{-3}$	2.05%	1.45%
Post-retrieval sample C-106 Estimated (200 ft^3 [sludge only])	$9.49x10^{-7}$	$1.71 x10^{-1}$	$1.10x10^{-8}$	$1.39x10^{-3}$	1.16%	0.81%

Notes:

[1]See inventory definitions in RPP-20577 for a complete description of how each inventory is calculated.

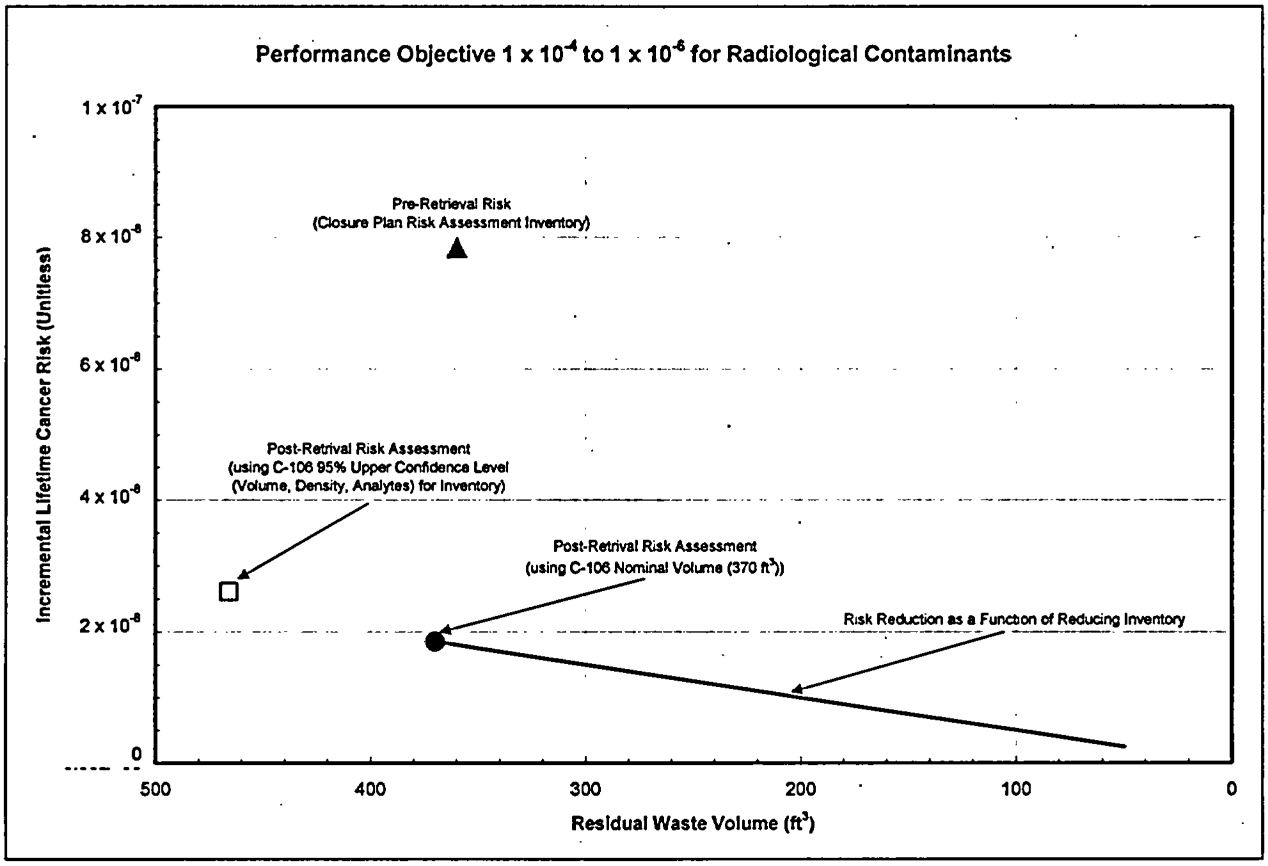
RPP-6924, 2002, *Statistical Methods for Estimating the Uncertainty in the Best Basis Inventories*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

ILCR = incremental lifetime cancer risk.

SST = single-shell tank.

WMA = Waste Management Area.

Figure 11. Change in Incremental Lifetime Cancer Risk for the Industrial Worker for Single-Shell Tank C-106 Residual Waste as a Function of Waste Volume Reduction.



2.4.3 Conclusions

Evaluation of all 42 COPCs clearly shows the major human health and groundwater risk driving analyte for radionuclides in this tank is ^{99}Tc. For nonradionuclides, chromium is the primary risk driver.

Risk for the total of all WMA C SST residuals was calculated using the inventory given in the SST Closure Plan (RPP-13774, Attachment C-1). For that assessment, the ILCR for the SST C-106 residual waste for the industrial receptor was 7.8×10^{-8}, while the ILCR for all residuals in WMA C was approximately 1.0×10^{-6}. The percentage of the risk represented by the pre-retrieval residual in SST C-106 is approximately 7.7% or 1/12 of the total cumulative risk using the inventory used in the SST Closure Plan risk assessment. Replacing the SST Closure Plan inventory with the inventory calculated from the post-retrieval sample reduces the risk posed by SST C-106 from 7.7% to approximately 2.6% for the 95% confidence level volume (467 ft^3) and to 2.1% for the nominal case (370 ft^3).

The two key points from this risk assessment are 1) the WMA C numbers contained in this analysis and those contained in RPP-13774, Attachment C-1, for the entire WMA are nearly the same and 2) the impacts estimated for SST C-106 are smaller in this analysis than those in RPP-13774. The conclusions in RPP-13774 are unchanged by the present analysis using residual SST C-106 waste samples.

Finally, a further reduction in residual waste volume from the current estimate of 467 ft^3 to the HFFACO Milestone M-45-00 series retrieval criteria of 360 ft^3 would result in an insignificant 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 only be reduced from 2.6% of the total risk to 2.1%. Deployment of a new waste retrieval technology that would reduce the volume of residual waste by approximately 160 ft^3, assuming a comparable reduction in the COPCs, would not have a substantive effect on the risks associated with SST C-106 residual waste or the overall risks associated with WMA C. In fact, removing essentially all waste from SST C-106 would result in a WMA C risk reduction from current levels of 9.57×10^{-7} to 9.4×10^{-7} under the industrial worker scenario.

2.5 ADDITIONAL INFORMATION REGARDING CONFORMANCE WITH RELEVANT REQUIREMENTS

This section responds to HFFACO, Attachment 2, Criteria #6: "Additional information is required by EPA and/or Ecology." At meetings with Ecology staff in May 2004, no additional information or documents beyond that provided in this document was identified. The remainder of this section provides information regarding conformance with relevant requirements as identified in HFFACO, Appendix H. Information provided includes the relationship between this request for an exception to the HFFACO retrieval criteria and the component closure plan for SST C-106 and interface with the U.S. Nuclear Regulatory Commission (NRC).

If Ecology approves this petition for exception from the HFFACO retrieval criteria for SST C-106, DOE will address the remaining issues associated with SST C-106 in accordance with RPP-13774.

Ecology and DOE are currently working to address aspects of the HFFACO, Appendix H, that present an interface role for the NRC associated with allowable residual wastes. DOE continues to consult with the NRC regarding issues associated with near-surface disposal of radioactive waste. In 2003, an interface with the NRC staff regarding SST C-106 residual waste was initiated. After Ecology and DOE reach an agreement regarding the language and it is incorporated into Appendix H of the HFFACO, DOE will pursue additional interface as appropriate.

what does this mean?

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3.0 CONCLUSIONS

This section responds to HFFACO, Appendix H, Attachment 2, Criteria #1: "Why DOE does not believe the retrieval criteria can be met." Based on the information provided in Section 2.0 in response to Criterions #2 through #5, DOE concludes that there is no technical, risk reduction, or economic justification supporting deployment of additional technologies for additional waste removal from SST C-106. This conclusion is the basis of DOE's request that Ecology and EPA concur that retrieval of SST C-106 is complete.

Information summarized in this report and presented in detail in supporting documents establishes that:

- In response to HFFACO, Appendix H, Attachment 2, Criteria #2: The limits of technology for retrieval of waste from SST C-106 have been reached for deployment of sluicing (initial retrieval technology deployed in 1998-1999 to resolve high-heat safety issues) and modified sluicing and acid dissolution (retrieval technology demonstration under the HFFACO for modified sluicing in a sludge tank), using the available riser configuration.
- In response to HFFACO, Appendix H, Attachment 2, Criteria #3: The impacts of implementing any retrieval technology to remove additional waste from SST C-106, whether additional available or potential future, would include a minimum $5.7 million in cost, 12 months in additional retrieval time, exposing tank farm workers to additional radiological, chemical, and industrial risk, and placing constraints on DST storage space. These impacts are not offset by commensurate reductions in long-term human health and environmental risk. In addition, there is uncertainty whether the deployment would result in the removal of waste to the HFFACO retrieval criteria or result in a measurable reduction in the COPCs to an extent that would be meaningful given measurement uncertainties for waste volume and characteristics.
- In response to HFFACO, Appendix H, Attachment 2, Criteria #4: The waste remaining in SST C-106 exceeds 360 ft^3. However, the nominal value of the measured waste volume is approximately 370 ft^3. This volume includes the volume of the tank bottom solids, the volume in the abandoned in-tank equipment, the volume on the stiffener rings and the volume of liquids. The 95% upper confidence level volume is 467 ft^3. The 95% lower confidence level volume is 275 ft^3. The chemical and radiological characteristics of that waste have been analyzed in accordance with the approved data quality objectives (RPP-13889).
- In response to HFFACO, Appendix H, Attachment 2, Criteria #5: The expected impacts to human health and the environment if the residual waste is left in place have been analyzed consistent with the methodology used in *WMA C Closure Action Plan*, Appendix C (RPP-13774). The results of the risk assessment are summarized herein and presented in its entirety in RPP-20577. ILCR risks from the residual waste do not exceed EPA ILCR threshold values of 1.0×10^{-4} to 1.0×10^{-6} or the Ecology threshold of 1.0×10^{-5} for the industrial receptor at the WMA C fenceline. The cumulative risk for WMA C, inclusive of the SST C-106 residual inventory is 9.57×10^{-7} for the industrial receptor scenario. Based on the current residual inventory no groundwater quality

standards would be exceeded under assumptions consistent with the tank farm closure approach identified in RPP-13774.

- In response to HFFACO, Appendix H, Attachment 2, Criteria #6: RPP-13774 identifies and provides a pathway to resolution of all currently unresolved regulatory issues and securing all necessary permits and approvals under the authority of Ecology, DOE, and other agencies.

On the basis of information presented in this document, DOE requests Ecology and EPA concur that retrieval of waste from SST C-106 is complete. This request is pursuant to criteria set forth in HFFACO, Appendix H, Attachment 2.

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APPENDIX A

RELATIVE COMPARISON OF THE RETRIEVAL ALTERNATIVES AND NO ACTION

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Table A-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

ID	SUMMARY EVALUATION DESCRIPTION	VALUE	Base 100 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 A-2. Criteria Blank. (2 sheets)

10 = HIGHEST 1 = LOWEST		A. Cost	Cost Comments: A higher value means the cost 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 A-2. Criteria Blank. (2 sheets)

10 = HIGHEST 1 = LOWEST		A. Cost	Cost Comments: A higher value means the cost 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